N

GICAL COMMISSION OF BRAZIL,

PROFESSOR CH. FRED. HARTT, CHIEF.

RAPHICAL SURVEYING,

S USES, METHODS AND RESULTS,

BY

DE YEAUX CARPENTER, C.E

Geographer to the Commission.

NTED FROM VAN NOSTRAND'S MAGAZINE

NEW YORK:

AN NOSTRAND, PUBLISHER,

MURRAY AND 27 WARREN STREET.

1878.

GEOLOGICAL COMMISSION OF BRAZIL,

PROFESSOR CH. FRED. HARTT, CHIEF.

GEOGRAPHICAL SURVEYING,

ITS USES, METHODS AND RESULTS,

BY

FRANK DE YEAUX CARPENTER, C.E.

Geographer to the Commission.

REPRINTED FROM VAN NOSTRAND'S MAGAZINE.

NEW YORK:

D. VAN NOSTRAND, PUBLISHER,

23 MURRAY AND 27 WARREN STREET.

1878.

PREFACE.

Charles Frederic Hartt, Professor of Geology in the Cornell University, and Chief of the Geological Commission of Brazil, died on the eighteenth of March last, in Rio de Janeiro, where he was engaged in preparing the reports of his Survey.

His death and the dissolution of the Commission, of which he was the founder and director, have prevented the realization in Brazil of the plan of surveying proposed in the accompanying pages.

F. D. Y. C.

New York, *July*, 1878.

GEOGRAPHICAL SURVEYING.

In this paper I shall present a scheme for the organization, the gradual development, and the prosecution of a geographical survey in connection with the Geological Commission, which, in the efficiency of its results, will satisfy not only the present demands but also the future needs of the Empire of Brazil for very many years to come. In the rapidity of its progress, this survey will be especially adapted to a country of so vast an area and comparatively sparse population, and as an adjunct to the above Commission, and in great part carried on by the members of the same, without interfering with the ends of that body, it can be maintained at an expense so moderate as to be in conformity with the present desire for economy and retrenchment in the public service.

THE PROPOSED PLAN OF SURVEY.

The immense empire of Brazil is yet without reliable geographical maps. These are necessary to the national welfare. The question arises as to what kind of maps will be sufficient to satisfy the imperative needs of the country and of science. The plan of survey which I shall advocate is a mean between that system which takes cognizance of every house in a village and every little undulation in the landscape, and that want of system in which are represented whole mountain-chains that do not exist, or actual topographical features are delineated with gross inattention to accuracy. It is a judicious mean between the slow and laborious processes used, for instance, in the Ordnance Survey of Great Britain, and the sketchy and unreliable information gained by the early explorers of the New World, from whose results our first maps were compiled.

These last are scarcely more graphic and complete than our present maps of the moon, and in fact, speaking broadly, they are not so accurate as the latter, which are, in great part, photographs of the surface which they represent. With these mere hints of the geography of its country a people should not feel obliged to rest satisfied until it can sustain a minutely topographical survey.

AN EVOLUTION IN CARTOGRAPHY.

The demand for maps depends upon the population and civilization of a country. In the beginning a rough sketch will answer the purposes of the pioneer. As the region becomes inhabited better maps are wanted, and finally the people require the nearest possible approach to absolute accuracy in the delineation of topographical features. Map-making in every country must follow a regular evolution from the incomplete to the complete.

Reviewing the origin and growth of the cartography of a country, we see how faulty it is liable to be. The first explorer is the first contributor to the geography of a region. By way of illustration, let us follow one of these pioneers as he traverses Brazil from South to North. Following up a branch of the River Plate, he records the approximate directions and distances of his journey, which he obtains, perhaps by the use of unreliable pocket instruments, perhaps by an occasional glance at the sun and his watch, or, more probably, by estimating at night the latitude and departure which he has made during the day. At a certain period of his march he finds a river entering from an easterly direction, whose volume he measures with a glance of the eye. Farther on, he encounters a tribe of Indians, whose village is situated upon the west bank of the river; he counts their houses, and makes the number of these a key to the extent of the population. At the following night he camps at the foot of a cataract. Impressed by its grandeur, and also by a kind of optimism, common to early explorers, and which will not allow him to underrate any of the glories which he sees, he estimates its height to be at least twenty meters, when in reality it is but ten.

At a certain point whose latitude and longitude he determines in a rude and hasty way with the sextant which he carries, he leaves the main stream and follows a tributary to its head in the highlands, where he crosses the divide between the great Paraná—Paraguay basin and that of the Amazon. Upon the summit of the plateau he tests his altitude above the sea by noticing the temperature of boiling water, or by reading the indication of his single aneroid, unreliable methods which have been known to give results even a thousand meters wide of the truth.* Continuing down

* Gibbon's observations at the head of the Amazon, both the mercurial and thermo-barometer being used, show a discrepancy between the two which is equivalent to 300 meters of altitude. The height of Mount Hood, in Oregon, as given by one authority, who determined it by the boiling point of water, is almost 2,000 meters greater than that indicated by the cistern barometer and by triangulation. In the writer's own experience he has encountered an aneroid record, upon one of the peaks of

the Araguaya, he observes the trend of the mountain-range along his route, and, descending the Tocantins, he makes a similar survey extending to Pará.

We do not disparage the work of this man. Under the circumstances of hardship and peril by which he is surrounded he does all that is possible, and his report is really of great value until some more reliable exploration can be made; still, for all of that, it is none the less incorrect and incomplete.

It is from such sources as this that the material for our first maps is drawn. In later revisions there may be introduced the results of desultory explorations of mines, railway routes and navigable waters, as well as the meagre topographical data acquired by the land surveyor

---

the Sierra Nevada Mountains of the United States, which made the height of this mountain to be 3,000 feet above its true altitude. It is a noteworthy fact that these preliminary determinations, made with the above faulty methods, resemble the estimates of the early explorers, inasmuch as they almost invariably give exaggerated altitudes; perhaps the opinions and imagination of the observer are allowed to form, in some unaccountable way, a factor in these results.

in running boundary lines of private estates, but still, taken at its best, a map constructed in this way falls far short of its purpose as a picture of the conformation of the earth's surface, or as a guide to the traveler, the geologist, or to the capitalist who wishes to invest his money in the development and internal improvement of his country.

FAULTS IN EXISTING MAPS.

In his compilation of the scattered information at his disposal the cartographer finds that a certain district of country has never been entered by the engineer. He knows, however, that two rivers rise somewhere in this terra incognita, and he feels it safe to predicate a divide between them. He also thinks it safe to presume that this divide is a range of mountains, of greater or less height, and, in his desire to give an appearance of finish to his chart, he does not scruple to insert at this place an ideal mountain system, and represent it as drained by the upper tributaries of the two rivers, concerning whose head-waters in reality nothing is known. These physical features soon come to be reproduced, with more or less variation, in other maps, and in this manner errors are grounded in the national geography, from which they can only be eliminated by a systematic geographical survey. Like national myths they stubbornly refuse to give way until eradicated by true scientific research.

Supposing, on the other hand, that the compiler, accepting the report of the explorer, who claims to have discovered a range of mountains between the Rio Paraná and the Rio Araguaya, wishes to represent them upon the map. He has no mathematical data to insure their position, and no sketches or other information from which to draw their intricate topographical features, and so he evolves from his imagination an utterly impossible chain of mountains, out of place, artificial, conventional, and even mechanical in their regularity. These he depicts in that stereotyped form of delineation, which is known in the modern geographical draughting-room as the "caterpillar" formation.

THE RELATIONS OF GEOGRAPHY TO GEOLOGY.

Upon such an unfaithful map as this it is impossible to faithfully represent the geology of a country. If the geologist attempts to lay down his conclusions upon a sheet of this kind, its errors will continually clash with his truths. The configuration of the land, as it appears upon this erroneous drawing, might indicate that it belonged to a certain geological age, and that, in fact, it could not be referred to any other; the geologist, visiting and studying the country itself, finds that it is of a later and entirely different period. But if he paints it as it really is he publishes a glaring anachronism to the world, for the color which represents the rock of one geological epoch overlies, upon the map, the physical features which are peculiar to another age. As in the artistic and true delineation of the human figure every feature must be the exponent of anatomical structure, so in topography, every representation of topography must be true to geological structure. Ranges of mountains mean disturbance or great erosion of certain strata, and each has its own characteristic features as sharply defined as those of an animal. This should be thoroughly understood, and those immense lines of sierras which are supposed to separate certain river basins, or are delineated in the very heart of regions of which we have no knowledge whatever, should be erased from the national maps until these districts can be explored. In the course of his travels the geologist may find some physical feature of great importance, which he wishes to portray, in area and position, upon his chart, but the best maps at his disposal represent a topography utterly at variance with geological structure, perhaps a sharp ridge of mountains where there should be a plain, and so they are of no use to him. Or he may find himself obliged to color the top of a mountain peak with the tint conventional to the bed of a lake, and in this manner science is made ridiculous.

To take an illustration nearer home, suppose that the group of mountains that abut into the sea in the vicinity of Rio de Janeiro have intervening valleys filled with alluvium, which is really the truth. Suppose that the limits of these mountains have never been accurately determined, which is also true. In this case, it is easy to be seen that if the geologist lays down upon the map the alluvial deposits in their true extent, they will here and there encroach upon and overlap the rugged masses of gneiss, and in places will extend far up the steep precipices of the mountain side. To avoid this absurdity the geologist is forced to be as inaccurate as those who have gone before him, and, in general, every error in the geographical map must be continued and apparently sanctioned in the geological chart that is based thereon.

It becomes therefore absolutely necessary that the work of the geologist should be preceded by and based upon that of the geographer, and that he should work in conjunction with the latter. In the exploration of a new country the geological party should make its own topography; and in the United States of North America, where the experiment has been most efficiently tried, this is always the case.

A good geographical map would give, with sufficient completeness, all the leading topographical features of the region explored, delineating with especial care those peculiarities of structure which are the keys to the different formations. It would display the shape and position of bodies of water, and show how the direction of a stream is changed and determined by the accidents of a broken and displaced stratification, and by other circumstances of its boundaries. If restrained by cañon walls its route would be angular; down a steep gradient it would be direct; and in the level alluvium near the sea its track would be tortuous and broken into bayous. This map would distinguish between the rounded slopes of a synclinal valley and the abrupt sides and angular cross section of an anticlinal cleft; and between the sharp edges of the volcanic rock and the eroded angles of the sand-stone. If there was exposed a great "fault" in the stratification, it would show it at a glance, with its precipitous bluff of exposed strata on one side, and, on the other, its gentle declivity of tilted surface rock. And, drawn in contour lines, it would reveal, not only the heights of peaks and passes and other vertical distances from plane to plane, but also the various orographic forms, each of which is full of meaning to the geologist.

ECONOMICAL USES OF THE PROPOSED MAPS.

Aside from being quite indispensable to a scientific commission, in the various ways that have been mentioned, these maps can be made a graphic supplement to their report in numerous other particulars, and can be made to embody the stores of practical information which they gather incidentally to their regular work. Upon it they can display the valleys of arable land and the plains adapted to grazing. The forests of timber can be laid down, and, from this drawing, their areas and values can be closely estimated. Advantageous sites for colonies can be noted here. The superficial contents of coal-beds and ore-deposits are given, and not only does a geological chart reveal where the precious and useful minerals are, or may be found, but it also furnishes that negative information, equally valuable to the miner, which defines to him the larger districts in which it is impossible for them to exist, and in which, consequently, it is a waste of effort to search for them; it is here that the science of palæontology is especially useful. If any portion of the country lies at a great elevation, the altitude limits of the various forms of vegetable growth may be traced, and also the limits of the possible culture of grain, coffee, cotton, and the other principal products. In this manner the map is made a general statistical report upon the value of the national domain.

The economical ends served by a work of this nature in the development and settlement of a new country, cannot be too highly esteemed. Every stream of importance is surveyed, in all except those minor branches whose courses can be traced in from the adjacent mountain stations. The frequent tests for altitude along its banks determine the rapidity of its descent, the amount of water-power which it represents, and its value as a motor for machinery, and as an agent in hydraulic mining and diamond-washing. This profile of the bottom of the valley also decides the feasibility of railways or other lines of communication by this route, while the sketches of the adjacent hills show what room there is for such a road, and, in connection with this, the geologist's report will give a general idea of the rock or other material with which the engineer will have to contend and work. In the survey of a range of mountains careful readings for altitude are made, not only on the summits of the peaks, but also at the passes, or low depressions in the divide, while the slope of the descent from the summit to the valley will be delineated in contour lines, drawn at such vertical distances as circumstances may require. It must be admitted that these contours will only approximate to their true places, yet their number will be correct, and their positions will be such that they will give with sufficient certainty the various gradients that occur in the ascent, so that, by counting the meters of rise for every kilometer of horizontal advance, as shown by the scale of the map, the engineer or capitalist, in his distant office, with this sheet before him, can form a very satisfactory idea of the practicability of a proposed railway, and can select the most advantageous route for the preliminary survey.

The meteorological data accumulated in the process of this work are valuable, not only in the determination of the vertical elements of the survey, but also as an illustration of the general laws of drought and excessive rainfall. At intervals throughout the country, the declination of the compass needle will be observed, and will be published for the guidance of land surveyors who may not be proficient in astronomical observation. The positions and supra-marine elevations of all villages, important fazendas, medicinal and thermal springs, ancient ruins or other discoveries in archæology, supplies of water in a dry country, or of pasture in a barren district, and all other places of interest to the traveler, will be determined. The roads and trails already in existence will be surveyed and mapped, while a leading object of this enterprise will be to find shorter and easier lines of travel. The explorer who opens a new pass through the mountains is a far greater benefactor to mankind than he who discovers and names a conspicuous peak.

Many of the national surveys of Europe were founded on military necessity, that is, the necessity of having correct information to govern the movements of armies in time of war and the incessant transfer of troops in time of peace. In some of these countries their early maps were withheld from the citizen whose taxes had paid for their construction, and to as recent a date as 1857, in one or two cases, they were kept secret for use in some contingent war. This argument of military necessity will have but little weight in Brazil, whose rulers, knowing that a country strong in peace will also be strong in war, take the enlightened and advanced policy of encouraging the peaceful pursuits of life, as the surest basis of national strength. Still it must be acknowledged that these maps would be of excellent service in the administration of the affairs of distant provinces, in the transportation of military supplies, and in the garrisoning of frontier posts, although the country is to be congratulated that, for every soldier to whom they would be useful, a hundred immigrants would be benefited by them.

THE INTENTS OF THIS ESSAY.

While entertaining no wish to make this article popular, in the ordinary sense of the word, I shall seek to exclude from it all formulas, equations for computation, and other material, purely mathematical, upon which the surveyor bases his work, and as far as possible I shall avoid those technical terms which would be embarrassing to the reader who is not an engineer. The fundamental principles of geographical engineering are the same all the world over, and in every mathematical library there are books of reference which give all the laws and formulas necessary for a work of this kind. Therefore, nothing would be gained by their repetition here. Specialists in geodesy, astronomy, and hypsometry have investigated their various branches, have published their results, and these, in their purity, are applicable to any quarter of the globe. One, for instance, has applied the theory of least squares to geodetic computation; another has invented the zenith telescope for latitude observations; and a third has traced the horary curve in the barometric record. All of these discoveries fall within the comprehensive department of the geographer, who supplements these studies by utilizing their results in his labors in the field and office; or, if he is about to write a brief exposition of the subject of geographical surveying, it is his business to describe, in a straightforward manner, the way in which practical application of these truths is made.

This paper will be, in general, a description of the most approved methods, the economical devices, and the practical results of a successful geographical survey, working in obedience to the directions of the chief of the commission to which it is attached, and covering such areas as may be designated by him as most worthy of geological and geographical delineation. From time to time, as occasion may offer, and especially at the conclusion, the project will be adapted to the Empire of Brazil, as it is quite impossible to propose a plan of survey which will be applicable to all countries. Although, as has been stated heretofore, the general principles underlying this kind of work are the same wherever physical laws prevail, and the face of the country is wrinkled with mountains and valleys and furrowed with the river-bed and cañon, yet there are physical conditions peculiar to every land, as well as circumstances of area, population, and wealth, which require that it should have its own type of geographical survey, and not copy too exactly those of any other nation.

THE BEST TYPE OF SURVEY FOR BRAZIL.

Considering the circumstances of area, population, and wealth it is evident that the national surveys of Brazil should be "geographical" in a very liberal sense of the word; that is, that they should be comprehensive in their scope, rapid in their execution, and sufficiently accurate without being too punctilious and too excessively minute. It is only within the present generation of engineers, and particularly in the western hemisphere, that there has grown up an important distinction between topographical and geographical surveying, and even now it is hard to define the limit between them. The latter is an outgrowth and extension of the former and an adaptation of it to the mapping of large domains at the least possible expenditure of money and time.

DISTINCTION BETWEEN THE GEOGRAPHER AND TOPOGRAPHER.

As one of the many points of difference between the geographer and the ordinary topographer, we may mention that the former, in his travels and surveys, accommodates himself to the roads, trails, or other open and easy routes that already exist, and it is but seldom that he finds himself obliged to make a path for his survey to follow. In the ascent of some mountains it may be necessary to cut a road, and in the measurement of the base line for his triangulation he may have to prepare the ground before him, but these are almost the only instances. The topographer, however, in tracing a contour line around the side of a mountain, or in making parallel profile sections of the land, is not allowed to deviate therefrom, and if the way is not clear, he must wait, perhaps at great loss of time, until his assistants have removed the brushwood, or whatever other obstacles may intervene; in this respect he resembles the railway engineer. Again, in the selection of the stations for his triangulation, the geographer makes the best possible use of the mountains of a country as he finds them, generally accepting them as they occur; though their arrangement, it may be confessed here, is not always in such well-conditioned triangles as he would desire. The topographer, on the contrary, delays his work by the establishment of arbitrary stations where natural points are lacking, and by the erection of artificial signals on those mountain tops which the former observes without such aid.

In the end it will be found that the topographer's notes are so numerous and in such detail that it may require several centimetres of map to represent one kilometre of the earth's surface; while to the geographer, who is satisfied with the general shape of a mountain-spur, the approximate width of a valley, and the more important bends of a stream, a scale of one centimetre to several kilometres may be sufficiently large for the portrayal of the earth as he finds it. But it will also be observed, by an economical government, that while the topographer consumes several years in the survey of a thousand square kilometres, the geographer will obtain a very satisfactory knowledge of thousands of kilometres in one year. And, in general, the superior accuracy, or rather detail, of the former, is purchased at an expenditure of time and money so great that only the older and wealthier nations can afford the investment; while I hope to demonstrate that the geographer's results are sufficiently complete for the needs of Brazil.

THE GEOGRAPHER'S PROFESSION.

The geographer's work is a peculiar and difficult one, and one for which his ideas must become enlarged by a special training. This is a branch of our profession for which no training-school prepares its student and no text-book yet published can instruct him. This is a field in which the experienced topographical engineer, fresh from his labors on park and landscape, or on the detailed surveys of thickly-populated Europe, finds himself unhandy and incompetent, for much of the experience and tradition that he brings with him is an incubus to retard him. To become efficient in this new service he must forget much of the rule and routine that he has learned, and accustom himself to taking broad and bird's-eye views of the country.

Strange as it may sound, he must make it a matter of duty and pride to overlook and neglect much that is near at hand, and remember that, although a mole-hill at a distance of a few feet subtends a greater visual angle than a mountain as many miles away, yet it is the mountain, and not the mole-hill, that deserves delineation upon his map. Hitherto he has been local and narrow in his range; he must now become geodetic, else he will accumulate a mass of minutiæ, whose representation would be infinitesimal on a map of the proposed scale, and which is hence but an incumbrance to his books, and even worse than cumbersome, inasmuch as its presence excludes other and more valuable data. In short, the topographer considers the earth minutely, and with a microcosmic view, but the geographer is a man of no such narrow horizon, and trains himself to look upon it as a macrocosm, or great world.

