DEPARTMENT OF THE INTERIOR
Franklin K. Lane, Secretary

UNITED STATES GEOLOGICAL SURVEY
George Otis Smith, Director

TOPOGRAPHIC INSTRUCTIONS
OF THE
UNITED STATES GEOLOGICAL SURVEY

EDITION OF 1918

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CONTENTS.

ILLUSTRATIONS.

PREFATORY NOTE.

This book is intended to replace the instructions relating to the topographic work of the United States Geological Survey issued as a part of the general Survey instructions of 1903, which are now in many respects obsolete, although revised portions of them have, from time to time, been issued as circular letters or printed leaflets. The several portions of this book were prepared by the members of the topographic branch best qualified for the task and were assembled and revised by the division chiefs and finally reviewed by the chief geographer. It is desired to make the instructions complete so far as the technical work of map making is concerned and to reduce to a minimum the necessity for personal instructions.

The first edition of these instructions, issued in 1913, and the second edition, issued in 1915, contained a request for criticism or suggestion for their improvement. All errors reported in those editions have been corrected, and careful consideration has been given to all suggested additions or changes. The request is renewed for criticisms or suggestions regarding this edition.

R. B. MARSHALL,
Chief Geographer.

Approved.

GEO. OTIS SMITH, *Director.*

WASHINGTON, D. C., *February 28, 1918.*

TOPOGRAPHIC INSTRUCTIONS

OF THE

UNITED STATES GEOLOGICAL SURVEY.

GENERAL INSTRUCTIONS.

ADMINISTRATION.

ORGANIZATION.

The topographic branch is organized under the direction of a chief geographer into five areal divisions (Atlantic, Central, Rocky Mountain, Northwestern, and Pacific), each of which is in charge of a geographer. The members of the technical force are graded as chief geographer, geographers, topographic engineers, topographers, assistant topographers, junior topographers, topographic aids, and draftsmen.

RELATIONS TO THE GOVERNMENT.

Loyalty on the part of every member to the Survey as an organization is essential to its continued efficiency and high standing. The enviable position which the organization now holds in the esteem and confidence of the public is a most valuable asset, and each member should feel that he is personally responsible for maintaining and bettering that standing. The personality or the work of other members of the topographic branch or of other branches of the Survey or of other Government bureaus should never be publicly criticized. If criticisms seem necessary, they should be communicated through the proper official channels to the responsible officer, who will give them full consideration.

The topographic branch cooperates with other branches of the Survey, and to render such cooperation effective the interests of the Survey as a whole must be kept in mind rather than the special interests of any particular branch or division.

Members of the topographic branch should keep themselves informed regarding Survey work in general and topographic work in particular. They are referred in this connection to the leaflet "Nature and use of the topographic maps of the United States Geological Survey," and to Bulletin 227, "The United States Geological Survey, its origin, development, organization, and operations."

The topographic branch is frequently called upon to cooperate with the General Land office, the Forest Service, the Bureau of Soils, the Reclamation Service, and other Government bureaus. Topographers assigned to such work should familiarize themselves with the regulations and methods of procedure of the cooperating bureau and should conform to them.

RELATIONS TO STATE SURVEYS.

It is essential to efficiency and economy that cordial relations exist between the United States Geological Survey and the State surveys. When formal cooperation with a State is in force, topographers submitting expense vouchers should first familiarize themselves with the State methods of accounting, so as to avoid confusion and delay in settlement of vouchers. It should be clearly understood that the Federal and State surveys are not competitors occupying the same field, but that each organization has a province of its own and that each supplements the work of the other.

RELATIONS TO THE PUBLIC.

Courtesy to the public is enjoined on every member and employee of the topographic branch. Discourtesy to the public will not be tolerated, and chiefs of party will be expected to discipline or discharge employees for flagrant neglect to conduct themselves with politeness and propriety. When persons make serious inquiry concerning work that the Survey is carrying on, time should be taken to give them the information; and when Federal and State Governments are cooperating, Survey employees will be expected on all proper occasions to make known to citizens the relations of the State to the work which is being done.

Objection is sometimes made to entry on private property by members of the Survey engaged in official work, but it is believed that such objections may generally be overcome by an explanation of the public character of the work. Laws enacted by the legislatures of Arizona, California, Illinois, Maine, Montana, New York, Ohio, Pennsylvania, and Washington grant authority for such entry to officials of the United States Geological Survey.

INFORMATION TO THE PRESS.

It is desirable that information concerning the progress of Survey work and matters of public concern in connection therewith shall be supplied to representatives of the press. Such information is usually given through the weekly Press Bulletin, and it is expected that members of the Geological Survey will utilize this in matters of routine importance. It is sometimes advisable, however, for a member of the Survey to give information direct to a newspaper man; in such cases it is of the utmost importance that all statements shall be well considered and that they shall be correctly reported. The tendency among a certain class of newspaper men to wrongly interpret or to recklessly color an oral expression in order to produce a "good story" necessitates the adoption of safeguards which shall be automatic in operation and general in application.