THE INSTRUMENTS USED.

Of scarcely secondary importance to the men of a geographical corps, are the instruments with which they shall work. The tools which have been devised for the ordinary surveys of land and landscape must be left at home with the slow and tedious methods from which they cannot be divorced. In a work of geographical extent the spirit-level, chain, and tally-pins are out of place, and whosoever, making accuracy his plea, attempts to introduce them there, will find his own ends defeated by them. Once upon a time, for instance, an engineer was intrusted with the survey of a large tract of new country. A certain sum of money and a limited period of time were given to him, a stated area of territory was assigned to him, and in return the authorities expected of him the most accurate and impartially complete map that his means would allow.

The time and resources granted him would permit him to touch the country but lightly and by swift marches, but, as this was intended to be only a reconnoissance, nothing more was expected of him than to trace the conformation of the land in a general way. He was an honest and conscientious engineer, and so great was his zeal for accuracy, or nicety rather, that he was scrupulous to a fault. He abused the maxim which says that whatever is worth doing at all is worth doing well. For determining the altitude of stations along the route he used the spirit-level, and their intermediate distances were found by stadia measurements, which system, though considered incautiously rapid in topography, is too laggardly slow for the ordinary purposes of geography. In this manner he crossed his territory with a few lines of march whose profiles were as trustworthy as those of a railway survey, and far more accurate than the public interest demanded, while between them there were large areas untouched and unseen, and of these the public, whose agent he was, had commissioned him to obtain information. The failing of this engineer was a common one; he neglected to distribute his resources fairly and impartially, and while half of his map is reliable the other half is conjectural.

It would be too long a task to describe in detail all the instruments used in geographical work, or to rehearse all of the devices employed in its prosecution; however, the most necessary and novel features will be noticed here. At the basis of the work is the transit, or theodolite, which, with compass-needle attached, is the engineer's constant companion, without which his occupation is gone, no matter in what field his labor may lie. As an appurtenance to this, not the chain nor the stadia, but the odometer wheel, has become the recognized means of linear mensuration in the survey of streams and the determination of those distances of route and detour which are so useful in filling in a triangulation chart. Instead of the level, the cistern barometer gives the heights of mountains, mines, passes, camps, villages, and other important positions, while the aneroid barometer, portable as a watch, and as easily read, will tell the altitude of minor points and give with sufficient closeness the data from which may be plotted the profile of the odometer's itinerancy.

THE PERSONNEL OF A GEOGRAPHICAL CORPS.

These are the three classes of instruments that are indispensable; the purely geographical party required to use them need consist of but three men, the engineer, the meteorologist, and the odometer recorder. To this corps it may be deemed advisable to add a fourth member to act as an assistant to the engineer, and, by personal obervation and experience acquire that facility in the practice of his profession which will fit him, in the course of a brief period of training, for the responsible position above him. Such a person should already have the theoretical education of an engineer, and some skill in drawing.

If it is not practicable to make this addition to the corps, it is well to choose as an odometer recorder one who possesses the acquirements stated above, and to consider that position, whose appertaining duties are light, as preparatory to the grade of engineer. As for the meteorologist, his is an intricate science which cannot be studied too thoroughly, and barometric hypsometry should be regarded as a profession quite distinct from the engineer's, although necessarily subordinate to it.

The various duties involved in the measurement of the base-line, at the opening of the season, may demand the services of a larger body of men than this, but, once in the field, any addition to the above number, except as muleteers and servants, will be superfluous, as far as the geographical work is concerned. One surveyor can see as far as two, and one man is able to take note of all of the country visible from his route of travel. No axemen are needed, for if there is a tree in the way, the line must yield to the tree; the resultant error will be trifling and will not be apparent in a map which represents several kilometres of territory on one centimetre of space. Neither is there any necessity for rodmen, with rods of two targets for micrometer measurements or one target for levels, who would retard the corps by the long delays consequent upon their transfer from the stations in the rear to those in advance. This party travels as a unit, moving as fast as its animals can walk, and is never broken, a consideration which is of value in a country of hostile people.

Of course the scope of the work may require the service of a great number of professional men, but its best progress demands that they should be divided into corps of the above size, which shall work in concord and under one general head. This director will assign to each party its territory for the season, and upon the borders of these areas, the various engineers will make rendezvous from time to time, as circumstances may admit, with their neighbors of the adjoining fields, for the purpose of reorganization, exchange and issue of material, and especially for the comparison of sketches and geodetic data, so as to insure the proper union of their several schemes of triangulation. In order to make the different systems of triangles interlock in one grand plan, the observer will frequently be obliged to read angles to stations which lie in an adjacent district, and which will be occupied by his co-laborers for the purpose of reciprocal observations. It is therefore necessary that they should meet in occasional conference for the mutual identification of those stations.

THE STATIONS OF SURVEY.

Guided by these thoughts, let us suppose that we have completed our organization for a season in the field, and that we are now on the ground ready for work, at the place selected as the initial point of the survey. As with all surveys, this one will be executed from stations, meaning thereby any points at which a tripod is planted and an instrument adjusted, angles are read and sketches may be made. Of these we shall occupy four orders, of which, in importance, and consequently in accuracy, the astronomical is first. Then comes the geodetic, or triangulation station; the topographical station, so designated for the sake of convenience; and, finally, the odometric, or route station. In addition to the ends which they are especially intended to serve, each of these will be a meteorological station as well. These five classes, with the incidental details pertinent to them, will now be considered in the order named.

THE ASTRONOMICAL STATION.

Since the positions determined by triangulation, or other system of survey in which terrestrial objects alone are considered, are only relative to each other and to the first station occupied, it is evident that a map may be completed, which, in itself, will have all of the exactness of perfect truth, but whose place on a projected surface of the globe will still be uncertain. A map of a continent may be made, and this may be of great use in the guidance of travelers across the continent, and for the local information of its inhabitants, but still it does not play its proper part in the grand plan of this earth's geography, and define the situation of this land relative to the other continents of the earth, until it is bound into place by the meridians and parallels, which are the warp and woof of the structure of geography. Therefore, in order to adjust our map, when made, into its true place, we must have the absolute determination of one or more of its positions.

Now there is but one way of finding the absolute position of an object on the earth, and that is by going beyond the earth, consulting the stars, and ascertaining its place relative to them. Having two triangulation stations thus located, the whole chart becomes adjusted to its place. Or, having the latitude and longitude of our initial point and the astronomical azimuth of a side of a triangle leading from this origin, the former serves to pin the plot to the projected map, and the latter is instrumental in orienting it into the area to which it belongs.

POSITION OF THE ASTRONOMICAL STATION.

For every base-line measured and developed there should be an astronomical station occupied, and as a matter of convenience and co-operation they should be in the same vicinity, although it is not necessary that the station should be directly over either end of the base. Indeed, owing to great exposure to the wind, or to inconvenience of approach, it may not be found practicable to locate the astronomical station at any of the points of the triangulation system, or, to secure proximity to the telegraph, whose office may be hidden in the heart of a town, or the bottom of a valley, it may be so secluded as to be quite invisible from those points.

If so, it may be easily connected with them by running a careful linear survey from the astronomical station to the nearest geodetic station. If, owing to the disadvantageous nature of the ground, or other obstacles in the way, it may be impossible to measure the distance directly between these two points, the engineer can connect them by a broken line, reading at the astronomical station the angle between the meridian mark, already fixed by the astronomer, and the direction of his first course, and afterwards referring the direction of each measured section of his traverse to that immediately preceding. From these results he calculates, in meters, the difference of latitude and departure between the two points, and then, transforming the meters into seconds of arc, he computes their difference of latitude and longitude.

NUMBER OF ASTRONOMICAL STATIONS.

For a commission of moderate size, including one, two, or three engineering corps, the triangular development of one base will cover as much territory as can be surveyed by them in a single campaign, and therefore one astronomical position a season is all that this survey would require during the first year or two of its organization. A series of observations extending through a couple of weeks, in favorable weather, or through a month at the farthest, will determine the geographical co-ordinates of our point of departure. These can be made by the astronomer while the engineers are measuring the base-line and developing the same, the director is perfecting his arrangements, and the purveyors are preparing and distributing the supplies, instruments, and all of those numerous articles of equipment which are the furniture of a scientific field season. At the same time, the meteorologist, by a set of hourly barometric and psychrometric readings accumulates data whose digest will give the vertical co-ordinate of this place with the possible error of a very few feet, and this completes the determination of its position with reference to a system of co-ordinates whose origin is at the level of the sea at the point where the first meridian crosses the equator.

For so short an annual term of service it might not be advisable to keep an astronomer constantly in commission, nor, at present, might it be well to go to the expense of the costly and elaborate instruments requisite for the best astronomical observation, provided that the co-operation of the Imperial Observatory could be secured and an astronomer could be detailed from there for that purpose. In addition to the gratification to be derived from the warranted excellence of the results which would be furnished by the skilled assistants of that institution, this coöperation would be a matter of economy to the Government, and also, what is especially to be desired between any two scientific bodies, a means of friendly relation and interchange of information which would certainly prove of mutual value.

ASTRONOMICAL METHODS.

For the determination of the latitude of our point of outfit the zenith telescope would be used; while the longitude would be found by the telegraphic exchange of time signals, a method which has lately been so successfully introduced by the Astronomical Commission. The present wide-spread extension of lines of electric telegraph within the borders of Brazil is especially favorable for a survey of this nature, whose longitudes would be based upon telegraphic communication with the national observatory. The lines along the coast afford a general connection with the northern and southern provinces of the Empire, while, by the numerous branches which accompany the railways into the interior, points which lie far to the inland could be referred to the meridian of Rio de Janeiro, which, in its turn, has communication by cable with the observatories of Europe.

Thus it will be seen that the engineer need not be confined to any unfavorable locality in the selection of the ground for his base line, nor need the chief of the commission be restricted in his choice of areas to be surveyed. From the railways either constructed or contemplated it would probably be possible to reach any of the settled portions of Brazil without seriously overtasking the accuracy of the triangulation, and, if it were required to carry the survey still farther, longitudes determined by the method of moon-culminations would be sufficiently exact for the less important regions beyond.

ORIGIN OF THE TRIANGULATION.

An inland survey, based upon trigonometrical methods, progresses most successfully from an initial source concentrically outwards. The most fortunate location for the initial line is in the center of some broad valley or intermontane plateau, whose level expanse offers fair ground for the measurement of the base, and whose open field is favorable for the gradual and symmetrical development of the same until it shall reach the lines of the remotest triangles, in which it becomes a metrical standard for finding their length. In an extensive survey, lasting for years and covering broad territory, a series of bases are indispensable. These act as checks upon each other, and the net-works of triangles emanating therefrom are dovetailed into each other, and, in their adjustment to fit, each to each, what little error they may have accumulated is reduced to a minimum.

For instance, on each side of a range of mountains there is an open basin. In each of these an astronomical station is established and a base is measured. On the comb of the intervening sierra, one-hundred miles apart, stand two pre-eminent mountain peaks. The latitude and longitude of each of these, with the distance between them, is determined from the two origins independently. They check each other, verifying, in their agreement, the accuracy of both systems, or showing by their disagreement that there is an error somewhere; and the long line, drawn by the labor-saving appliances of trigonometry, through a hundred kilometres of aerial route, a thousand meters above the valleys and chasms which it spans, is now ready to be used as a new base in the primary triangulation.

It may be difficult to find a favorable locality for the source of a triangulation immediately upon the sea-shore, as there, unless there are islands in the adjacent ocean, one side of the field is quite open and affords no stations to be occupied. If it were not for this objection it would seem best to measure a succession of bases along the coast of Brazil, and thence develop them westward. A triangulation is always most accurate in the vicinity of its origin, and as it becomes more and more remote from its initial ground it becomes less reliable, owing not only to the continued multiplication of the original error of the base, but also to the accumulation of inaccuracy and mistake * from other sources. Now, the population of Brazil is thickest along the sea, and thence, into the interior, at least in many provinces, it gradually thins out. The importance of the country and the necessity of having truthful maps correspond to the density of the population. Add to this the fact that the most interesting geology of Brazil is on the sea-board, and, furthermore, the important consideration that the coast of a country, for purposes of navigation, demands a more rigorous geographical determination than the interior, and it will be seen that the triangulation upon which this delineation depends should not originate too far away. In a general survey of Brazil, therefore, the first series of astronomical stations and bases should be established, if not upon the sea-shore itself, at least

* There is an important difference in the meanings of the terms "mistake" and "inaccuracy." If a man, carelessly reading a vernier whose indication is 38′ 45″, calls it 39′ 45″, he is guilty of a mistake. If from parallax or some defect in vision or judgment, he calls it 38′ 40″, he is inaccurate. Mistakes are due to want of care; inaccuracy, to want of precision.

upon the first plateaus that are encountered between the mountains of the inland.

POSITION OF THE BASE-LINE.

In its direction and position the base-line should bear judicious relations with certain hills, knolls, corners of terraces, or other prominent elevations in the vicinity, which may be selected as sites for the stations to be occupied in its development. The plans for its expansion, matured before its position is selected, should include two prominent peaks in the horizon, remote from the origin and from each other, whose distance apart this measured length will be instrumental in determining. The ground upon which it is to be measured should be as smooth and bare as possible. It should be free from brush, tall grass, or other vegetation, and also from hillocks and gulches, which are serious impediments to a work of delicate mensuration. Whether it is level or not, provided its slope be gradual and even, is of secondary importance, as corrections may be easily applied to cancel the effect of its gradients.

LENGTH OF THE BASE.

The length of the base may vary from two to ten kilometres. In the opinion of many engineers more than four kilometres of measured length is zeal gone astray, for the advantages of accuracy gained by such excess would be obtained more easily by devoting the extra time to a more elaborate trigonometrical development. No arbitrary rule can be applied here, however. All must depend upon the judgment of the engineer, who will consider his surroundings, and if they are favorable for a slow and progressive development, a short base will answer; but if he is obliged to carry his triangulation from the base stations to the distant mountains by an abrupt transition, a longer one will be required, to prevent too great acuteness in those remote angles.

INSTRUMENT OF MEASUREMENT.

Since rapidity, as well as accuracy, is

an object, we use a steel tape, ten or fifteen metres in length, as a measuring unit. In the swivel at one end of this there is a thermometer which tells the heat to which the tape is exposed at any time; there is also a micrometer screw, by which it can be lengthened or shortened in compensation for any possible change of temperature; and there is a dynamometer attached to govern the tension applied, which should amount to three or four kilograms, being at every application the same as it was in the original test for length, to which the tape was subjected.

Thus, as this apparatus is applied, in the process of measurement, it is under a constant strain, which preserves it from the error from sagging, to which all flexible cords are liable, and its length is always corrected to meet the contraction and expansion which the metal is constantly undergoing as the temperature varies. Should this micrometer be but incompletely graduated, so, for instance, as to be adjustable only for every five or ten degrees of thermometric change, or should it even be wanting entirely, very good results can still be obtained with the steel tape by reading the thermometer at every application, and, in the final computations for length, making the necessary temperature corrections. Used carefully and with intelligence, this instrument is one of the most valuable adjuncts of the geographical survey, and, in the hands of conscientious and interested observers, it is capable of results that are very near the exact truth; the error ought not to exceed one centimeter for every kilometer of measured distance.

METHOD OF MEASUREMENT.

The mensuration may be made on wooden plugs, with smooth, flat upper surfaces. These are driven firmly into the ground along the alignment at intervals equal to the length of the tape, and should be allowed to project above the earth sufficiently to permit this cord to swing clear of all inequalities in the surface, or other obstacles between the two stations. Or, instead of these, little stools of plank may be used; these should have short, pointed iron legs, to be forced into the ground, so as to hold the wooden block firmly in position.

When all things are ready a distance of one or two kilometers can be measured in one day. But, on account of any possible inefficiency in the compensation for temperature, and also because even the best assistants are liable to a personal equation in sticking the marking pin, some invariably inserting it to the right of perpendicular, and others the reverse, it is well that it should be measured several times, and by different persons, and a mean of the results taken. Then it should be leveled, in order that each tape-length may be corrected for its gradient, which is done by a simple trigonometric process, and finally it is reduced to its corresponding concentric arc at the level of the sea, when it is ready for use in the system of triangulation.

THE ASTRONOMICAL BASE.

The method of base-measurement by astronomical observation is sometimes resorted to in geographical surveying, but this process will be noticed here only sufficiently to point out the serious objections that there are to its use. Having the latitudes of the two ends of the base and the azimuth of one from the other, it is a simple matter to compute their distance apart. This seems to afford an economy of labor, over the former method, that involves the determination of the latitude and longitude of the first station, the azimuth of the base-line, and its length by direct measurement; this one requires the determination of the latitude and longitude of the first station, the azimuth of the base-line, and the latitude of the second station. The latter is apparently the simpler and shorter task, and since both methods are based upon astronomical observation they would appear to be equally reliable. But they are not.

Experience has long since taught the

scientific world that the probable error of any ordinary astronomical result is several meters at the very least, and that it is not safe to put absolute reliance in those reports which give a latitude down to a very small fraction of a second. Now, in that system of triangulation whose position is based upon the astronomical determination of one point only, an error of a few meters in the latitude of that point will not do material injury. It will simply displace the entire triangulation scheme, as a whole, so much to the north or the south, while, since the length of the base, or measuring unit of the proportions of this scheme, was accurately found, there will be no error in these proportions. But, in the astronomical measurement of a base, suppose its two terminal points to be in their most favorable position, that is, on the same meridian. The latitude determination of the southern station places it several meters too far to the south of its true position; that of the other, perhaps, makes it an equal distance too far to the north. Hence it follows that there is an error in the length of the base equal to the sum of the two astronomical errors, and this, in the development, is multiplied almost indefinitely, being repeated in any side of triangle as often as the length of the base is contained in the length of that line. This is supposing the base to be an arc of meridian; the greater its divergence from the meridian, the more seriously, for obvious reasons, will an error in the astronomical determination affect the length of the base. An astronomical base-line, therefore, should only be used when there are difficulties which make a direct measurement impossible.

THE DEVELOPMENT OF THE BASE.

In the early stages of the development, occurring, perhaps, on the level surface of the plain, it will be found necessary to use artificial signals. Great tripods of frame-work, ten or fifteen meters high, are constructed, leaving ample space within for the observer and his instrument. In erecting these, care must be taken that none of the legs of the tripod interfere with the view towards any of the proposed triangulation stations. Each of the signals terminates at the summit with a flag-staff, to which voluminous folds of white muslin are nailed, while the body of the steeple is wrapped with the same material and decked with loose tatters and streamers, which, by their ceaseless flutter in the wind, offer occasionally a surface from which the light is reflected to the eye of the distant observer. The same purpose may sometimes be better served by the use of glittering sheets of tin, or by a cone of the same material. These methods all have one very great advantage over the more accurate heliotrope, that is, they are always in position, and ready for observations to be directed upon them at any time. The use of the reflecting mirror, however, unless there are a number of heliotropes in the field, involves the loss of much time, as the instrument is transferred from one to another of the neighboring stations.

The development stations should be erected in conspicuous places, on high ground or the salient angles of bluffs, that the observer may know where to direct his instrument in searching for them, as it is extremely difficult to pick out the faint glint of a few yards of muslin on the broad light surface of a remote plain. As the development continues and climbs from the foot-hills into the high and peaked mountains, these natural points are sharp and distinct enough, being projected against the sky beyond, and the labor of station-building ceases, except in cases that are very unfavorable.

True, this triangulation by natural points is not so precise as it is in some geodetic surveys, and especially in the surveys of coasts, where even the phase of the conical signal is considered too important an element of error to be neglected; nor is it wise that it should be so, for a fault of a few meters in the position of a mountain-top in the remote interior of Brazil, located by this plan, is at present of no practical consequence, and the nation cannot afford to purchase an accuracy imperceptibly greater than this by an expenditure that would many times exceed the cost of this method of survey. Considering a mountain as a land-mark by which travelers are assured of their place and are guided as they go, it will be seen that, to men who travel by land, a small fraction of a kilometer, in latitude and longitude, is a deviation which they cannot notice; to the voyager at sea, however, the exact site of the sunken rock which he shuns should be known to him, in order that he may certainly avoid it. This is why the coast survey, in most countries, precedes that of the inland in the degree of accuracy which characterizes it, as well as in the amount of expense which attends it.

TRIANGULATION BY NATURAL POINTS.

It must not be inferred, however, that the use of natural points in triangulation necessarily involves a serious accumulation of error. In general, the engineer, looking from one station to the next, can readily cover, with the thickness of the spider-line of his instrument, the highest ground of the distant mountain, and that point is selected as a correlative station, because that is the spot which can be most easily identified, either from a distance, or upon the ground itself. If this place is uncertain, as where there are a number of pinnacles of equal altitude, or not sufficiently prominent, as in a plateau summit, some peculiar object, as a solitary tree, or an isolated boulder, should be chosen as a center upon which to sight. If the profile of the mountain has but little curvature, its culminating point is usually determined by a pile of rock, a clump of vegetation, or other body upon its crest, which, although it may not be distinctly visible from a distance, yet has the effect of increasing the apparent altitude at that precise locality. In the same way the usefulness of a monument of rock, which a party should always leave behind it upon a mountain, as a signal to look back upon, does not terminate at that distance at which it becomes apparently invisible. The eye will still be impressed with the superior elevation of the place where it stands.

If the round top of a mountain is perfectly bare, and offers none of these accidental aids to the observer, it is well for him, in reading his first angle to it, to keep the horizontal cross-wire tangent to the surface, while he makes a careful and deliberate search for its highest point. Having decided upon this, he brings the vertical wire upon it, and then follows down the thread with his eye until he finds it bisecting some well-defined body in the field before him, such as a corner of rock or the trunk of a tree, and, in his repetitions of the angle he fixes the vertical wire always upon this object, while keeping the horizontal thread tangent to the surface. In this manner he secures to each of the following readings the advantages of the prolonged study given to the first, and not only are his results more accurate, as a whole, but they also agree better among themselves, which is always a source of gratification to the engineer.

THE MOUNTAINS OF BRAZIL.

In those lands which are remote from the equator the summits of the high mountains, of an altitude of three thousand metres or more, are above all vegetation and in the belt of perpetual snow, and their occupation is a work of great privation and exposure. The mountains of Brazil are exempt from that disadvantage to triangulation, as the climate is never rigorously cold here, and the elevation of the highest land is less than three thousand metres. The only obstacles to be feared here are the opposite disadvantages of too much vegetation, either hiding the tops of the peaks, or embarrassing the ascent to them, and too little height, whose result is liable to be a system of round, well-preserved, and insufficiently pointed mountains. But if those in the vicinity of Rio de Janeiro are to be accepted as a criterion, nothing more could be desired in the way of natural aids to triangulation.

PROGRESS OF THE TRIANGULATION.

In some cases it may be absolutely necessary to send a party in advance to erect monuments of stone, or signals of timber upon proposed stations which are at the same time important and unfavorable for observations; or, should the mountain be covered with forest, it may be necessary to send axemen to clear away all but the largest and most central of these trees. Such action, however, causes a vexatious delay on the part of the engineer, and is contrary to the fundamental principles of this method of survey, whose work should be a steady and unretarded progress, and should be reconnoissance and completion in itself.

From the top of his first high mountain station the engineer sees his allotted territory spread out before him, and he immediately begins to lay his plans for the coming season. He selects two distant peaks, which, with his present station, will form a grand triangle. Beyond these, far in the distance, there is yet another, and these four constitute a great quadrilateral, the lengths of whose diagonals may each be determined by two independent sets of observations, checking each other. In like manner he makes the circuit of the horizon, utilizing, as best he can, the peaks which rise around him.

Although, owing to the many obstacles and unforeseen difficulties which are experienced in traveling through an unknown country, he may be compelled to modify and alter his first plans very often, yet as soon as he abandons one feature of his scheme he immediately adopts a substitute to take its place. To be provided for such an emergency, if a distant peak, as, for instance, one of the sharp pinnacles of the Organ Mountains, should appear impossible of ascent, he will select another in the same vicinity, and consider that as an alternate to the first, reading angles to it and treating it in all respects as a regular station as long as such a reserve may seem necessary.

In proceeding from one mountain to the next he surveys all of the intermediate country, his course being governed by the advantages and obstacles which present themselves from day to day. His route should never be an arbitrary one, determined at a distance and weeks beforehand, but he should be free to act upon the spur of the moment, following a stream to its source here and surveying a lake there, according as these geographical features may be encountered. If these features are depicted on maps already made, then there is no need of a second survey of the country; if they are not, he is not likely to know of their existence until he finds them.

EQUIPMENT OF THE PARTY.

Since the terminus of a day's survey cannot always be advantageously decided upon, even in the morning on which it is begun, it is especially desirable that the party may carry with it its own equipage and supplies, so as to be prepared to camp anywhere that night may overtake it. As it is a part of the policy of geographical work that the engineer should never follow the same route twice, a survey carried on by daily excursions from fazendas, settlements, or other fixed points of supply, returning to this base by the same road in the afternoon, would cost a great waste of time and energy. The necessary outfit of a scientific corps, consisting of instruments, clothing, cooking utensils, and provisions, can be carried by a train of pack-mules equal in number to the people whom they accompany. With this equipment the party are independent, and can camp anywhere that wood for fuel, forage for the animals, and a supply of water are found. This arrangement is particularly necessary in the occupation of a mountain station, upon which, for successful observation, it may be imperative to arrive at an early hour in the morning and to remain through the greater portion of one, two, or three days. From a camp near the summit this may be reached in an hour or two; but from a distant base almost the entire day would be consumed in the journey to and fro.

THE TRIANGULATION STATION.

The mountain will be ascended by the engineer, the meteorologist, and such assistants as may be required to carry the implements of the work and the food and water necessary for the maintenance of the party, and to build the stone monument, which, if possible, should always crown the peak, to receive the records deposited here, to assist in the future identification of this station, and to serve as an object upon which to direct the telescope in subsequent observations. One day will be a sufficient time of occupation for the ordinary triangulation station, provided the weather be favorable. To the more important ones, however, it may be advisable to devote two days, spending one night upon the crest in astronomical observations for the determination of the azimuth of some line radiating from here; this will serve as a check upon its computed value, as derived from the original azimuth determination made by the astronomer at the base-line. In times of high wind, or cloudy and stormy weather, especially liable to occur upon the summits of peaks, it may be several days before satisfactory results are obtained, and therefore the party should always go well equipped for a prolonged stay in their mountain camp.

PROFILE SKETCHES.

As an economy of time, which is of the greatest value here, the observer should make all reasonable haste in his operations. Especially is this so in his sketches, over which he must not linger, which, if he is anything of an artist, he will be sorely tempted to do. He may see before him broader views and scenery more grand and impressive than ever was painted yet, but picturesque effects are no business of his. To the geographer of artistic tastes there is great temptation to finish his sketch by inserting a pine-tree in the foreground, and, perhaps, an eagle's-nest in the tree; this is all very wrong, as such dalliance may cost the omission of that far distant peak, which is printed like a fine point against the horizon, and which, insignificant and low as it appears, is yet of vital importance to his scheme.

His sketch is perforce but the outline and skeleton of a picture. Two converging straight lines, with a few strokes of shading, hastily thrown in, are sufficient to represent the ordinary mountain peak. Yet, if the peak should possess any oddity or marked individuality of shape, this feature should be preserved and even magnified in the drawing, as a key to the identification of this point when seen from elsewhere at some other time. Since any mountain, from different points of view, presents phases that are quite dissimilar, it is one of the greatest difficulties of triangulation to make sure of the identity of a station previously occupied, or, where there are a number of observers in the field, to secure uniformity in the choice of the same.

CONTOUR DRAWINGS.

The expert geographer is proficient not only in rapid profile but also in contour drawing, and on every mountain station he executes a contour plot of that scope of country which he sees beneath his feet, and of whose conformation he is reasonably certain. But in the preparation of this local plot he should not be too comprehensive, and go beyond the bounds of certainty into the outer limits of conjecture. Every mountain is surrounded by valleys, on whose farther side are other ranges perhaps as high as this, and they form the limit beyond which no contour sketch should presume to go, else it becomes conjectural and unreliable. It may include those environs of valleys, with a periphery of the foot-hills which are beyond them, and an indication of the cañons which indent the same, but no more.

In the office a contour sketch is accepted as truthful evidence of the ground as it really is, while a profile drawing is considered only a copy of the country as it appears to be, when uncorrected for the illusions of perspective, and is studied and deciphered accordingly. Looking abroad from this station, the successions of distant ranges, which are in reality separated by broad interspaces of valley and plain, are projected into a dense and circular wall, apparently unbroken by pass or intermission, whose serrated outline is seemingly as continuous as the horizon. It is an error to which the human sight and judgment are subject, and so, in orographic delineation, the impressions of the eye are to be received with caution, and only the readings of the theodolite are to be accepted in full faith.

PHOTOGRAPHS.

As a supplement to the pencil of the engineer, the photographer's camera can often be used to good advantage in securing, in their true proportions, the many details of geological structure which are necessarily omitted from a hasty sketch. In the best geographical delineation of a country, a series of photographs are almost indispensable, as, aside from affording much material for the filling in of a map, they reveal the nature of the surface which they represent, showing whether it is regular or broken, well-preserved or eroded, whether a cliff is impassable or easy of ascent, and whether a coast is smooth and sandy, or irregular and rocky. All of these conditions should be made to appear in every good map, whether in contour lines or hachures, and particularly so, when, as in this case, the map is intended as a basis for geological representation.

READING THE ANGLES.

The instrument of triangulation is a theodolite, whose accuracy and weight increase with the minuteness of the graduation, but, in this work, in which rapidity and ease of transportation are to be considered, there comes a limit beyond which it is imperative to sacrifice nicety to portability. This is reached when the limb is graduated so as to discriminate to ten seconds of arc, between which divisions the observer may estimate to every intermediate five seconds. With this he reads and repeats the angles, singly and in combinations, that lie between the visible points of the triangulation scheme. It is advisable to make at least six determinations of each angle upon each of the two verniers of the instrument, amounting to twelve repetitions in all. The greater the number of readings from which the mean is derived, the less will be the probable error of observation affecting that mean.

The observer may complete the repetition of each angle by itself, or, what is more convenient, he may read them in conjunction, by making six complete circuits of the horizon. In either case the graduated limb of the theodolite will be turned 30° in azimuth at every return to the initial point. In this manner each angle is read upon twelve different and equi-distant divisions of the circle, and the faults arising from eccentricity or imperfect graduation are reduced to a minimum.

The most opportune moments of the day will be devoted to this important task, and all other duties will be neglected for this. Successful triangulation demands perfect quiet and a clear horizon. In a dense and hazy atmosphere, or in a region of low clouds, the observer may find his opportunity in the evening or early morning, when the sun is behind the hills, and the rim of the earth is seen in silhouette against the rosy background of the sky.

SUBORDINATE ANGLES.

Upon the triangulation station the engineer also reads angles for the direction of the spurs which project from here and of the streams that debouch from here, estimating the distances of geographical features in his immediate vicinity. How far he may trust to his judgment in this respect, will be determined by the circumstances by which he is surrounded. It is the engineer's duty to make the best map of a country that is possible with the advantages at his command, and if he should see before him a tract of country, distant even ten or twenty kilometres, which he will never see again, he should take note of it on his contour plot; but if he knows that some future route of his will cross it, he can afford to neglect it now.

In addition he takes readings to inferior elevations which, although they may never be occupied for reciprocal observations, may yet be located by intersections from two or more triangulation stations. Some point, or "tit," standing on the edge of an abrupt bluff, where the rapid descent begins, is used as a means of marking the end of a neighboring mountain range. A solitary butte on the plain, insignificant in itself, is very useful in determining the locus of the stream which flows by the side of it. A promontory, jutting into the confluence of two rivers, is instrumental in fixing the place of their union. Sights are also taken to the junctions of streams, the mouths of cañons, and to the church or other central object of a distant village. A spot of green on the desert, evidence of a spring of water there, is located, for it will perhaps be camping-ground some day for himself or his co-laborers. A minute patch of white lake-bed, or red escarpment, or a solitary tree, is sighted upon, because on such a day he made an odometric station there, and this sight will serve to check his position.

NOMENCLATURE.

In his note-book and mind he has dubbed all of these things with graphic titles, or designated them by letters of the alphabet, and by these tokens he will know them when he sees them again. But this system of names is only a transient device for the assistance of himself and those who work in concord with him, and should not appear upon the printed sheet to the exclusion of tne native and established nomenclature of the country, which should be investigated as far as possible, and, upon the final maps, should be adopted in preference to the arbitrary naming of any one man. The usefulness of a map, as a guide to the traveler, is in a great degree invalidated by a nomenclature which is at variance with that in use upon the ground itself. Perhaps the modern geographer is guilty of no more common and high-handed outrage against right, convenience, and beauty, than by ignoring the appropriate titles which abound in every country, however wild and uncivilized, and attaching his own, or by mutual and tacit agreement, the names of his comrades, to the mountains of that land, thus announcing themselves to the world as nostrums are advertised on the pyramids.

THE TOPOGRAPHICAL STATION.

All of the preceding description that does not refer to the triangulation process is also pertinent to the topographical tation. This term is applied to those isolated stations of survey, apart from the route of the odometer, and intermediate to the points of primary triangulation. They are more numerous than the primary stations, being usually scattered over the country at intervals of not more than twenty kilometres, but are less important, since there is no great responsibility of accuracy resting upon them. The topographical stations correspond, in position and numbers, with the secondary triangulation stations of a more elaborate geodetic survey.

A SECONDARY TRIANGULATION.

Even here the topographical station may be made a point in a subordinate scheme of triangulation if its situation is elevated, distinct, and capable of recognition from a distance. Of course, it is desirable that every occupied station should subsequently be made an object of reciprocal observations, and the engineer should neglect no opportunity to confirm his position in this manner.

Each point thus fixed becomes the center of a plexus of triangles, of each of which the three angles have been observed; the total error of observation in these three angles becomes apparent, and the computer is enabled to distribute it judiciously among them before he proceeds to the computation of the sides.

For this reason the observer upon any topographical station will make careful search for other points which he may have occupied or may contemplate occupying, and will be more than usually cautious in reading angles to them. On his return to the office, at the end of the season, he will pick out from the multitude of his notes as many complete triangles as he may have observed, and these will be so much gain attained at a cost of but little extra labor. But if he makes it imperative upon himself to carry on a complete and systematic triangulation within the first, the additional refinement gained will by no means compensate him for the disadvantages of reconnoissance and delay which this involves.

It is safe to say that it is a longer and more laborious work to accomplish an unbroken secondary triangulation than a primary, as the stations are more numerous, less elevated and conspicuous, and oftener in the shadow. On the other hand, the results are by no means so valuable. The primary triangulation sustains the general and continued accuracy of the survey; the secondary does little more than to insure the individual positions of its own stations.

POSITION OF THE TOPOGRAPHICAL STATION.

Although not necessarily a point in the triangulation proper—the site of the topographical station must afford angular data sufficient for the determination of its position by the three-point problem. After that, its predominant idea is that it is a means of local geography, or topography, and a center for a series of contour sketches. In addition to these detailed plots of the country in the immediate vicinity, profile drawings of the more distant regions are made. Then, by lines of sight, which shall be intersected by other rays from other topographical or triangulation stations, the most prominent features within a radius of twenty or thirty kilometres are crossed, and, as a precaution, angles are also read to all eminent points visible at a greater distance, even to the horizon, as they may come into use in some future dilemma in map-drawing.

While the site of the topographical station should be as elevated and marked as possible, yet any hill, however humble and inconspicuous, or even the level surface of a plain, may serve this purpose, provided that there be three triangulation stations, or other known points, visible, and there is any useful information to be gained by lingering here. A few hours are usually enough for its occupation, and the route between points of triangulation should be marked at regular intervals by the monuments of these stations. It is a good plan for the engineer to make a practice of diverging from his route at some point in each day's odometric survey, and, ascending a suitable eminence close at hand, make a topographical station there. As far as a general rule can be given for the occurrence of mountain stations, it is advisable for the party to advance by linear survey every second day, remaining in camp on each alternate day, while the engineer ascends some peak in the vicinity for the purpose of establishing a topographical or triangulation station there.

The large triangulation theodolite should be used in the more important topographical stations, or those which may possibly be treated as points in a secondary triangulation, but, for the sake of convenience, the small route transit must be made to suffice for those which are made in the course of the daily march.

THE ODOMETRIC, OR MEANDER SURVEY.*

The meander survey is useful as an

* *Note to the Portuguese Edition.*—This term, which is now firmly grounded in the technical language of

adjunct to the triangulation, filling up its skeleton with that detailed information which alone can give practical and popular value to a map. It determines the courses of valleys and streams, the routes of roads and trails, the peripheries

---

geographical surveying in the United States, is a misnomer, and therefore, in introducing a corresponding one into the Portuguese, it will be well to adopt some more appropriate expression. For this reason "odometric survey" will be used to designate line surveys in which the odometer takes part, and "route survey" (*caminhamento*) as a general term, to include not only the above, but also those in which distances are determined by time, by the chain where that method is employed, or by paces, whether of man or horse, and whether recorded by the pedometer or by direct counting.

As the meander survey is understood, where this expression is used, it is simply any survey following a zigzag line, whose angles in general, are alternately salient and re-entrant, as the line accommodates itself to the route of travel. But this word "meander," having been derived from the river of the same name, in ancient Phrygia, which was celebrated for its winding, sinuous course, literally means "abounding in curves." It will thus be seen that the more a survey approaches to a true meander, the farther it departs from the first principles of accurate linear surveying, which dictate that it shall consist of straight lines and angles only. Since it is always to be regretted when a survey is confined to a true meander line, as for instance, in tracing the course of a road along and up the side of a mountain range, so it is also a matter of regret that this word should have been introduced into the language of engineering, apparently sanctioning a faulty survey.

of lakes and basins, and the distances between springs of water, villages, areas of pasture, fords of rivers, and other points of interest to the future traveler. Finally, it is a commendable occupation for the engineer while on his way from one mountain station to the next, and, since it occasions no delay in the general progress of the work, as the engineer can, as a rule, meander as much road as his pack-train can travel in one day, its results are net gain to the survey.

In the theoretical journey of this kind, the engineer would follow the edge of the dividing ridge from one station to the next, from which lofty promenade he could see the earth like an extended scroll beneath his feet, and make a survey that would be exhaustive and complete. But in the real, hard practice, he finds this path an impracticable one, for it is broken by precipices and blocked by abutments often a hundred metres or more in height. His easiest route of travel is by the side of flowing water, whose tendency it is to erode abrupt cliffs and soften steep gradients into an average and even slope. Besides, along the streams there are trails made by the wild animals which come here for drink and covert, and by the people of the country who come hither to hunt and fish. Therefore, if the detour be not too great, the most expedient route from mountain to mountain, is down one valley and up another, and the geographer who traverses a valley without taking some sort of a survey of it, is culpably negligent of his duty. On the other hand, if in a block of mountains the pre-eminent peaks be occupied, and the streams which emanate therefrom be meandered, nothing more is needed for a most excellent geographical map of that country.

THE MEANDER TRANSIT.

It is supposed that all transportation of outfit, and all travel, even in the meander survey, is accomplished on the backs of horses or mules. Riding in the saddle, the surveyor can devote but one hand to the grasp and protection of his instrument, the feet of whose tripod rest in a holster attached to the left stirrup. To facilitate his secure hold, the members of the tripod are thirds of a cylinder, which fold into the smallest possible compass, and are easily held in the grip of one hand.