No statement relative to official matters may be given to the press without previous authorization from the Director. Whenever any member of the Survey is asked for a statement regarding any public matter, he must, before giving it, ascertain by consultation with the Director whether authorization has been granted. No interview is to be given without obtaining from the person soliciting the same a promise that he will, before submitting his manuscript to his publication office, present a copy of it to the Director for approval. If any such promise is violated, the incident will be made a matter of record, and future interviews will be denied to the person guilty of such violation.

These restrictions are regarded as essential to the continued welfare of the organization and must apply to all employees in the field, as well as in Washington, with the exception that field men may make general statements to representatives of the press regarding their own field plans or work accomplished.

No statements touching upon the policy of the Survey or any other Government bureau should be made except in the manner above outlined.

ORGANIZATION AND MANAGEMENT OF FIELD PARTIES.

PERSONNEL.

CLASSIFICATION.

The letter of assignment issued to the party chief specifies the number and class of field men who are to make up his party, and their compensation. Field men are graded as follows: (1) Topographic aids; (2) grade 1: recorders, rodmen, chainmen, etc.; (3) grade 2: laborers, including teamsters, packers, and cooks.

APPOINTMENT.

Topographic aids.—Topographic aids are selected from a list of eligibles furnished by the United States Civil Service Commission.

Applications for employment.—Persons desiring temporary employment on the field force in grade 1 must file application, on the form provided for that purpose, with the chief geographer in Washington. Laborers (grade 2) will be employed in the field by chiefs of parties as necessity may arise, and no applications for such employment will be received or filed in Washington. All persons are ineligible for employment who are suffering from any contagious or other disease, and, in grade 1, who are under 20 or more than 40 years of age, or who are students pursuing a college course, unless they bind themselves to remain with the party until their services are no longer needed. Preference is given to applicants from States in which the work is to be done, and in case of residents assigned to parties working in Western States, the age limit for rodmen, recorders, etc., may be waived, provided that no such employee is less than 18 years of age.

Employment contracts.—Before entering upon his field duties every employee must sign a contract specifying the terms of his employment and containing an agreement to remain with the Survey until the close of the field season, provided his services are satisfactory.

TRAVELING EXPENSES.

In addition to compensation, necessary living and traveling expenses incurred during employment will be refunded to topographic aids and to employees in grades 1 and 2. They must report at the point of beginning of field work, however, at their own expense.

FIELD INSURANCE.

As no leave is given to temporary employees in the field, whether employed by the month or day, their pay stops immediately if they become incapacitated by reason of accident or sickness. In order that other members of a party may not be called on to bear the expenses entailed by sickness or accident of one of its members, chiefs of party are instructed to urge all employees to take out insurance. To provide this at the lowest possible rate, a mutual benefit association has been formed by members of the Geological Survey and other Government bureaus. This association exists solely for the purpose of giving health and accident insurance to field men at cost and of preventing unnecessary burdens from falling on the immediate associates of those disabled. Information concerning membership can be obtained from chiefs of parties.

CAMP SUBSISTENCE AND MANAGEMENT.

If camp outfits are used, their character should be determined by the size of the party, the means of transportation, and the nature of the work. They should contain the essentials for efficiency and comfort. Unnecessary hardships should be avoided as much as unnecessary luxury, as both lower efficiency.

SUBSISTENCE.

Rations.—Economy in the purchase of supplies is expected, but the supply should be ample and of good quality. The subjoined ration list is recommended as a general guide. Experience has shown it to be ample in amount as regards all essential articles.

Ration list for topographic field parties.[1]

	100 rations.
Fresh meat, including fish and poultry	100 pounds.
Cured meat, canned meat, or cheese	50 pounds.
Lard	15 pounds.
Flour, bread, or crackers	80 pounds.
Cornmeal, cereals, macaroni, sago, or cornstarch	15 pounds.

[1] The following substitutions may be made: 8 eggs for 1 pound of meat; 5 pounds of fresh meat for 2 pounds of cured meat; 5 quarts of fresh for 1 can of condensed milk; 5 pounds of fresh fruit for 1 pound of dried fruit; 3 pounds of fresh vegetables for 1 pound of dried vegetables.

	100 rations.
Baking powder or yeast cakes	5 pounds.
Sugar	40 pounds.
Molasses	1 gallon.
Coffee	12 pounds.
Tea, chocolate, or cocoa	2 pounds.
Milk, condensed	10 cans.
Butter	10 pounds.
Dried fruit	20 pounds.
Rice or beans	20 pounds.
Potatoes or other fresh vegetables	100 pounds.
Canned vegetables or fruit	30 cans.
Spices	4 ounces.
Flavoring extracts	4 ounces.
Pepper or mustard	8 ounces.
Pickles	3 quarts.
Vinegar	1 quart.
Salt	4 pounds.