The instrumental part of the meander transit is neat, solid, and compactly constructed. Its graduated limb is of small diameter, and its horizontal vernier reads to minutes only, which is all very well, since no smaller divisions can be plotted on the map. This graduation is used in the occupation of topographical stations, at those meander stations where the view is extended enough to make it profitable to linger an hour or so in the accumulation of notes and sketches, and at all those which are three-point stations as well. But in the general survey, not the vernier-plate, but the compass needle, is used, on account of its greater convenience. The compass box is graduated, from zero at the north, around by the left to 360° at the north again, so that a reading of 90° corresponds to magnetic east, and 270° to west. The field records are kept in this manner, and in the office the declination of the needle is first applied to each bearing, after which it is reduced to its true direction, preparatory to the plotting.

THE ODOMETER.

The distances from station to station of the meander are measured by the odometer, an implement of survey which, in some of its forms, has been long in use in Europe, and has of late years received especial attention and improvements in the reconnoissances and other geographical surveys carried on by the War Department of the United States of North America. In this service it has been adapted to the severe conditions of travel in a new country. It has been strengthened so as to withstand any shock or fall to which it may be subject. The recording apparatus is made so compact and simple that there is no danger of disarrangement there. Instead of the old laborious process of pushing it by hand, the wheel has been fitted with shafts, so as to be drawn by a mule, and so efficient is the method of attachment that the odometer can follow any route, however rough, precipitous, or narrow, that will admit of the passage of a pack-mule.

In its simplest and best form the odometer vehicle is a solitary wheel, a little more than a meter in diameter, or about the size of a light carriage-wheel. It is strongly constructed of the best material, and is braced by opposite inclinations of alternate spokes, so as to be uninjured by the heaviest jars and collisions. A pair of shafts are attached to it, and into these a strong and steady mule is firmly harnessed by straps from above and underneath. The vehicle is close in the rear of the animal, and the shafts are made short and heavy, and in this manner the wheel is preserved in a plumb or upright position as it runs, not swaying from side to side. The length of the circumference of the wheel being accurately known and the number of revolutions being recorded by the attached apparatus, it is a simple matter to learn the distance between any two points.

The recording instrument hangs in a cylindrical box which is strapped to the wheel. It consists of a mechanical combination attached to a heavy block of metal, whose center of gravity is at one side of the axis to which it is suspended. As it is free to revolve upon this axis it always maintains a vertical position, while its box turns with the wheel, and the apparatus scores the number of revolutions, of which it is capable of recording 9900, or a distance of about forty kilometers, when it begins anew.

USEFULNESS OF THE ODOMETER.

This detailed description of the odometer is in accordance with the promise, made in the early part of this article, to dwell upon the novel features of this work, even to the exclusion and apparent neglect of others, already well-known, which are really of greater importance. Still it would be difficult to over-estimate the usefulness and practical value of this instrument. It requires but little technical knowledge to use it and to conduct the meander survey which accompanies it, and any person educated in the simplest rudiments of surveying is competent for this kind of work.

For this reason every party of scientific exploration and reconnoissance, every preliminary survey for railways, and every marching body of troops should consider its outfit incomplete without the implements of an odometric survey. Aside from the mass of notes and sketches that would be accumulated by them, and the itinerary maps that would result, in the item of distances alone the country would be more than repaid for the cost of these surveys. As a means of mensuration the odometer will determine distances *en route*, as the wagon travels, more truthfully than the chain itself. These, being published, are of profit, not only to the ordinary traveler, but also to the general government, whose agents and officials, in one capacity or another, are constantly passing to and fro.

ERRORS OF THE ODOMETRIC SURVEY.

Nor is there any very great error in the ordinary surveys which the odometer is likely to be called upon to perform. Having the geographical positions of two towns forty kilometres apart, they may be connected by an odometric survey, the plot of which can be adjusted between these two positions so that no intermediate points will be appreciably out of place on a map of the usual scale. Since this is a map for practical use and for the public good, it fulfills its purpose as well as if its distances had been measured by the most refined methods.

The great objection to its use is the tendency towards the accumulation of error in an odometric meander, and the farther it is from the known point which is its origin, the greater is the probable error of any position determined by it. Therefore, in a prolonged journey, or in a general survey of the country, the odometric position should frequently be verified, or checked and rectified, by connection with known points. This can be accomplished by making a station at some point on a railway, boundary, or other line of accurate survey ; by astronomical observation, which, however, if taken with a sextant, is often less reliable than the meander itself; or by making a meander station dependent upon the accompanying triangulation, by means of the three-point problem. The last method, which is by far the most reliable, will be explained further on.

ERROR OF DIRECTION.

The meander is affected by error of two kinds, of direction, and of distance. The former, in its most serious nature, is incurred in the survey of a tortuous valley, whose general course must be accepted, or in crossing a timbered country, or a pathless plain, where the surveyor is in a constant state of uncertainty as to whither he is to go, or, taking a back-sight, as to whence he has come. Sometimes the engineer is obliged to keep his eye on the sun and get a general idea of the course from that. Or, in traversing a dense forest, he may find himself compelled to resort to the paradox of sighting upon a sound; that is, he allows the pack-train to keep a certain distance in advance, and from time to time he directs his telescope to the tinkling of the bell which is carried by the horse that leads the train. It must be confessed that these make-shifts are loose methods of survey, but they are better than none, since they give the prominent directions and the distances between streams, divides, etc., and months afterwards, when the engineer comes to make the map and lay down upon it the trail of that day's march, he will find the poorest and most incomplete notes more reliable than his present memory and judgment.

Even under the most favorable circumstances it will seldom be possible to direct the telescope with greater precision than to the nearest degree, nor, as a consequence, will it ever be worth while to record any fraction of a revolution in the odometer. A road does not usually change direction by an abrupt angle, but by a gradual curve, and the bearing is made approximately tangent to that curve. Or, in the survey of a stream, it is not known on which side the trail will run at some point a kilometre in advance, and so the approximate center of the valley is accepted. But if there should be a solitary tree, bush, house, rock, or other prominent object fortunately situated for a station, the course will be made closely tangent to that, a reading of instruments will be taken upon arriving there, and, going on to the next station, the engineer will take a back-sight to the same point. In general the system of back-sights will be found more satisfactory than that of foresights, as it is easier, on a strange route, to tell whence you have come than to decide where you are going.

ERROR OF DISTANCE.

This error of direction, it will be seen, is thrown by the law of chance alternately to the right and left of the true line, and so has a tendency in its elements towards mutual compensation, and in a measure it corrects itself. But not so the error of distance, which is always plus, and cumulatively so. The test of the odometer wheel, by which its number of revolutions per kilometre is ascertained, is made upon a level surface and along a staked alignment, giving a result almost absolutely correct. In practice, however, the vehicle climbs acclivities of every grade, tacks hither and thither as it follows the trail up the mountain, winds incessantly in its route through the forest, and is disturbed by frequent jolts and collisions along the rocky floor of the canon. In a theoretical traverse the straight line between any two stations is determined, but in an odometer survey the measuring implement usually follows a beaten path, and the route distance, by road or trail, is rarely the shortest distance between two points. Hence an "overrun" in its record, which can only be remedied, and that approximately, by the judgment of the surveyor, who is taught by experience to estimate very closely the surplus in a given run, and who applies a correction accordingly.

Still, to such perfection has the odometer survey been brought, that it is a common occurrence for a skilled worker to meander a closed circuit of one hundred kilometres, and plotting the route, to find the plot also close within a small fraction of a kilometre. Even this error, being judiciously distributed in the process of adjustment, different weights being assigned to different runs, according to their probable accuracy, may be reduced so as to be practically imperceptible.

OCCURRENCE OF MEANDER STATIONS.

No general rule can be given for the

frequency of meander stations, but in ordinary country they will average perhaps one to the kilometre. In this all will depend upon local circumstances and exigencies. In the survey of a long and hidden valley, affording no opportunity for checks, especial care must be taken to preserve the integrity of the meander, and the stations must be especially frequent; but in a survey by a direct line across the plain two or three stations a day may be sufficient. In a winding path up a mountain side a dozen stations may be necessary if there are no chances for checks; but if the ends of the trail, at the top and bottom of the mountain, can be located by the three-point problem, the intermediate route can be neglected, being, at most, sketched in by the eye.

There are two considerations to govern the occurrence of stations; first, to preserve the continued accuracy of the survey, and second, to note the local geographical features which may be encountered. For the latter purpose stations will be made at the center of every village, at every country-house of importance, at the crossing and divergence of streams, roads and trails, at the opening of a valley, at the foot and summit of a mountain, and at the many other geographical vantage-grounds which the practical engineer will know how to select. But in this, as in the other departments of the survey, too punctilious zeal may defeat its own interests by causing delay, and the surveyor who is too scrupulously exact in the forenoon may have to virtually abandon his task in the afternoon, in order to reach a suitable camping-ground by night.

SCOPE OF THE MEANDER SURVEY.

The zone of country considered from a meander line may extend to the farthest visible point, as a series of sights upon a mountain even twenty-five kilometres away will give its position to a close approximation; but its principal intent is the preparation of a narrow route map, the areas encompassed by whose windings will be filled in from the topographical stations. Since, from its nature and narrow scope, it is fuller and takes cognizance of objects more minute than can be noticed in the other systems, in this the engineer is liable to a charge of partiality, reproved in the early part of this article. But this is not partiality in one field at the cost of neglect in another, and the greater excellence of this work is so much clear gain. Moreover, since the meander is usually by way of roads of frequent travel, and since a map is useful, and should be excellent, exactly in proportion to the number of people who are guided by it, it is well that the meander plot should excel in completeness those almost inaccessible parts which will never be seen except by the hunter or bandit.

MAKESHIFTS IN THE SURVEY.

In a forced march of forty kilometres or more, the meteorologist and odometer recorder, the safe carriage of whose implements requires a slow and steady gait, may proceed at a walk after taking their readings at a meander station, which task will occupy them but a few minutes, while the surveyor lingers behind to make the necessary sketches and observations, and then, riding at gallop, overtakes his comrades before the next station is reached. Many such shifts as this are known to the practical and energetic geographer, who learns to emancipate himself from too close dependence on the text-books of surveying, some of whose rules are very common-place and pedantic, and brings into play his powers of ingenuity and invention, to adapt himself to the peculiar circumstances by which he may be surrounded. If he finds himself alone, out on some trip of hasty reconnoissance, or on some hunting excursion on which he could not carry both rifle and transit, he draws from his watch pocket an aneroid, and from his saddle-bags a pocket compass or an altazimuth, and his equipment for survey is complete; as for distances, he can estimate them, or determine them by the time they take, calculating at the rate of five kilometres an hour, or, better still, by counting the steps of his horse and allowing six hundred double paces for a kilometre.

In a geological survey of Brazil very much of the travel and exploration is necessarily done by water, as the outcrop of the various formations is most favorably shown upon the banks of the rivers, along which there is frequently no passable route by land. Here the stadia may be used, provided there are two or more boats in the party, or, in the less important instances, the methods of obtaining distances by estimation or by time would have to suffice. In either case the surveyor should lose no opportunity to emerge from the trough of the stream, or to ascend some eminence, and insure his position by observations upon three or more known points. Should these be wanting, he should resort to the sextant and to its use in astronomical determinations.

Since the attention of the geologist is in great part absorbed in the duties peculiar to his profession, he cannot usually carry any but the lightest and most convenient implements of survey, and since these are amply sufficient for his geological notes of dip, strike, trend, etc., it is a matter of expediency to make them answer for his geographical work as well. With the engineer, however, there rarely comes a necessity for being separated from his portable transit, which admits of being firmly set on its tripod, and from which angles, either horizontal or vertical, may be accurately read to the nearest minute. And in the general geographical plan it is wise to deprecate as far as possible the employment of unreliable pocket instruments, or of the devices for learning distances that have been detailed above. Since nothing is to be gained in time by their use, and very much may be lost in accuracy, the engineer should teach himself to consider that any method less complete than that of the portable transit and odometer is but a temporary expedient and makeshift, serving an excellent purpose when all other means fail, but not to be relied upon as a permanent constituent of the survey.

CO-OPERATION OF THE TRIANGULATION AND MEANDER.

While the meander survey is an excellent apprenticeship for the young engineer, it should not be despised, as an occupation, by even the director of the triangulation. Humble as it is, it performs a task in the geographical plan which no system of triangulation can be relied upon to perform in a rapid work of this nature. It enables the survey to reach any point, however remote and secluded, and to determine its positions; it makes the map complete in all of the details which are so useful to the traveler; and as an agent in what we may call the practical or economical branch of geography it is without an equal.

It is dependent upon the triangulation, it is true, but then the dependence is mutual. The full benefit of either can only be secured through the co-operation of the two. As without the triangulation the map is unreliable, so without the meander it is incomplete. To use a homely illustration, the triangulation may be compared to the framework of the dwelling, and the meander to the intermediate filling of wall or other substance which makes the house habitable, and is a shelter to the inmates. This frame, if its lines are true and its angles correct, is a beautiful thing for the artisan to contemplate, but without its completion of walls and furniture, it is of no real benefit to the world. In the same manner a bare triangulation scheme may be an interesting study to the geographer himself, but to the traveling public and the people at large, it possesses neither interest nor value. On the other hand, as the frame of the house is an absolute necessity to it, securing and sustaining it in its proper proportions, so is the triangulation the rigid frame work of the map and the skeleton to which the useful data of the meander are attached.

CHECKS BY THE THREE-POINT PROBLEM.

Since the meander is from its very nature so hasty and loose, the system of frequent checks can alone make it reliable, and at intervals of every few kilometres, and especially at the crossing of divides and other eminences from which there is a broad scope of country visible, connection should be made with the triangulation. Each of these stations then becomes a new initial point, at which the survey begins afresh and the error again begins to accumulate.

This rectification is accomplished by the use of the three-point problem, a geodetic determination which, as a means of locating topographical stations, and as a connecting link between the meander and the triangulation, is of the highest importance in geographical surveying. Having three triangulation stations in sight, and favorably situated, it is possible for the observer to determine his position in a few minutes of time and by the simple operation of reading the two angles included by those three stations. From these and the data pertinent to the triangulation stations he can compute his distance from them, and hence his present latitude and longitude. Or, plotting these angles from any center on a piece of tracing cloth, he can lay this upon the projected map and swing it around until each of the three plotted rays covers its proper triangulation point, when this center will indicate the position of the three-point station, as it is called. For this graphic determination not only three points, but four, and even more, if they are visible, should be observed, as a greater number facilitate the operation and insure the accuracy of the result.

This method of trilinear determinations cannot be introduced too often. A three-point station in the streets of a settlement, at the forks of a road, or at the end of a mountain range, will locate these important places, and in camp, even in the center of a broad and vacant plain, there is no more profitable manner in which the engineer can spend his leisure time, before or after dinner, than by making a three-point station there and determining his position. Every camp thus fixed is a new and reliable origin at which the meander of the next morning will begin.

A SURVEY BY THREE-POINT STATIONS ALONE.

In some cases a successful meander may be carried on by three-point stations alone, when all other means would fail. Take, for instance, the rugged shores of a lake or bay, which are inaccessible except to a man on foot or in a boat. In the mountains on the other side of the water a series of triangulation stations stand up in full view. By means of these the engineer, working his way, transit in hand, from bay to bay, and from point to point, along the water's edge, makes three-point stations at all prominent changes of curvature, and, sketching in the intermediate shore, he determines its line by tangents and intersections, and thus secures a good survey of the coast. If there are islands out in the water they may be surveyed in the same way.

If the engineer was confronted with a piece of geography like the bay and islands of Rio de Janeiro, and if there were no roads along the beach to make direct linear measurements feasible, he could extend his triangulation to include all of the prominent peaks in the vicinity, and then, by means of three-point stations, he could rapidly trace in the shore-line. As the surroundings of Rio are so broken and irregular, the triangulation points could be made so numerous that it would be difficult to find a spot on the beach of mainland or island so secluded that some three of these stations would not be visible from there.

THE MEANDER PLOT.

Every three-point station, as well as every other meander station, should partake more or less of the nature of a regular topographical station; that is, contour sketches should be kept constantly on the plotted page as it progresses, and a continuous panorama of profile views, drawn in a separate portion of the book, should accompany the survey, so that, as some geographical features are left in the rear, others may be introduced in advance.

As from one topographical station to its neighbor, so every distance from one meander station to the next should be considered a base to be used in the location of points useful in the structure of the map. The longer this base, the more distant may be the range of these views. In case several meander stations intervene between one observation and the following, this total intermediate distance becomes what is called a broken base, but it is none the less useful for all of that. The above considerations will influence the engineer in his choice of stations, which will always be situated in such positions as may offer the best advantages for the accumulation of whatever information he most needs.

THE DECLINATION OF THE COMPASS NEEDLE.

The variation of the compass needle, or, more properly, its declination, will be carefully watched throughout the survey, and determinations of its angle will be made from time to time; these will be more than usually frequent wherever there is suspicion of some attraction immediately local, arising from the presence of magnetite or other ore of iron, basaltic rock, or other disturbing influence. These determinations are important, not only in the reduction of the meander notes taken in this vicinity, but also for the practical use, both present and future, of the country at large. In addition, their results will aid the general cause of science in its investigation of the laws of terrestrial magnetism, and in tracing the course of isogonic lines around the world.

At every triangulation, topographical, and three-point station, the observer will note the direction of magnetic north, as indicated by the pointing of the compass needle. If his instrument has a double movement in azimuth, as all should have, it is well, for the sake of convenience, to first set the zero of the graduated limb upon the same point of the vernier plate, by the upper motion, and then, by means of the lower movement, bring the north end of the needle to the zero of its circle. His initial entry in his note-book will then be "Magnetic North, 0° 00′ 00″." This direction of the telescope being referred to some line proceeding from here, whose true azimuth will be found by subsequent computation, the magnetic azimuth or declination of the needle at that place will be determined; it will simply be the difference between the true azimuth of the line, reckoned from the north point of the horizon, and its apparent azimuth, or the vernier reading which he enters in his notes.

BY DIRECT ASTRONOMICAL OBSERVATION.

The declination of the needle will also be determined directly by astronomical observation in the evening at camp. For this purpose the engineer will select such nights, clear and still, as may appear to him most favorable, and such camping places as may most urgently require this information. A star as near as possible to the pole will be chosen, as, from its greater declination, an error in the latitude of the observer's place, and, from its slower motion, an error in the time of the observation, will result in less serious errors in the azimuth; and the smaller the polar distance of the star, the more convenient will be the observation and the computations which follow, and the more exact is the result likely to be. In the northern hemisphere *α Ursæ Minoris*, or *Polaris*, is almost always used, as it is at present only about 1° 20′ from the pole, and it possesses the additional advantage of a brilliancy of the second order. But south of the equator there are no available stars so favorably situated as this. The most southern one of any considerable size is *β Hydri*, of the third magnitude, whose polar distance is a little more than twelve degrees.

This would have to be accepted in a survey of this nature in preference to any of the less brilliant stars of greater declination, as the observations would have to be made frequently by engineers of little astronomical experience, and with instruments not especially adapted to this kind of work. Indeed, it might be necessary at times to use the small meander transit for that purpose; and it is seldom that the telescopes of even the theodolites for triangulation, as now constructed, are provided with the hollow rotation axis requisite for a proper illumination of the diaphragm, without which it is difficult to see both cross-hair and star, unless the latter is of conspicuous magnitude.

Knowing, at least approximately, the latitude of the place, and also the declination of the star and its hour angle at the time of observation, its azimuth angle from the south point can be computed. But as the hour angle depends upon the local time at that place, and there is great room for error there, the observer, unless he has full confidence in his ability to make an accurate time-determination, should find the approximate minute of the star's greatest elongation, and follow it with the transit thread until it reaches the dead point in its azimuth motion, where it seems to stop a few moments between its advance and retrogression. Then, being at its greatest elongation, the sine of its azimuth angle is equal to the cosine of its declination divided by the cosine of the latitude of the place.

Should the star *β Hydri* not arrive at its east or west point at a convenient hour, as at certain seasons of the year it will not, the star *Canopus*, differing in right ascension about six hours, or *a Trianguli Australis*, of about sixteen hours greater right ascension, may be employed. These are respectively of the first and second magnitude, and hence are very well adapted to this purpose, but, owing to their greater polar distances, it would be necessary, in their use, for the observer to be especially sure of the correctness of his latitude.

The sun is not usually available for determinations of azimuth or time, as the engineer is generally upon the march throughout the day. The use of a star, however, admits of greater precision in the observations, while the resulting computations are less complicated, and, in the case of an azimuth determination, a south star is doubly convenient from the fact that its two daily elongations always come above the horizon, and whichever one occurs most opportunely may be used; or it may be possible at times to observe both, in which case it becomes unnecessary for the engineer to know his latitude. The same difficulty of latitude, may also be avoided by the method of equal altitudes of a star, taken at several hours before and after its meridian passage; the middle point between the two corresponding azimuths will be upon the meridian.

THE METEOROLOGIST AND HIS INSTRUMENTS.

In all of his travels the meteorologist will be the constant companion of the engineer, so as to be prepared to take observations at any point that the latter may designate. At the beginning of the field season he will be furnished with, at least, two complete sets of meteorological instruments, to be carried by himself and by others who may be appointed to assist him. Each set will be composed of a cistern barometer, an aneroid, maximum and minimum thermometers, pocket thermometers, and a psychrometer, consisting of two similar thermometers, one with its bulb capable of being moistened by the capillary attraction of a loose cord of cotton filaments leading to it from a cup of water, and the other dry, as in the ordinary instrument.

Prior to taking the field he will compare these barometers by a series of readings extending through several days, with some standard barometer whose error is known, in order to obtain the instrumental errors of the instruments at hand. Throughout the season, also, he will lose no opportunity for comparisons with any reliable barometers that may be encountered, as well as for frequent comparisons between these two. In this manner the time of any possible dislocation of the scale, or other source of error, will be determined.

As in the rough and rapid travel of a geographical survey, there is great liability to break the fragile glass tube which contains the heavy mercurial column, an extra supply of barometer tubes and mercury should be transported with the party, and also an assortment of tools and material for the filling, boiling, and fitting of a fresh tube. This is a delicate and difficult task, but it is one in which every meteorologist should be proficient. As full instructions for the use and repair of meteorological instruments have already been prepared by the Commission, it is needless to repeat them here.

METEOROLOGICAL OBSERVATIONS.

At every station of the survey, the meteorologist will read from his instruments the data from which the elevation of that point may be subsequently computed. Nothing more is then needed for the precise determination of that station's position. The engineer has fixed it in latitude and longitude; the meteorologist, in its altitude above sea-level. The meteorological data will be more or less comprehensive and will be read from instruments more or less reliable, according to the geographical importance of the place at which they are taken. The more frequent the readings, and the more prolonged the series, the more trustworthy will the resulting mean be, and the less liable to be materially affected by errors of observation, and by those erratic fluctuations to which the barometer is subject, owing to the constantly varying atmospheric currents and other disturbing physical conditions to which it is exposed, and whose effect cannot be entirely eliminated by any formulas that it is possible to devise.

Beginning at the point of outfit, which, on account of the work of preparation and the measurement of the base-line, may be occupied some weeks or a month, hourly readings will be taken throughout the day and night for as long a time as possible. The cistern barometers will be read, as the height of the mercurial column is the basis upon which all barometrical determinations rest. The attached thermometer will be read, to learn the temperature of the mercury, and hence what correction must be applied to reduce it to the freezing point, at which all barometrical heights are compared. The isolated thermometer will give the temperature of the surrounding atmosphere, to be used in determining the mean temperature of the stratum of air intermediate between this and the reference station. And the psychrometer will reveal the amount of aqueous vapor in the atmosphere, and the influence of its pressure upon the height of the column of mercury. In addition to these, note will also be taken of the direction and force of the wind, the condition of the sky, the proximity of storms, and other atmospherical phenomena, as this information may give the key to some abnormal barometric oscillation which would otherwise have to remain unexplained.

HORARY AND ABNORMAL OSCILLATIONS.

The hourly observations will be continued throughout the day and night for the purpose of determining the amount of the horary oscillation at that place. This horary oscillation is a somewhat regular rise and fall of the barometer, occupying a period of twenty-four hours. The range of this fluctuation in some parts of the world is so great, that its effect upon the mercurial column may equal that which would be produced by a change of fifty meters in altitude. It is such that, if the successive heights of the column be represented graphically by a curve, this curve will show two daily maxima and minima, occurring at intervals of about six hours, the morning maximum being attained at about ten o'clock A. M. This horary curve, as it is called, varies with the latitude, altitude, and climate of a place, as well as with the different portions of the year. The value of the horary variation for any hour of the day is revealed by a study of the prolonged series of observations at that place, and may be assumed to be the same for all observations taken in the vicinity of that station and in the same season of the year.

The barometer is also influenced by the abnormal oscillation, apparently resulting from the progress of great atmospheric waves across the country, affecting the mercurial column by a gradual rise of several days, followed by a period of subsidence of about an equal duration. The effect of this disturbance can be eliminated, approximately, by taking the difference of the barometric readings at the beginning and ending of any one day of its rise or fall, and considering this as its amount for that twenty-four hours, a proportional part of which will be its value for one hour.

To obtain the altitude of the first station of the survey, a mean of the corrected heights of the mercurial column is compared with a corresponding mean of the same hours of the same days at some permanent station, whose elevation above the sea is definitely known, as, for instance, the Imperial Observatory at Rio de Janeiro. This, by a process of computation, gives their difference of altitude, and hence the total elevation of the point in question.

Now, making this point of outfit a reference station, at which an observer is left with meteorological instruments to be read at stated intervals throughout the day, the party takes the field, and the traveling meteorologist reads a series of barometrical and other observations at the first camp and at all others to which they may come during the season. These will be compared, as before, with synchronous* observations at the refer-

* It is well to distinguish between the meanings, as now understood, of the two words "synchronous" and "sim-

ence station, and the differences of altitude will be calculated. At every topographical station, and station of importance along the meander survey, such as villages, fazendas, mines, mountain passes, divides, etc., and at all other points that may be designated by the engineer, the meteorologist will read the cistern barometer, the watch, the thermometer, and the psychrometer, and, for the purposes of comparison, the aneroid barometer as well. These isolated observations will also be referred to the main barometrical station at a distance.

But, on the occasion of the ascent of a mountain peak from a fixed camp, better results will be obtained by consider-

---

ultaneous." The term "simultaneous" is applied to observations which are made at the same absolute instant of time, as, for instance, upon the occultations and eclipses of the heavenly bodies. Synchronous observations are taken at the same hour of the day, local time, irrespective of the difference of longitude between the two stations. Therefore, observations can be both simultaneous and synchronous only when the observers are upon the same meridian. The word "simultaneous" belongs especially to the province of astronomy, whilst "synchronous" is most frequently used in connection with the phenomena of physical geography.

ing the camp a reference station in the determination of the altitude of the mountain. This ascent will necessitate the occupancy of the neighboring camp for two nights and a day at least, and perhaps longer, while the peak may be occupied only a portion of a day, during which time, however, there will be corresponding hourly observations at camp and mountain-top. Hence the altitude of the mountain will be most truthfully ascertained by referring it, by these synchronous observations, to the camp, and then the camp, in a similar manner, to the distant reference station.

HORARY CURVES AND REFERENCE STATIONS.

Whenever the party, or a portion of it, remains stationary in camp for a few days at a time, hourly observations day and night will be taken to determine the horary curve at that place; the longer the series, the better will be the result. Since the horary variations are constantly changing with altitude, country and climate, it is important to have as frequent determinations of them as can practicably be made, so that no very great distance may intervene between the place where a table of horary corrections is constructed and the place where it is used.

For a similar reason it may be deemed necessary to establish and sustain a second meteorological reference station, if the field of the season's survey should be a wide one, or if it should vary greatly in the atmospherical condition of different portions of its area. No comprehensive rule can be given to govern the number of these reference stations; all must depend upon the judgment of the director of the survey, and the resources at his command. In general, the farther the place of an observation from its reference station, the less reliable will be its result. But, as an exception, let us take the example of a broad inland plain, separated from the sea and its influences by a wall of mountains, within which, upon the plain, the reference station is situated. In this case it may be more justifiable to refer to this station a point on the plain, five hundred kilometres distant, than one just over the mountains, only one hundred kilometres away. This is owing to the widely different climatic circumstances of inland and sea-coast, resulting in meteorological conditions so dissimilar that equal amounts of pressure cannot be relied upon as an indication of equal thickness of the atmospheric envelope.

THE ANEROID BAROMETER.

At the many stations of the meander survey that are comparatively unimportant, and that are occupied for a few minutes only, it will suffice for the meteorologist to read only his aneroid, watch, and thermometer. Although the aneroid is not a reliable instrument, yet it serves an excellent purpose where rapid and approximate work is sufficient. Since its principal use is in obtaining profiles of the meander routes, which will enable the engineer to properly distribute the contour lines upon his map, and since, farther, the error of an aneroid will rarely exceed the vertical distance between two of these contours, the resulting inaccuracy upon the plot will be quite inappreciable.

The aneroid is to the cistern barometer what the meander is to the triangulation, that is, a means of filling in, which, while costing but little extra effort, is productive of very valuable results. The engineer who rejects the meander and the aneroid, because they are not rigidly exact in their functions, will find himself reduced to the necessity of tracing in the roads and streams of his map, locating many of the villages, cross-roads, etc., and drawing in the contours from his judgment and memory alone; and it is safe to say that the conjectures of the most able and trained topographical intellect are by far less reliable than the figures of those humble instruments, the aneroid and odometer, when judiciously used.

At every camp the aneroids are compared with the cistern barometer, their scales are adjusted in compensation for any error that may have crept in, and the vertical element of the survey starts from a new and true datum plane when the march is resumed. At the end of the day's journey, also, they are immediately compared again, and the error accumulated throughout the day is noted, and, by a process of distribution along the day's profile, may be reduced to a minimum. Before and after every side trip, reconnoissance, or ascent of mountain, the aneroid is compared with the mercurial barometer, and thus, by a continual and careful watch over it, it may be relied upon to give results not seriously in error. But if left to itself and unchecked for any great length of time, or for any great distance of journey, or great change in altitude, this fickle instrument may continue to go astray, by a shifting of its scale, exhaustion of its spring, or from other causes, until its readings are hundreds of metres too high or too low. Even then, however, it may be of use to the geographer in drawing in the relief of the country, as the discrepancy is usually of gradual growth, and the relative altitudes during the progress of the survey, as, for instance, the height of a bluff above the neighboring valley, are sufficiently exact to be of much assistance to him in his plotting.

BAROMETRICAL RESULTS.

As to the reliability of altitudes determined by the cistern barometer, evidences and opinions differ, but those persons who are most thoroughly informed are generally the most lenient in their acceptation of results. Colonel Williamson, of the United States Army, who has probably given more intelligent study to the barometer than any other man, has compiled a table of the maximum errors which occur in numerous series of observations taken both in North America and Europe. Among these are many that exceed fifty meters in amount, and he assumes that the barometer under similar circumstances will be liable to equal errors elsewhere. These, however, are not to be considered as representing the probable error of barometrical results; they are rather the extreme limits of probable error, and may be taken as the error to which the barometer is liable under certain rare and very unfavorable conditions. While exact truth concerning altitudes is something which no barometer can be expected to tell, and while it is never safe to guarantee the accuracy of such a determination, even within many meters, yet when barometrical work is prosecuted judiciously and systematically, as it would be in this survey, and based upon formulas which represent the latest and most complete knowledge of meteorology, its tendency is to give results that are seldom more than a few meters wrong.

It is often difficult for the popular mind to comprehend how an error of meters may be inevitable in some of the processes of barometric hypsometry. Since the scale of a barometer may be read to a thousandth of an inch, and that amount of variation is supposed to correspond to a change of one foot in altitude, it would naturally be thought possible to determine the elevation of a place to the nearest foot. But this difficulty will be better understood when it is remembered that the barometrical measurement of the difference of altitude between two places depends upon the determination of the weights of a column of atmosphere at each of these stations; that this atmosphere is in a state of constant change and perturbation, its pressure being modified by variations of heat and cold, storm and calm, and the absence and presence of moisture throughout different portions of its extent; and that, while some of these conditions are quite unknown to the observer, those that are apparent to him can be but incompletely compensated for. Therefore, since barometric hypsometry is not one of the exact sciences, but is affected by every change in the wind and weather, any determination of altitude that is true within a meter is as much a source of surprise as of gratification to the meteorologist, who will be obliged to confess that this closeness could scarcely be possible without some coincidence and accidental equilibrium in the disturbing influences to which the barometer is subject.

DIFFICULTIES IN BAROMETRIC HYPSOMETRY.

At times men of little experience may have to be accepted as meteorologists. They work, perhaps, under the embarrassments of exposure, fatigue, and a lack of appreciation of the responsibilities that rest upon them. It may be long before they can be taught to regard those niceties of barometrical work without which it cannot be truly successful; although there is but little hope of determining an altitude to the single foot, yet they have to learn that this is no reason for neglecting that thousandth of an inch which corresponds to a foot. Their instruments may be out of order, owing to the hardships of travel to which they are exposed; the readings may have to be referred to a distant station of very dissimilar physical surroundings; or they may have been taken upon the top of a lofty mountain, in a belt of the atmosphere with meteorological phenomena quite different from those properties of the lower strata of the air, for which our formulas were framed.

These are some of the sources of error which may have conspired to vitiate those results which are fifty meters or more at fault. In Brazil, however, it is hardly necessary to anticipate discrepancies so great as this, since it is a country in which no very great change of altitude is possible, violent and phenomenal storms are not frequent, and the atmosphere is of comparatively steady temperature, and not liable to sudden transitions from one extreme to the other.

BAROMETRIC FORMULAS.

Even if the observations have been made under the most favorable conditions of atmosphere, elevation and location, and are perfect as far as human intelligence can make them so, that is, free from all personal and instrumental errors, there yet remains a consideration which may materially affect the completed altitude. The same observations, reduced by different formulas, will give results in some cases widely different, the discrepancy between the returns of two well-authorized methods of computation frequently amounting to the sum of the real errors of both; this is exemplified in the following determination of the height of Corcovado, in which one system of reduction gives an altitude above the true one, and the other places it too low.

The barometric formula is composed of several terms, each of which is a combination of some physical constants, such as the relative weight of air and mercury, or the variation of gravity with latitude, and some of the barometrical data, as the temperature or moisture of the atmosphere. Of these formulas, there are two general classes, based upon the equations of Laplace and Bessel. Not only do they differ in those constant quantities upon which all barometrical determinations must depend, but also in the presence or absence of an entire term, as the formula of Bessel has a separate factor as a correction for the humidity of the air, while Laplace includes the influence of the aqueous vapor with that of temperature.

Thus it will be seen that the formula of Laplace is more convenient, while that of Bessel is more complete. The scientific world has found it difficult to choose between them, and while Delcros, Guyot, and others have accepted the formula of Laplace, that of Bessel has been adopted by Plantamour, Williamson, and others. But it is admitted, even by those who are in favor of the former method, that the constants in use in Bessel's formula, as modified by the more recent arrangement of Plantamour, are later and more reliable than those accepted by Laplace, and there is also a prevalent opinion among scientists that some accuracy has been sacrificed to convenience in Laplace's method, a concession which it may sometimes be justifiable to make in the application of a formula, but never in its construction.

The advocates of each system have published examples showing the close accordance of their results with altitudes determined trigonometrically or by spirit-level. But as the number of these remarkable coincidences is about equal on each side, and as in each instance the observations would have given results considerably wrong by the application of the other formula, they prove simply two things; first, that they are coincidences, and that to certain cases the method of Laplace is more applicable, while to others that of Plantamour will yield better returns; and second, that it is quite impossible to devise any formula that will yield an accurate solution of all problems in the barometrical measurement of heights.

Since there seems to be a preponderance of evidence and a growing disposition in favor of Plantamour's formula, it has already been adopted by the Geological Commission as a basis for its barometrical work, and its several terms have been developed into tables for the convenient computation of altitudes. After the preparation of those tables and as a test example with which to prove their efficacy, the height of Corcovado Peak was determined barometrically with the following results:

	Metres.
Altitude of Corcovado, by tables of the commission, based upon Plantamour's formula..................	705.84
By Laplace's formula.................	702.15
Determined by triangulation.........	704.74

	Metres.
Error by Plantamour's formula......	+1.10
" Laplace's "	−2.59
Discrepancy between the two........	3.69

The foregoing is a very creditable and satisfactory barometrical result, and is one more argument in favor of the use of Plantamour's complete formula.

ALTITUDES BY VERTICAL ANGLES.

As a supplement to the barometric

hypsometry, every theodolite, whether for meanders or triangulation, is fitted with a vertical circle, from which to read the angles of elevation and depression of those points which are located by intersections, in order to compute the heights of the same. From this angle and the horizontal distance between any two peaks, their apparent difference of altitude is obtained by a trigonometrical calculation, and then a correction is applied for earth's curvature and refraction. In the field these angles are recorded as plus or minus, according as the objective point is above or below the observer's station, whose altitude is invariably determined by barometric readings.

In this manner the heights of hundreds of points throughout the field of survey are found with an accuracy nearly equal to that of the peak from which the angle is taken. Indeed, a mean altitude derived from the three angles of elevation, read from three different triangulation stations, will give the altitude of the point of intersection with less probable error than that of either of the mountains from which it was derived.

METEOROLOGY IN THE SOUTHERN HEMISPHERE.

Brazil stands almost alone as a great civilized country lying in the Southern hemisphere. It is comprehensive in its latitude, reaching from north of the equator far into the south temperate zone. From this unique and favorable position upon the earth's surface, as well as from the liberal patronage bestowed by its government upon the development of science, it needs no prophetic eye to see that this empire is destined to become one of the busiest and most fruitful fields of scientific research. Especially is this the case in the investigation of those great questions concerning the terrestial shape and dimensions, and those others, still more numerous, which from the form of the earth, or from other and unknown causes, vary with geographical position. Important among the latter is the science of meteorology, whose general laws are not the same all the world over, but which are largely influenced by latitude and by proximity to either pole.

The following extract from Colonel Williamson's valuable treatise on the barometer and its uses, will illustrate the absence and the need of meteorological observations south of the equator:

"It has been determined by actual observations, and confirmed by theory, that the sea-level pressure varies in different latitudes by a definite law, modified in practice by local peculiarities of climate. It has been found that the mean barometric pressure is less in the immediate vicinity of the equator, and it increases towards the north to between latitude 30° and 35° where it is greatest. It then gradually decreases to about latitude 60°, and from there towards the north pole there is a slight increase. In the southern hemisphere, where the observations have been less numerous, the mean pressure seems to increase to between 20° and 30° of south latitude, when it gradually decreases to about 42°, and then commences a remarkable fall, so that towards the south pole, the mean pressure is said to be less than 29 inches."*

In the table of mean heights of the barometer at the sea-level, given in various works on meteorology, there are but two stations south of the equator; these are Rio de Janeiro and the Cape of Good Hope. In north latitude, however, the list comprises more than thirty places at which this determination has been satisfactorily accomplished, by years of observations, and these are favorably situated at intervals between the equator and the pole.

Again, while the horary oscillation in the atmospheric pressure is greatest near the equator, and diminishes thence each way to the poles, the abnormal oscillation is least in regions of small

---

* 736.6 millimetres.

latitude, and increases with the distance from the equator. As the latter is the more incomprehensible and less regular of the two, and consequently the greater source of error, it would appear that, in general, barometrical work would be most reliable in tropical regions, and hence this system of hypsometry would be especially applicable to Brazil. And, in addition to their immediate and practical use in the construction of maps, the meteorological results of a survey of the proposed nature, taken at low and high altitudes, at the sea-coast and in the remote inland, with permanent stations at intervals where long series of observations would be accumulated, would form a basis upon which to establish the general laws of barometric fluctuation throughout this vast portion of the Southern hemisphere.

CONTINGENCIES IN THE SURVEY.

The foregoing are the general divisions and some of the novel features of the geographer's work in the field.

While these are sufficient to carry the survey across any ordinary country, certain districts may be encountered in which these methods may not be easily applicable. It is impossible, in a paper of this nature and length, to foresee and provide for all of the emergencies that may arise; it is necessary for the geographer to first see his territory, and then, if he is a true engineer, he will be able to devise some means of survey which will be competent to meet the difficulties, however great they may be.

For instance, it may be asked how a survey based upon triangulation can be carried across the smooth and unbroken table-lands of a country. The answer will be that the plains are not usually so broad that they cannot be spanned by the length of a triangle-side; and, furthermore, if there are no eminences that can be used for triangulation points, so much less is there need for this system of survey. Over the smooth plain it is possible to travel in straight lines, such being the usual character of roads in a level country, and since a meander by direct routes is reliable, the survey can proceed from one known point to the next with comparative accuracy, tracing in the rivers, lakes, and other geographical features as it goes. As a rough, mountainous country is its own remedy, furnishing a great number of advantageous stations for the survey, so, with the absence of these mountains, vanishes in great part the labors and difficulties of this work.

THE STADIA, OR TELEMETER.

Although the stadia, or *telemeter* process, is too slow for the general prosecution of a geographical survey, there may be occasional areas in which the previous methods will fail, and this will suffice. The direct linear survey of a river, by this means, has already been mentioned. As another illustration, take the case of a valley—as, for instance, the valley of the Amazon—which is so broken with lakes, swamps, and the many channels and arms of the river, that its islands and shores cannot be reached and located by any means of direct measurement; and where, farther, the vegetation is so abundant and dense, that ordinarily no three fixed points are visible from the water's edge. Here the telemeter may be the only instrument by which the required distances may be obtained. The observer, establishing his instrument in open ground, from which triangulation stations can be seen, sends his assistant, in a boat or otherwise, to such points along the water as may be in sight. These he locates by single observations, reading the distances from the rod held by the assistant. Thus the telemeter station is referred to the observer's position, which, in its turn, can be fixed by means of three-point observations upon the triangulation stations of the bordering cliffs.

In this simple and ingenious way of determining distances by single observations, it is necessary that the diaphragm of the telescope of the observer's instrument should be fitted with two horizontal cross-wires, and that his assistant should be furnished with a graduated rod, or telemeter. Then looking through the telescope, the projection of the cross-wires upon the rod includes a certain amount of the graduation. This is a chord subtending a certain constant angle in the line of collimation, and, by a principle in geometry, this chord increases directly with its distance from the angle which it subtends.

THE PLANE TABLE.

With the use of the plane table, there comes so great a temptation to go into the details of the work, to linger over a small area, and to finish the sheets with a topographical completeness, that its too general adoption will be found to retard the progress of a geographical survey. In addition, it is cumbersome in its shape, offering a broad surface of exposure, and for that reason is not well fitted for service upon high mountain stations, where the wind is strong and storms are frequent. In its favor, however, it must be said that this instrument has been successfully employed upon the extensive geological and geographical surveys under Major J. W. Powell, of the United States, and that very favorable reports have been made concerning its usefulness. The inconvenience of its shape has been modified in this service, the table being composed of slats hinged together, so that it may be folded into a small compass for the purpose of transportation.

When, in the course of a work of this nature, there is encountered a district where the importance of the field will justify a minute and laborious survey, the plane-table will serve an excellent purpose there. It is very useful in the mapping of a populous district, the suburbs of a city, a mining region, or in the representation on large scale of a piece of topography which is interesting as a type of geological structure. It is always an easy matter for the geographer to accommodate himself and his methods to detailed surveys like the above, and it is a mistaken idea to suppose that the exploration of a province, unfits an engineer for the topographical delineation of a parish. In all work of engineering there is a constant tendency towards greater accuracy, refinement, and detail, and it is not freedom which the geographer enjoys, in neglecting the minor features of the earth's surface, but rather a necessary restraint that is imposed upon him, to keep him from sacrificing the important to the unimportant.

THE OFFICE WORK.

As for the computations and other reductions of notes which follow a field season of the survey, there is not space to discuss them here, nor is there any special need of such a discussion, as they do not differ materially from those which apply to geodetic work in general. Nor are the duties of the draughting-room greatly distinguished above the customary routine of such office work. This thing only, may be noticed, that the hand-to-hand struggle which the field engineer constantly sustains with the forces and obstacles of nature blunts the delicacy of his touch, and makes his hand too heavy for the fine drawing necessary in a map finished for publication, and there should be in every office a superior draughtsman who is accustomed to the use of no heavier implement than the artist's pen.

This artistic finish is bought by some sacrifice of accuracy, however, and between the field engineer and the final draughtsman there should be few, if any, middlemen to compile and replot the work, because only the man who has seen the country can reproduce its physical characteristics with truthfulness. In every copy that is subsequently made the face of the land grows more artificial and ideal; each mountain loses its individuality of shape, and assumes a symmetrical regularity which it does not possess in nature; some of the niceties of truthful representation are magnified into exaggeration, and others are overlooked and obliterated; the bed of every cañon grows broader in each successive transcript; and the large hills grow larger as the smaller ones dwindle away. As in a popular parlor game, a whispered story, passing current from mouth to mouth throughout the round of a circle, grows strange and distorted beyond recognition, so in the successive reproductions of a map by strange hands, it loses its photographic truth of execution as the idiosyncracies of the various draughtsmen are wrought into the plan. Finally it comes to represent a country that is unnatural in its regularity, made not so much by the accidents of nature as by the design of man, and moulded by the rules of a uniform and rigid geometry.

PLOTTING THE NOTES.

It is necessary that each engineer shall plot his own notes, as he alone is familiar with their arrangement throughout his books, and only he is able to derive the full benefit from them. Therefore during the office season he will be engaged upon a contour plot of the area which he has surveyed during the preceding half of the year. Here he will collect and compile in graphic shape all of the information which lies scattered throughout the dozen note and sketch-books which represent his labors in the field. Upon this map fine drawing will not be so essential as truthful representation and the utmost accuracy of position that can be attained from the material at hand; an inaccuracy that is barely apparent upon the paper will correspond to a very large error in the field, and so a moment's oversight in the office may invalidate the scrupulous care of a day's or week's work upon the survey.

These sheets will be the basis of all the maps of the survey, no matter in what shape they may be published, and hence the urgency of having them correct in all of their positions, statements and figures, and so complete as to include every detail upon the pages of the sketch-books, down to the shape of a mountain-spur or village, or the presence of a spring of water or dwelling place. As the expense of sustaining an engineer in the field is at least double the cost of his office-work, he should confine himself to what is absolutely necessary in the collection of his notes, and then utilize even the least of these in his subsequent plotting and development of them.

CONTOUR PLOTS.

The plots will be constructed in contour lines, as that is the only method in which the engineer can give precise expression to his information and impressions concerning the heights, slopes, and forms of the country that he has surveyed. While a map executed in hachures would be more artistic and more pleasing to the eye, it cannot be made so mathematically invariable in its conveyance of ideas, that is, it cannot be made to convey the same ideas to all persons; the bluff that would seem high to one observer would seem low to another, and the depth of shade that would represent a steep gradient to one draughtsman would stand for a moderate declivity to another, according to their peculiarities of judgment, or to the different schools of drawing in which they had been educated. The most skilled cartographer, with one of the best of hachure maps before him, would find it difficult to estimate the angle of any mountain slope, or to tell which of two neighboring peaks was the highest, unless their heights were given in figures.

In a glance at a contour plot, however, he could count the excess of lines in one of these mountains, and so compute its superior altitude; or note the number of lines in a centimeter of space, and so determine the gradient of the earth's surface there. For this reason the contour plot is the only true basis from which subsequent maps can be made; then, no matter how many field engineers may contribute to this work, their reports will all come to the compiler and final draughtsman, written in the uniform language of lines at regular vertical intervals. Otherwise, if the plots were in hachures, this draughtsman would find it well-nigh impossible to so assimilate them that his finished map would not reveal traces of the many different hands from which it originated.

FINAL MAPS.

Unless the contour lines are so numerous and close together as to produce striking contrasts of light and shade as the slope varies, this map has no meaning to the popular eye. The ordinary observer sees in it only a maze and confusion of lines, of whose design and importance he is ignorant, and so it is of no assistance to him. Therefore, since maps are usually published for the information and guidance of the people at large, it is wise that they should be drawn with hachure shading, which gives a more intelligible but less precise picture of the country. In the construction of this, the contours of the engineer's plot are so many guide-lines to the draughtsman, who graduates the light and darkness of the shade to accord with the divergence or approach of these wavering lines.

In addition to these a map in contours may also be issued for the use of engineers, the projectors of railways, and, more especially, as a basis of the geological and resource charts, to which this system is peculiarly adapted, as its lines of equal level are of great assistance in determining the extent of the various formations, and for depicting those areas of vegetable growth which are bounded by fixed limits of altitude. The dip and strike of a bed of uniform slope being given at any one point of its outcrop, it is an easy matter to trace upon this map its line of reappearance upon the farther side of a mountain-range, or at any other point at which it may be exposed again. Or, by counting the lines of vertical equi-distance, the geologist learns the thickness of the various strata, the extent of a fault, or any other fact in geological dimensions.

REVIEW OF THIS METHOD OF SURVEY.

In this paper the writer is at a disadvantage in appearing to advocate inaccurate methods, and perhaps, at times, actuated by a desire to give a perfectly frank and honest exposé of the subject under discussion, he has magnified the amount of inaccuracy to which the operations described in these pages would be liable; at all events he has been very liberal in his allowance for probable error. Indeed, to those who have been in the habit of reading, and believing, barometrical altitudes that are given down to the tenth of a foot, or sextant determinations to the hundredth of a second, it may appear unpardonably liberal to allow for an error of meters or seconds in these classes of work, and perhaps to some it may seem indicative of professional unfitness in the engineer who would acknowledge the liability of such. But while results like the above are frequently published, their authors would be either sciolists or charlatans if they were to claim that they were absolutely reliable down to those small fractions; it is often the custom among the most conscientious and intelligent engineers to make their reports in that elaborated form, since those are the figures at which their computations finally arrived, and hence there are certain weights of probability in their favor.

In like manner, in the computations of a survey of the proposed nature, it would never be allowable to neglect or throw away any odd figure or fraction, on the plea that it was probably exceeded by the error of the whole. By following this system, not only are habits of accuracy inculcated and sustained among the assistants of a survey, but the closest possible approximation to the truth is attained.

In the ordinary branches of his profession, habits of rigid precision, at whatever cost of time and money, are the best recommendations for an engineer. In a geographical survey, however, to enforce this rule beyond the triangulation, upon which the integrity of the whole depends, and to continue it in full force throughout all of the subordinate branches of the work, would be to make such a survey impossible in Brazil, owing to the enormous expense that would attend it. Viewed theoretically, the best of maps, even those produced by the tedious processes of the European topographical surveys, are but approximations to the truth; the question now arises as to how close it is profitable to bring this approximation. Viewed practically, the maps that would result from the proposed system of survey would be seldom, if ever, in error to a perceptible degree, and it would seem that this is the limit of accuracy beyond which this country cannot well afford to go.

To condemn a method of surveying because it is not absolutely accurate would be to condemn all of the survey of the world, and especially all of the systems of ordinary land surveying, which are so faulty that it is very seldom that a purchaser of land does not get either considerably more or less than he pays for. Still, that has not been deemed sufficient reason why all buying and selling of real estate should cease until its boundaries could be determined by the instrumentality of such rods, compensated for temperature or packed in ice, as are used in the measurement of geodetic base-lines. In one respect the proposed system is far superior to the land survey, as it is founded upon the principle of triangulation, which, securing it in its true proportions, prevents any great accumulation of error. In the United States of North America, where surveys of this nature are in active and successful operation, it has been earnestly advocated that the triangulation of the geographical survey should be made the basis of the land survey, the different triangulation stations serving as initial points from which to run the land boundaries, and it is very probable that, within a year or two, this plan will be adopted there.

There are different degrees of accuracy, each adapted to the end which it is intended to serve; this degree, explained here, is sufficient for the rapid preparation of a very useful and complete geographical map. It would not suffice for the measurement of an arc of the meridian, such as has been proposed for this empire. That is a work in which no error, however small, that is not beyond the cognizance of the human senses and judgment, can be excused or overlooked. To publish a wrong result here would be not only a national disgrace, but a misfortune to the whole world, as it is upon the shape and dimensions of the earth that many of our geodetic and other scientific formulas rest, while it is from the same source that the world derives its standard unit of length, by which the interests of all civilized people are affected. Or, if Brazil were prepared to enter into that honorable rivalry in geodetic work, in which some of the older nations are engaged, each seeking to produce instruments, methods, results, discoveries, and developments that may be in advance of everything hitherto achieved, this system of survey would not be recommended. It is not impossible, however, that, from this as a beginning, there might grow, keeping pace with the general progress of the country, a geodetic institution that would be equal to the best.

ORIGIN OF THIS SYSTEM.

The writer by no means pretends to be the inventor of the combination of methods described in these pages, although hitherto there has been but little description of them in print. An efficient system of survey cannot be the invention of any one man; it must be the outgrowth of years of practical experience, resulting in the gradual accumulation of ideas and improvements contributed by those who have been engaged upon it. This one is the result of a growth of at least a quarter of a century, and therefore is not open to the serious objection of being new and untried. During that length of time, the enterprise of geographical surveying has been receiving more and more encouragement from the government of the United States, which has wisely adopted that plan, in connection with geological and other scientific research, as a means of opening and illustrating its vast public territory.

At the present day there are actively engaged upon this duty in that country three important commissions of survey. That of Dr. F. V. Hayden, geologist in charge, is known throughout the world by its extensive and important work, not only in geology and geography, but in all their kindred sciences as well. A second is under Major J. W. Powell, the intelligent geologist and intrepid explorer who was the first to descend the great cañon of the Colorado River. Another, more strictly geographical in its nature, is under the auspices of the War Department, and is conducted by Lieut. George M. Wheeler, an officer of enviable reputation in the United States Corps of Engineers. While the general plan is much the same throughout these three commissions, it is especially to his former associates, the geographers and officers of the last-named organization, that the writer wishes to acknowledge his indebtedness for whatsoever of value there may be in this paper.

BRAZIL AND THE UNITED STATES.

Although, as has been stated heretofore, it is not wise for any nation to copy, blindly, and without adaptation to its own peculiar needs, the system of survey employed by any other country, yet it would seem that the processes that are fitted to the United States would require but little modification to be adapted to use in Brazil, so analogous are the two countries in many respects. They have equal amounts of territory as near as may be, but, peopling this territory, there are four times as many inhabitants in the United States as there are in Brazil; thus it would seem that the methods that are deemed sufficient for the former would certainly suffice for the latter. In each country the population diminishes from a thickly-settled sea-coast back into an uncivilized and almost unknown interior. In each of these there is a great amount of wild land which the government is anxious to open to colonization and cultivation. To expose and popularize the natural wealth of this public domain, the U. S. Government resorted to the plan of scientific surveys, to which the Geological Commission of Brazil is very similar in all respects, and so efficiently have they accomplished their purpose that it has become a noticeable fact in the cartography of the United States that its maps of some of the remote and unsettled districts of the Rocky Mountains are superior to those of its oldest and richest States, and, therefore, there are now plans on foot looking to the extension of these geographical surveys over the entire surface of the country.

As the American manner of railway-building, more expeditious and involving less first cost than the European methods, has been found practicable in Brazil, in some instances, in which all other plans would fail, so with this question of geographical surveys, it may prove to be the American system or none.

RESULTS OF THIS SYSTEM.

Considering now the results that could be expected from such a geographical survey of Brazil, this question can be best answered by referring to areas surveyed in the same manner in the United States. From Lieut. Wheeler's annual report, which the writer has before him, it appears that in six years' continuance of his commission an approximate extent of 800,000 square kilometres has been surveyed. Allowing an average of five parties in the field during that time, the season's work of one engineer reduces itself to about 25,000 square kilometres. Allowing proportional returns from the various other geographical surveys at present in commission, or that have been in existence during the last ten years in the western portion of the United States, it appears that one-third of the area of that great country has been thus surveyed in that period.

This is at a total expenditure which, while including the cost of all other concomitant scientific labors, to which the geographical work has been in large part incidental and tributary, has never exceeded four hundred contos ($ 200,000) per year. There is probably no other department of public enterprise which has yielded so extensive and valuable returns for an equal amount of money.

AN ESTIMATE FOR ONE SEASON.

In general, an area of from 10,000 to 30,000 square kilometres, varying according to the geographical nature of the country, is assigned to each party for a season of four, five, or six months, and its ability to satisfactorily cover that district in that time is conceded. To illustrate the possibility of such rapid progress, let us take a typical area of 20,000 square kilometres and see what can be done with it by one party and one geographer in one season's work of six months in duration. Of this time the first month will be consumed in the measurement and development of the base, and in other preparation. Of the remaining period one month more will perhaps be lost in unavoidable delays resulting from storms or other causes. There will then remain four months, which, at twenty-five available days in each, will afford one hundred days for active service in the field.

Allow one half of these days for the meander survey, and the other half for the occupation of mountain stations. Fifty mountain stations will thus result, and, in addition to these, there will be a topographical station either upon or adjacent to each day's meander. So there are one hundred triangulation and topographical stations distributed at judicious intervals over this territory. That is, there is one for every two hundred square kilometres of ground, or, typically, they are but about fourteen kilometres apart, and the piece of country to be sketched in contours need not extend more than seven kilometres in each direction; this estimate ignores the meander surveys, to which fifty days of the season will be devoted, and by which these stations will be separated and surrounded.

At twenty-five kilometres a day, a very reasonable allowance, the total distance of meander route will be 1250 kilometres. This distance would reach across our area nine times, cutting it into strips of sixteen kilometres in width. Hence, in order to include the entire country from this survey, the typical zone of each meander would not reach more than eight kilometres on either side of its path; but, since it would be superfluous to sketch from this base the country in the immediate vicinity of the mountain stations, these plots *en route* need never extend more than four kilometres from the central line. Of course, in practice, these surveys will not be thus distributed in straight lines at equal distances apart, but will communicate, intersect, and duplicate in every possible way. Still the meander will serve its original purpose of penetrating those regions and traversing those border-lands that are remote from the mountain stations, and will trace out the roads, trails, and important streams, whose entire length in this area will not be likely to exceed 1250 kilometres.

Returning to the office at the end of the season, the engineer will have material enough to make a plot of the country on a scale of one centimetre to the kilometre ($\frac{1}{100\,000}$), or one-half a centimetre to the kilometre ($\frac{1}{200\,000}$). Or, to put this statement with more precision, he will have so much and so detailed material, that he will not be able to portray it conveniently and intelligibly on a scale of less than $\frac{1}{200\,000}$. But when the final draughtsman comes to copy these plots, he may condense them, if it be thought expedient, to proportions of $\frac{1}{400\,000}$, or even smaller. On the other hand, portions of this area may be plotted upon a much larger plan than any here noticed, should such be found necessary for the clear and complete geographical and geological representation of the same.

EUROPEAN SURVEYS.

Now, in contradistinction to the above showing, let us take up the reports of some European surveys. In Prussia, 12,000 square kilometres, a little more or less, are surveyed annually, at a cost of 800,000 marks, or, as near as may be, four hundred contos of Brazilian money,* exclusive of the salaries of military assistants; notice that in the United States, with a total annual appropriation not greater than this, at least 300,000 square kilometres are geographically surveyed each year, this territory being studied at the same time by the geologist, the chemist and the naturalist.

Upon the Ordnance Survey of Great Britain there were over 1800 assistants

* A conto of reis, in Brazil, is equal to about five hundred American dollars, or a hundred pounds sterling.

and employés engaged during the year of 1874; the total area surveyed by them was not more than 8,000 square kilometres. With the methods in use in Austria an experienced topographer can survey in one field season of six months five hundred square kilometres at the farthest. In Switzerland the topography is in large part done by contract, and it alone, exclusive of triangulation and publication, costs 700 or 800 francs per square stunde, or about twenty-two mil reis* per square kilometre. So with the surveys of Italy, Spain, Sweden, and the other European countries of comparatively small extent; they are so slow, detailed, and withal so expensive as to be inapplicable to the great empire of Brazil.

AN ADVANTAGEOUS DEVELOPMENT.

So vast is the extent of this empire that the idea of a geographical survey of its territory, as a whole, is an astounding one, and is liable, in itself, to forbid all further consideration of the subject.

---

* Eleven American dollars.

But this plan does not necessarily imply the regular extension of this survey over the whole country, irrespective of population and wealth. On the contrary it would devote itself at first to such areas as, from geological or other economical reasons, might most urgently require it, and a region of especial interest to the geologist would be surveyed first and with especial care, to the neglect or even exclusion of those great stretches of country whose structure is unvaried and monotonous. In a few conditions of its plan, as, for instance, in the system adopted in the projection of its maps, it might provide for any possible ultimate extension, but in other respects it could operate with equal facility, in whatever districts might be assigned to it.

Nor does this plan imply the necessity of any great outlay at the beginning, but would ask to start upon a small scale at first, with a view to gradual growth as it proved itself worthy of encouragement. As the aim of this project would be not only the production of much-needed maps, but also the introduction of these methods of survey from abroad, and the training of Brazilian engineers in the use of the same, any very extensive initial basis would prove not only embarrassing at first but also probably disastrous in the end. A survey inaugurated upon a grandiose scale is too liable to exhaust the patience and liberality of its official patrons before it can exhibit results apparently equivalent to the expenditure that it has caused, and the frequent fate of such enterprises is that they are discontinued at about the time when, their organization being successfully completed, they are prepared to enter upon an area of efficient and fruitful labor; hence, all of the expense of organization and other preliminaries becomes a total loss to the government.

On the other hand, some of the most important surveys of the world have arisen from humble beginnings. Such an enterprise educates its own members, the assistant engineer of one season becoming the engineer of the next, and so on.

It develops gradually and with a healthy growth, perfecting its own methods, and always experimenting upon a small scale, so that it is never liable to serious disaster. And, above all, by its early production and exhibition of results commensurate with its size, and with its cost, which is insignificant at first, it buys the right to be continued, encouraged and increased from year to year.

A GEOLOGICAL AND GEOGRAPHICAL SURVEY.

There are two very good arguments for such a geographical survey in connection with the Geological Commission of Brazil; first, its necessity to the geological survey, as explained in the early part of this paper; and second, because in such a connection it can work most economically and profitably. With a combination of these elements comes much valuable co-operation between the representatives of the various branches of science, and this is constantly acting to lessen the expense and increase the returns of such a survey. For instance, as the meteorologist of the engineering corps, an assistant with some acquaintance with geology, could be chosen. As his meteorological duties upon the march would be but light, he could devote much of his time to a geological study of the road, leaving the regular geologist at liberty to go from camp to camp by any other route that he might select. Again, the meteorologist, or even the engineer himself, may make stratigraphical sketches upon every mountain, and bring specimens of rock from the same, while the geologist is away upon some detour to regions of interest in another direction.

Or, reversing this illustration, the geologist, whose profession is so closely allied to that of the geographer, is constantly making notes of direction, distance, slope, and altitude, which are of the highest importance and use in the construction of a map. These are lost to the world if there is not an accompanying geographical survey into whose plots they may be assimilated.

In witness of the sympathy with which the present members of the Geological Commission regard geographical work, and of their skill in the prosecution of the same, the writer would mention their intelligent and extensive surveys of the valley of the Amazon, from Monte Alegre westwards, and of its tributary, the Trombetas; of the island of Fernando de Noronha; and of many localities along the Atlantic coast and elsewhere in the empire. These are evidences of a willingness and an ability to collect geographical information, which, in themselves, assure the success of a system of geographical surveying in connection with the Geological Commission of Brazil.

**** Any book in this Catalogue sent free by mail, on receipt of price.*

VALUABLE

SCIENTIFIC BOOKS,

PUBLISHED BY

D. VAN NOSTRAND,

23 Murray Street, and 27 Warren Street,

NEW YORK.

WEISBACH. A MANUAL OF THEORETICAL MECHANICS. By Julius Weisbach, Ph. D. Translated by Eckley B. Coxe, A.M., M.E. 1100 pages and 902 wood-cut illustrations. 8vo, cloth, ... $10 00

FRANCIS. LOWELL HYDRAULIC EXPERIMENTS—being a Selection from Experiments on Hydraulic Motors, on the Flow of Water over Weirs, and in open Canals of Uniform Rectangular Section, made at Lowell, Mass. By J. B. Francis, Civil Engineer. Third edition, revised and enlarged, with 23 copper-plates, beautifully engraved, and about 100 new pages of text. 4to, cloth, ... 15 00

KIRKWOOD. ON THE FILTRATION OF RIVER WATERS, for the Supply of Cities, as practised in Europe. By James P. Kirkwood. Illustrated by 30 double-plate engravings. 4to, cloth 15 00

FANNING. A PRACTICAL TREATISE OF WATER SUPPLY ENGINEERING. Relating to the Hydrology, Hydrodynamics, and Practical Construction of Water-Works, in North America. With numerous Tables and 180 illustrations. By J. T. Fanning, C.E. 650 pages. 8vo, cloth extra, . $6 00

WHIPPLE. AN ELEMENTARY TREATISE ON BRIDGE BUILDING. By S. Whipple, C. E. New Edition Illustrated. 8vo, cloth, 4 00

MERRILL. IRON TRUSS BRIDGES FOR RAILROADS. The Method of Calculating Strains in Trusses, with a careful comparison of the most prominent Trusses, in reference to economy in combination, etc., etc. By Bvt. Col. William E. Merrill, U. S. A., Corps of Engineers. Nine lithographed plates of illustrations. Third edition. 4to, cloth, ... 5 00

SHREVE. A TREATISE ON THE STRENGTH OF BRIDGES AND ROOFS. Comprising the determination of Algebraic formulas for Strains in Horizontal, Inclined or Rafter, Triangular, Bowstring Lenticular and other Trusses, from fixed and moving loads, with practical applications and examples, for the use of Students and Engineers By Samuel H. Shreve, A. M., Civil Engineer. Second edition, 87 woodcut illustrations. 8vo, cloth, . . . 5 00

KANSAS CITY BRIDGE. WITH AN ACCOUNT OF THE REGIMEN OF THE MISSOURI RIVER,—and a description of the Methods used for Founding in that River. By O. Chanute, Chief Engineer, and George Morison, Assistant Engineer. Illustrated with five lithographic views and twelve plates of plans. 4to, cloth, . . . 6 00

CLARKE. DESCRIPTION OF THE IRON RAILWAY BRIDGE Across the Mississippi River at Quincy, Illinois. By Thomas Curtis Clarke, Chief Engineer. With twenty-one lithographed Plans. 4to, cloth, ... $7 50

ROEBLING. LONG AND SHORT SPAN RAILWAY BRIDGES. By John A. Roebling, C. E. With large copperplate engravings of plans and views. Imperial folio, cloth, . 25 00

DUBOIS. THE NEW METHOD OF GRAPHICAL STATICS. By A. J. Dubois, C. E., Ph. D. 60 illustrations. 8vo, cloth, ... 2 00

EDDY. NEW CONSTRUCTIONS IN GRAPHICAL STATICS. By Prof. Henry B. Eddy, C. E Ph. D. Illustrated by ten engravings in text, and nine folding plates. 8vo, cloth, 1 50

BOW. A TREATISE ON BRACING—with its application to Bridges and other Structures of Wood or Iron. By Robert Henry Bow, C. E. 156 illustrations on stone. 8vo, cloth, 1 50

STONEY. THE THEORY OF STRAINS IN GIRDERS —and Similar Structures—with Observations on the Application of Theory to Practice, and Tables of Strength and other Properties of Materials. By Bindon B. Stoney, B. A. New and Revised Edition, with numerous illustrations. Royal 8vo, 664 pp., cloth, ... 12 50

HENRICI. SKELETON STRUCTURES, especially in their Application to the building of Steel and Iron Bridges. By Olaus Henrici. 8vo, cloth, ... 1 50

KING. LESSONS AND PRACTICAL NOTES ON STEAM. The Steam Engine, Propellers, &c., &c., for Young Engineers. By the late W. R. King, U. S. N., revised by Chief-Engineer J. W. King, U. S. Navy. 19th edition. 8vo, cloth, ... 2 00

AUCHINCLOSS. APPLICATION OF THE SLIDE VALVE and Link Motion to Stationary, Portable, Locomotive and Marine Engines. By William S Auchincloss. Designed as a hand-book for Mechanical Engineers. With 37 wood-cuts and 21 lithographic plates, with copper-plate engraving of the Travel Scale. Sixth edition. 8vo, cloth, $3 00

BURGH. MODERN MARINE ENGINEERING, applied to Paddle and Screw Propulsion. Consisting of 36 Colored Plates, 259 Practical Wood-cut Illustrations, and 403 pages of Descriptive Matter, the whole being an exposition of the present practice of the following firms: Messrs. J. Penn & Sons; Messrs. Maudslay, Sons & Field; Messrs. James Watt & Co.; Messrs. J. & G. Rennie. Messrs. R. Napier & Sons; Messrs J. & W. Dudgeon; Messrs. Ravenhill & Hodgson; Messrs Humphreys & Tenant; Mr J. T. Spencer, and Messrs. Forrester & Co. By N. P. Burgh. Engineer. One thick 4to vol., cloth, $25.00; half morocco, 30 00

BACON. A TREATISE ON THE RICHARD'S STEAM-ENGINE INDICATOR — with directions for its use. By Charles T. Porter. Revised, with notes and large additions as developed by American Practice; with an Appendix containing useful formulæ and rules for Engineers. By F. W. Bacon, M. E. Illustrated Second edition. 12mo. Cloth $1.00; morocco, ... 1 50

ISHERWOOD ENGINEERING PRECEDENTS FOR STEAM MACHINERY. By B. F. Isherwood, Chief Engineer, U. S. Navy. With illustrations. Two vols. in one. 8vo, cloth, 2 50

STILLMAN. THE STEAM ENGINE INDICATOR —and the Improved Manometer Steam and Vacuum Gauges—their utility and application. By Paul Stillman. New edition. 12mo, cloth, ... 1 00

MacCORD. A PRACTICAL TREATISE ON THE SLIDE VALVE, BY ECCENTRICS—examining by methods the action of the Eccentric upon the Slide Valve, and explaining the practical processes of laying out the movements, adapting the valve for its various duties in the steam-engine. By C. W. Mac Cord, A. M., Professor of Mechanical Drawing, Stevens' Institute of Technology, Hoboken, N. J. Illustrated. 4to, cloth. $3 00

PORTER. A TREATISE ON THE RICHARDS' STEAM-ENGINE INDICATOR, and the Development and Application of Force in the Steam-Engine. By Charles T. Porter. Third edition, revised and enlarged. Illustrated. 8vo, cloth, . . . 3 50

McCULLOCH. A TREATISE ON THE MECHANICAL THEORY OF HEAT, AND ITS APPLICATIONS TO THE STEAM-ENGINE. By Prof. R. S. McCulloch, of the Washington and Lee University, Lexington, Va. 8vo, cloth, ... 3 50

VAN BUREN. INVESTIGATIONS OF FORMULAS—for the Strength of the Iron parts of Steam Machinery. By J. D. Van Buren, Jr., C. E. Illustrated. 8vo, cloth, . 2 00

STUART. HOW TO BECOME A SUCCESSFUL ENGINEER. Being Hints to Youths intending to adopt the Profession. By Bernard Stuart, Engineer. Sixth edition 18mo, boards, ... 50

SHIELDS. A TREATISE ON ENGINEERING CONSTRUCTION. Embracing Discussions of the Principles involved, and Descriptions of the Material employed in Tunneling, Bridging, Canal and Road Building, etc., etc. By J. E. Shields, C. E. 12mo. cloth, 1 50

WEYRAUCH. STRENGTH AND CALCULATION OF DIMENSIONS OF IRON AND STEEL CONSTRUCTIONS. Translated from the German of J. J. Weyrauch, Ph. D., with four folding Plates. 12mo, cloth, . . . $1 00

STUART. THE NAVAL DRY DOCKS OF THE UNITED STATES. By Charles B. Stuart, Engineer in Chief, U. S. Navy. Twenty-four engravings on steel. Fourth edition. 4to, cloth, ... 6 00

COLLINS. THE PRIVATE BOOK OF USEFUL ALLOYS, and Memoranda for Goldsmiths, Jewellers, etc. By James E. Collins. 18mo, flexible cloth, ... 50

TUNNER. A TREATISE ON ROLL-TURNING FOR THE MANUFACTURE OF IRON. By Peter Tunner Translated by John B. Pearse. With numerous wood-cuts, 8vo, and a folio Atlas of 10 lithographed plates of Rolls, Measurements, &c. Cloth, . . 10 00

GRUNER. THE MANUFACTURE OF STEEL. By M. L. Gruner. Translated from the French, by Lenox Smith, A.M., E.M.; with an Appendix on the Bessemer Process in the United States, by the translator. Illustrated by lithographed drawings and wood-cuts. 8vo, cloth, ... 3 50

BARBA. THE USE OF STEEL IN CONSTRUCTION. Methods of Working, Applying, and Testing Plates and Bars. By J. Barba. Translated from the French, with a Preface by A. L. Holley, P.B. Illustrated. 12mo, cloth, 1 50

BELL. CHEMICAL PHENOMENA OF IRON SMELTING. An Experimental and Practical Examination of the Circumstances which Determine the Capacity of the Blast Furnace, the Temperature of the Air, and the Proper Condition of the Materials to be operated upon. By I. Lowthian Bell. 8vo, cloth, ... 6 00

WARD. STEAM FOR THE MILLION. A Popular Treatise on Steam and its Application to the Useful Arts, especially to Navigation. By J. H. Ward, Commander U. S. Navy. 8vo, cloth, ... $1 00

CLARK. A MANUAL OF RULES, TABLES AND DATA FOR MECHANICAL ENGINEERS. Based on the most recent investigations. By Dan. Kinnear Clark. Illustrated with numerous diagrams. 1012 pages. 8vo. Cloth, $7 50; half morocco, ... 10 00

JOYNSON. THE METALS USED IN CONSTRUCTION: Iron, Steel, Bessemer Metals, etc, By F. H. Joynson. Illustrated. 12mo, cloth, ... 75

DODD. DICTIONARY OF MANUFACTURES, MINING, MACHINERY, AND THE INDUSTRIAL ARTS. By George Dodd. 12mo, cloth, 1 50

VON COTTA. TREATISE ON ORE DEPOSITS. By Bernhard Von Cotta, Freiburg, Saxony. Translated from the second German ed., by Frederick Prime, Jr., and revised by the author. With numerous illustrations. 8vo, cloth, ... 4 00

PLATTNER. MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOW-PIPE. From the last German edition. Revised and enlarged. By Prof. Th. Richter, o the Royal Saxon Mining Academy. Translated by Professor H. B. Cornwall. With eighty-seven wood-cuts and lithographic plate. Third edition, revised. 568 pp. 8vo, cloth, ... , ... 5 00

PLYMPTON. THE BLOW-PIPE: A Guide to its Use in the Determination of Salts and Minerals. Compiled from various sources, by George W. Plympton, C. E., A. M., Professor of Physical Science in the Polytechnic Institute, Brooklyn, N. Y. 12mo, cloth, 1 50

JANNETTAZ. A GUIDE TO THE DETERMINATION OF ROCKS; being an Introduction to Lithology. By Edward Jannettaz, Docteur des Sciences. Translated from the French by G. W. Plympton, Professor of Physical Science at Brooklyn Polytechnic Institute. 12mo, cloth, ... $1 50

MOTT. A PRACTICAL TREATISE ON CHEMISTRY (Qualitative and Quantitative Analysis), Stoichiometry, Blowpipe Analysis, Mineralogy, Assaying, Pharmaceutical Preparations. Human Secretions, Specific Gravities, Weights and Measures, etc., etc., etc. By Henry A. Mott, Jr., E. M., Ph. D. 650 pp. 8vo, cloth, ... 6 00

PYNCHON. INTRODUCTION TO CHEMICAL PHYSICS; Designed for the Use of Academies, Colleges, and High Schools. Illustrated with numerous engravings, and containing copious experiments, with directions for preparing them. By Thomas Ruggles Pynchon, D. D., M. A., President of Trinity College, Hartford. New edition, revised and enlarged. Crown 8vo, cloth, ... 3 00

PRESCOTT. CHEMICAL EXAMINATION OF ALCOHOLIC LIQUORS. A Manual of the Constituents of the Distilled Spirits and Fermented Liquors of Commerce, and their Qualitative and Quantitative Determinations. By Alb. B. Prescott, Prof. of Chemistry, University of Michigan. 12mo, cloth, . 1 50

ELIOT AND STORER. A COMPENDIOUS MANUAL OF QUALITATIVE CHEMICAL ANALYSIS. By Charles W. Eliot and Frank H. Storer. Revised, with the co-operation of the Authors, by William Ripley Nichols, Professor of Chemistry in the Massachusetts Institute of Technology. New edition, revised. Illustrated. 12mo, cloth, ... 1 50

NAQUET. LEGAL CHEMISTRY. A Guide to the Detection of Poisons, Falsification of Writings, Adulteration of Alimentary and Pharmaceutical Substances; Analysis of Ashes, and Examination of Hair, Coins, Fire-arms and Stains, as Applied to Chemical Jurisprudence. For the Use of Chemists, Physicians, Lawyers, Pharmacists, and Experts. Translated, with additions, including a List of Books and Memoirs on Toxicology, etc., from the French of A. Naquet, by J. P. Battershall, Ph. D.; with a Preface by C. F. Chandler, Ph. D., M. D., LL. D. Illustrated. 12mo, cloth, ... $2 00

PRESCOTT. OUTLINES OF PROXIMATE ORGANIC ANALYSIS for the Identification, Separation, and Quantitative Determination of the more commonly occurring Organic Compounds. By Albert B. Prescott, Professor of Chemistry, University of Michigan. 12mo, cloth, ... 1 75

DOUGLAS AND PRESCOTT. QUALITATIVE CHEMICAL ANALYSIS. A Guide in the Practical Study of Chemistry, and in the work of Analysis. By S. H. Douglas and A. B. Prescott; Professors in the University of Michigan. Second edition, revised. 8vo, cloth, ... 3 50

RAMMELSBERG. GUIDE TO A COURSE OF QUANTITATIVE CHEMICAL ANALYSIS, ESPECIALLY OF MINERALS AND FURNACE PRODUCTS. Illustrated by Examples. By C. F. Rammelsberg. Translated by J. Towler, M. D. 8vo, cloth, ... 2 25

BEILSTEIN. AN INTRODUCTION TO QUALITATIVE CHEMICAL ANALYSIS. By F. Beilstein. Third edition. Translated by I. J. Osbun. 12mo. cloth, ... 75

POPE. A Hand-book for Electricians and Operators. By Frank L. Pope. Ninth edition. Revised and enlarged, and fully illustrated. 8vo, cloth, ... 2 00

SABINE. History and Progress of the Electric Telegraph, with Descriptions of some of the Apparatus. By Robert Sabine, C. E. Second edition. 12mo, cloth, . . $1 25

DAVIS AND RAE. Hand Book of Electrical Diagrams and Connections. By Charles H. Davis and Frank B. Rae. Illustrated with 32 full-page illustrations. Second edition. Oblong 8vo, cloth extra, ... 2 00

HASKINS. The Galvanometer, and its Uses. A Manual for Electricians and Students. By C. H. Haskins. Illustrated. Pocket form, morocco, ... 1 50

LARRABEE. Cipher and Secret Letter and Telegrapaic Code, with Hogg's Improvements. By C. S. Larrabee. 18mo, flexible cloth, ... 1 00

GILLMORE Practical Treatise on Limes, Hydraulic Cement, and Mortars. By Q. A. Gillmore, Lt.-Col. U. S. Engineers, Brevet Major-General U. S. Army. Fifth edition, revised and enlarged. 8vo, cloth, 4 00

GILLMORE. Coignet Beton and other Artificial Stone. By Q. A. Gillmore, Lt. Col. U. S. Engineers, Brevet Major-General U. S. Army. Nine plates, views, etc. 8vo, cloth, ... 2 50

GILLMORE. A Practical Treatise on the Construction of Roads, Streets, and Pavements. By Q. A. Gillmore, Lt.-Col. U. S. Engineers, Brevet Major-General U. S. Army. Seventy illustrations. 12mo, clo., 2 00

GILLMORE. Report on Strength of the Building Stones in the United States, etc. 8vo, cloth, ... 1 00

HOLLEY. American and European Railway Practice, in the Economical Generation of Steam. By Alexander L. Holley. B. P. With 77 lithographed plates. Folio, cloth, 12 00

HAMILTON. Useful Information for Railway Men. Compiled by W. G. Hamilton, Engineer. Seventh edition, revised and enlarged. 577 pages. Pocket form, morocco, gilt, ... $2 00

STUART. The Civil and Military Engineers of America. By General Charles B. Stuart, Author of "Naval Dry Docks of the United States," etc., etc. With nine finely-executed Portraits on steel, of eminent Engineers, and illustrated by Engravings of some of the most important and original works constructed in America. 8vo, cloth, ... 5 00

ERNST. A Manual of Practical Military Engineering. Prepared for the use of the Cadets of the U. S. Military Academy, and for Engineer Troops. By Capt. O. H. Ernst, Corps of Engineers, Instructor in Practical Military Engineering, U. S. Military Academy. 193 wood-cuts and 3 lithographed plates. 12mo, cloth, . . . 5 00

SIMMS. A Treatise on the Principles and Practice of Levelling, showing its application to purposes of Railway Engineering and the Construction of Roads, etc. By Frederick W. Simms, C. E. From the fifth London edition, revised and corrected, with the addition of Mr. Law's Practical Examples for Setting-out Railway Curves. Illustrated with three lithographic plates, and numerous wood-cuts. 8vo, cloth, ... 2 50

JEFFERS. Nautical Surveying. By William N. Jeffers, Captain U. S. Navy. Illustrated with 9 copperplates, and 31 wood-cut illustrations. 8vo, cloth, ... 5 00

THE PLANE TABLE. Its Uses in Topographical Surveying. From the papers of the U. S. Coast Survey. 8vo, cloth, . . . 2 00

A TEXT-BOOK ON SURVEYING, PROJECTIONS, AND PORTABLE INSTRUMENTS, for the use of the Cadet Midshipmen, at the U. S. Naval Academy. 9 lithographed plates, and several wood-cuts. 8vo, cloth, . . . $2 00

CHAUVENET. NEW METHOD OF CORRECTING LUNAR DISTANCES. By Wm. Chauvenet, LL.D. 8vo, cloth, ... 2 00

BURT. KEY TO THE SOLAR COMPASS, and Surveyor's Companion; comprising all the Rules necessary for use in the Field. By W. A. Burt, U. S. Deputy Surveyor. Second edition. Pocket-book form, tuck, . 2 50

HOWARD. EARTHWORK MENSURATION ON THE BASIS OF THE PRISMOIDAL FORMULÆ. Containing simple and labor-saving method of obtaining Prismoidal Contents directly from End Areas. Illustrated by Examples, and accompanied by Plain Rules for practical uses. By Conway R. Howard, Civil Engineer, Richmond, Va. Illustrated. 8vo, cloth, ... 1 50

MORRIS. EASY RULES FOR THE MEASUREMENT OF EARTHWORKS, by means of the Prismoidal Formulæ. By Elwood Morris, Civil Engineer. 78 illustrations. 8vo, cloth, 1 50

CLEVENGER. A TREATISE ON THE METHOD OF GOVERNMENT SURVEYING, as prescribed by the U. S. Congress and Commissioner of the General Land Office. With complete Mathematical, Astronomical, and Practical Instructions for the use of the U. S. Surveyors in the Field. By S. V. Clevenger, U. S. Deputy Surveyor. Illustrated. Pocket form, morocco, gilt, ... 2 50

HEWSON. PRINCIPLES AND PRACTICE OF EMBANKING LANDS from River Floods, as applied to the Levees of the Mississipi. By William Hewson, Civil Engineer. 8vo, cloth, ... 2 00

MINIFIE. A TEXT-BOOK OF GEOMETRICAL DRAWING, for the use of Mechanics and Schools. With Illustrations for Drawing Plans, Elevations of Buildings and Machinery. With over 200 diagrams on steel. By William Minifie, Architect. Ninth edition. Royal 8vo, cloth, ... $4 00

MINIFIE. GEOMETRICAL DRAWING. Abridged from the octavo edition, for the use of Schools. Illustrated with 48 steel plates. New edition, enlarged. 12mo, cloth, 2 00

FREE HAND DRAWING. A GUIDE TO ORNAMENTAL, Figure, and Landscape Drawing. By an Art Student. Profusely illustrated. 18mo, boards, ... 50

AXON. THE MECHANIC'S FRIEND. A Collection of Receipts and Practical Suggestions, relating to Aquaria—Bronzing—Cements—Drawing—Dyes—Electricity—Gilding—Glass-working—Glues—Horology—Lacquers—Locomotives—Magnetism—Metal-working—Modelling—Photography—Pyrotechny—Railways—Solders—Steam-Engine—Telegraphy—Taxidermy—Varnishes—Waterproofing–and Miscellaneous Tools, Instruments, Machines, and Processes connected with the Chemical and Mechanical Arts. By William E. Axon, M.R.S.L. 12mo, cloth. 300 illustrations, . . . 1 50

HARRISON. MECHANICS' TOOL BOOK, with Practical Rules and Suggestions, for the use of Machinists, Iron Workers, and others. By W. B. Harrison. 44 illustrations. 12mo, cloth 1 50

JOYNSON. THE MECHANIC'S AND STUDENT'S GUIDE in the designing and Construction of General Machine Gearing. Edited by Francis H. Joynson. With 18 folded plates. 8vo, cloth 2 00

RANDALL. QUARTZ OPERATOR'S HAND-BOOK. By P. M. Randall. New Edition. Revised and Enlarged. Fully illustrated. 12mo, cloth, ... $2 00

SILVERSMITH. A PRACTICAL HAND-BOOK FOR MINERS, METALLURGISTS, and Assayers. By Julius Silversmith. Fourth Edition. Illustrated. 12mo, cloth, ... 3 00

BARNES. SUBMARINE WARFARE, DEFENSIVE AND OFFENSIVE. Descriptions of the various forms of Torpedoes, Submarine Batteries and Torpedo Boats actually used in War. Methods of Ignition by Machinery, Contact Fuzes, and Electricity, and a full account of experiments made to determine the Explosive Force of Gunpowder under Water. Also a discussion of the Offensive Torpedo system; its effect upon Iron-clad Ship systems, and influence upon future Naval Wars. By Lieut.-Com. John S. Barnes, U. S. N. With 20 lithographic plates and many wood-cuts. 8vo, cloth, 5 00

FOSTER. SUBMARINE BLASTING, in Boston Harbor, Mass. Removal of Tower and Corwin Rocks. By John G. Foster, U. S. Eng. and Bvt. Major General U. S. Army. With seven Plates. 4to, cloth, 3 50

MOWBRAY. TRI-NITRO-GLYCERINE, as applied in the Hoosac Tunnel, and to Submarine Blasting, Torpedoes, Quarrying, etc. Illustrated. 8vo, cloth, ... 3 00

WILLIAMSON. ON THE USE OF THE BAROMETER ON SURVEYS AND RECONNAISSANCES. Part I.–Meteorology in its Connection with Hypsometry. Part II.—Barometric Hypsometry. By R. S. Williamson, Bvt. Lt.-Col. U.S.A., Major Corps of Engineers. With illustrative tables and engravings. 4to, cloth, ... 15 00

WILLIAMSON. PRACTICAL TABLES IN METEOROLOGY AND HYPSOMETRY, in connection with the use of the Barometer By Col. R. S. Williamson, U. S. A. 4to, flexible cloth, $2 50

BUTLER. PROJECTILES AND RIFLED CANNON A Critical Discussion of the Principal Systems of Rifling and Projectiles, with Practical Suggestions for their Improvement. By Capt. John S. Butler, Ordnance Corps, U. S. A. 36 Plates. 4to, cloth, . . . 7 50

BENET. ELECTRO-BALLISTIC MACHINES, and the Schultz Chronoscope. By Lt.-Col S. V. Benet, Chief of Ordnance U. S. A. Second edition, illustrated. 4to, cloth, . 3 00

MICHAELIS. THE LE BOULENGE CHRONOGRAPH. With three lithographed folding plates of illustrations. By Bvt. Captian O. E. Michaelis, Ordnance Corpse, U. S. A. 4to, cloth, ... 3 00

NUGENT. TTEATISE ON OPTICS; or Light and Sight, theoretically and practically treated; with the application to Fine Art and Industrial Pursuits. By E. Nugent. With 103 illustrations. 12mo, cloth, ... 1 50

PEIRCE. SYSTEM OF ANALYTIC MECHANICS. By Benjamin Peirce, Professor of Astronomy and Mathematics in Harvard University. 4to. cloth, ... 10 00

CRAIG. WEIGHTS AND MEASURES. An Account of the Decimal System, with Tables of Conversion for Commercial and Scientific Uses. By B. F. Craig, M. D. Square 32mo, limp cloth, ... , . . 50

ALEXANDER. UNIVERSAL DICTIONARY OF WEIGHTS AND MEASURES, Ancient and Modern, reduced to the standards of the United States of America. By J. H. Alexander. New edition. 8vo, cloth, . . 3 50

WANKLYN. MILK ANALYSIS. A Practical Treatise on the Examination of Milk, and its Derivatives, Cream, Butter, and Cheese. By J. Alfred Wanklyn, M.R.C. S. 12mo, cloth, ... $1 00

RICE & JOHNSON. ON A NEW METHOD OF OBTAINING THE DIFFERENTIALS OF FUNCTIONS, with especial reference to the Newtonian Conception of Rates or Velocities. By J. Minot Rice, Prof. of Mathematics, U. S. Navy, and W. Woolsey Johnson, Prof. of Mathemathics, St. John's College, Annapolis. 12mo, paper. 50

COFFIN. NAVIGATION AND NAUTICAL ASTRONOMY. Prepared for the use of the U. S. Naval Academy. By J. H. C. Coffin, Professor of Astronomy, Navigation and Surveying; with 52 wood-cut illustrations. Fifth edition. 12mo, cloth, . . 3 50

CLARK. THEORETICAL NAVIGATION AND NAUTICAL ASTRONOMY. By Lewis Clark, Lieut.-Commander, U. S Navy. Illustrated with 41 wood-cuts, including the Vernier. 8vo, cloth, . . . 3 00

ROGERS. THE GEOLOGY OF PENNSYLVANIA. By Henry Darwin Rogers, late State Geologist of Pennsylvania. 3 vols. 4to, with Portfolio of Maps. Cloth, ... 30 00

IN PREPARATION.

WEISBACH. MECHANICS OF ENGINEERING, APPLIED MECHANICS; containing Arches, Bridges, Foundations, Hydraulics, Steam Engine, and other Prime Movers, &c., &c. Translated from the latest German Edition 2 vols., 8vo.

Van Nostrand's Science Series.

It is the intention of the Publisher of this Series to issue them at intervals of about a month. They will be put up in a uniform, neat, and attractive form, 18mo, fancy boards. The subjects will be of an eminently scientific nature, and embrace as wide a range of topics as possible,—all of the highest character.

Price, 50 Cents Each.

I. Chimneys for Furnaces, Fire-places, and Steam Boilers. By R. Armstrong, C. E.

II. Steam Boiler Explosions. By Zerah Colburn.

III. Practical Designing of Retaining Walls. By Arthur Jacob, A. B. Illustrated.

IV. Proportions of Pins Used in Bridges. By Charles E. Bender, C. E. Illustrated.

V. Ventilation of Buildings. By W. F. Butler. Illustrated.

VI. On the Designing and Construction of Storage Reservoirs. By Arthur Jacob. Illustrated.

VII. Surcharged and Different Forms of Retaining Walls. By James S. Tate, C. E.

VIII. A Treatise on the Compound Engine. By John Turnbull. Illustrated.

IX. Fuel. By C. William Siemens. To which is appended the value of Artificial Fuels as Compared with Coal. By John Wormald, C. E.

X. Compound Engines. Translated from the French of A. Mallet. Illustrated.

XI. Theory of Arches. By Prof. W. Allan, of the Washington and Lee College. Illustrated.

XII. A Practical Theory of Voussoir Arches. By William Cain, C.E. Illustrated.

XIII. A Practical Treatise on the Gases Met with in Coal Mines. By the late J. J. Atkinson, Government Inspector of Mines for the County of Durham, England.

XIV. Friction of Air in Mines. By J. J. Atkinson, author of "A Practical Treatise on the Gases met with in Coal Mines."

XV. Skew Arches. By Prof. E. W. Hyde, C. E. Illustrated with numerous engravings, and three folded Plates.

XVI. A Graphic Method for solving Certain Algebraic Equations. By Prof. George L. Vose. Illustrated.

XVII. Water and Water Supply. By Prof. W. H. Corfield, M. A., of the University College, London.

XVIII. Sewerage and Sewage Utilization. By Prof. W. H. Corfield, M. A., of the University College, London.

XIX. Strength of Beams Under Transverse Loads. By Prof. W. Allan, author of "Theory of Arches." Illustrated.

XX. Bridge And Tunnel Centres. By John B. McMasters, C. E. Illustrated.

XXI. Safety Valves. By Richard H. Buel, C. E. Illustrated.

XXII. High Masonry Dams. By John B. McMasters, C. E. Illustrated.

XXIII. The Fatigue of Metals, under Repeated Strains; with various Tables of Results of Experiments. From the German of Prof. Ludwig Spangenberg. With a Preface by S. H. Shreve, A. M. Illustrated.

XXIV. A Practical Treatise on the Teeth of Wheels, with the theory of the use of Robinson's Odontograph. By S. W. Robinson, Prof. of Mechanical Engineering, Illinois Industrial University.

XXV. THEORY AND CALCULATIONS OF CONTINUOUS BRIDGES. By Mansfield Merriman, C. E. Illustrated.

XXVI. PRACTICAL TREATISE ON THE PROPERTIES OF CONTINUOUS BRIDGES. By Charles Bender, C. E.

XXVII. ON BOILER INCRUSTATION AND CORROSION. By F. S. Rowan.

XXVIII. ON TRANSMISSION OF POWER BY WIRE ROPE. By Albert W. Stahl.

XXIX. INJECTORS; their Theory and Use. Translated from the French of M. Leon Pouchet.

XXX. TERRESTRIAL MAGNETISM AND THE MAGNETISM OF IRON VESSELS. By Prof. Fairman Rogers.

XXXI. THE SANITARY CONDITION OF DWELLING HOUSES IN TOWN AND COUNTRY. By George E. Waring, Jr., Consulting Engineer for Sanitary and Agricultural Works. Illustrated.

XXXII. CABLE MAKING FOR SUSPENSION BRIDGES, as exemplified in the Construction of the East River Bridge. By Wilhelm Hildenbrand, C. E.

XXXIII. MECHANICS OF VENTILATION. By George W. Rafter, Civil Engineer.

XXXIV. FOUNDATIONS. By Prof. Jules Gaudard, C. E. Translated from the French, by L. F. Vernon Harcourt, M. I. C. E.

XXXV. THE ANEROID BAROMETER, ITS CONSTRUCTION AND USE. Compiled by Professor George W. Plympton. Illustrated.

XXXVI. MATTER AND MOTION. By J. Clerk Maxwell, M. A.

XXXVII. GEOGRAPHICAL SURVEYING. Its Uses, Methods and Results. By Frank De Yeaux Carpenter, C. E.

XXXVIII. MAXIMUM STRESSES IN FRAMED BRIDGES. By Prof. Wm. Cain, A. M., C. E.

*** *Other Works in preparation for this Series.*

THE UNIVERSITY SERIES.

VAN NOSTRAND'S SCIENCE SERIES.

No. 40.—TRANSMISSION OF POWER BY COMPRESSED AIR. By Robert Zahner, M. E. Illustrated.
No. 41.—STRENGTH OF MATERIALS. By William Kent.
No. 42.—VOUSSOIR ARCHES, applied to Stone Bridges, Tunnels, Culverts and Domes. By Prof. Wm. Cain.
43.—WAVE AND VORTEX MOTION. By Dr. Thomas Craig, of Johns Hopkins University.
44.—TURBINE WHEELS. By Prof. W. P. Trowbridge.
45.—THERMODYNAMICS. By Prof. H. T. Eddy.
. 46.—ICE-MAKING MACHINES. From the French of M. Le Doux. Illustrated.
. 47.—LINKAGES; the Different Forms and Uses of Articulated Links. By J. D. C. De Roos.
No. 48.—THEORY OF SOLID AND BRACED ARCHES. By Wm. Cain, C. E.
No. 49.—ON THE MOTION OF A SOLID IN A FLUID. By Thomas Craig, Ph. D.
No. 50.—DWELLING HOUSES: their Sanitary Construction and Arrangements. By Prof. W. H. Corfield.
No. 51.—THE TELESCOPE: Its Construction, &c. B Thomas Nolan
No. 52.—IMAGINARY QUANTITIES: Translated fro French of M. Argand. By Prof. Hardy.
No. 53.—INDUCTION COILS: How Made and How
No. 54.—KINEMATICS OF MACHINERY. By nedy. With an introduction by Pro
No. 55.—SEWER GASES. By A. De Varona.
No. 56.—THE ACTUAL LATERAL PRESSURE WORK. By Benj. Baker, M. Inst. C
No. 57.—INCANDESCENT ELECTRIC LIGH Th. Du Moncel and Wm. Henry
No. 58.—THE VENTILATION OF COAL Fairley, M. E., F. S. S.
No. 59.—RAILROAD ECONOMICS; ments. By S. W. Robins
No. 60.—STRENGTH OF WROUG BERS. By S. W. Rob
No. 61.—POTABLE WATER, Detecting Im
. 62.—THE THEO Dugald C
. 63.—HOUSE ING. B-
. 64.—ELEC
. 65.—POC ES OF
No. 66.— y Silvanus
No. 67.—H n.
No. 68 —STEAM HEATING. By Robert Briggs.
No. 69.—CHEMICAL PROBLEMS. By Prof. Foye.
No. 70.—EXPLOSIVE MATERIALS. By M. P. E. Berthelot.

18mo, boards, 50 cents each.
☞ Sent free by mail on receipt of price.

D. VAN NOSTRAND, Publisher, 23 Murray & 27 Warren Sts., N. Y.