Rations for stock.—For stock the following ration may be used as a basis for estimate:

Daily ration, in pounds, for stock.

	Oats.[a]	Corn.[a]	Hay.
Heavy horses	12	15	24
Mules	10	12	20

[a] The rations of oats and corn are substitutes for each other.

CAMP ADMINISTRATION.

Discipline.—In camp the chief should insist on punctuality, order, and neatness. Proper discipline is absolutely essential to efficiency. It should be remembered that the Survey is judged generally throughout the country by its field representatives, and they should do it credit in personal appearance as well as in other ways.

A United States flag and a Survey pennant must be displayed over each camp.

Camp sites should be carefully selected and the tents arranged in definite order and not at random. Wagons and other vehicles should be parked on one side. Harness, saddles, etc., should be kept off the ground and either hung on racks or placed in the wagons. Animals should be corralled at sufficient distance from the tents to prevent them from interfering with comfort and sanitation. The camp should be kept neat at all times; no loose articles, papers, or refuse should be allowed to litter the grounds.

Topographers are by nature of their work called upon to sojourn in many different regions and to adapt themselves to changes of climate and environment. Their work frequently takes them to remote localities where medical aid is not readily obtainable, and it is therefore especially important that they should be personally familiar with and should habitually conform to the laws of hygiene and diet. It is especially important that all chiefs of party should be conversant with such matters, as it is a necessary part of their professional equipment. Promiscuous drinking from streams, failure to use boiled drinking water, carelessness in selecting camp sites, inadequate provision for the disposal of refuse, failure to observe sanitation in the arrangement of toilet facilities, insufficient screening from flies, and failure to use mosquito netting in malarial districts are responsible for most of the sickness in camp. All chiefs of party should formulate sanitary regulations for camp administration adapted to the locality and should see that they are rigidly enforced.

Typhoid-fever prevention.—Field men are more liable to contract typhoid fever than any other disease. It is therefore urged that everyone who has not already had that disease protect himself against it by inoculation with antityphoid serum or "vaccine" as prepared and administered by the United States Army surgeons.

The experience of the United States and foreign armies proves conclusively that the vaccine is an almost infallible preventive of the fever and that its effects last for several years.

Sufficient of the prophylactic for the complete treatment and a copy of instructions for its use may be obtained by any member of the field or office force of the United States Geological Survey on official request addressed to the Director, or it will be administered without charge by designated officers of the Public Health Service in each State upon presentation of a proper certificate of employment. (See Treasury Department Circular No. 43, Public Health Service, Feb. 12, 1915.)

Farmers' Bulletin 478 gives valuable data on the prevention of typhoid fever and the use of the prophylactic for its prevention.

Entertaining persons in camp.—Chiefs of party and all other employees of the Survey are cautioned, when on field duty, against entertaining in camp any persons, whether acquaintances, friends, or relatives, in a manner to interfere with public business. Instruments, outfits, and supplies are provided at Survey expense for official purposes only and should be used solely to advance official work. Members of the Survey are required to give their time and labor strictly to official business.

Personal baggage.—The bulk and weight of camping outfits should be kept as low as is compatible with comfort. To this end, personal baggage should consist of essentials only. It should be carried in canvas bags chiefly, and in pack outfits is limited to one bag for each man. Trunks should not be taken to camp, except where they may be readily transported by rail.

CAMP EQUIPAGE.

To facilitate field work in regions where camping is necessary or desirable, parties will be furnished with complete camp equipage, including tents, stoves, camp furniture, mess and cooking outfits, as well as means of transportation, such as wagons and other vehicles, harness, riding saddles, packsaddles, and necessary accessories.

Camp beds.—A camp bed, consisting of one folding cot, two lamb's-wool comforts, one woolen double blanket, one pillow, and one canvas bedcover, will be supplied to each field man holding a non-probational secretary's appointment, on properly approved requisition through the Washington office.

Care of public property.—Chiefs of parties will be held strictly responsible for the public property intrusted to their care and are expected to see that it receives no rougher usage than conditions necessitate. They should instill into their men a feeling of responsibility for the property and induce them to take pride in keeping it in good, serviceable condition. As wear results mostly from carelessness in packing, loading, and transporting when camp is moved, party chiefs should endeavor to instruct their assistants as to proper methods. Tents should receive particular care in transportation, for the best of them may be worn through or rendered leaky by a few hours' chafing against boxes or wagon bed. They should, therefore, be loaded with care, and should never be transported without being wrapped in some protective covering; the heavy tarpaulins used for tent floors are convenient for this purpose. In transporting tents by pack train special pains must be taken to keep them from contact with the animal's body, as they will be permanently ruined if permeated by its sweat.

Wagons and harness should be kept in repair. Wagons should be kept painted, as without such protective covering their woodwork, more especially that of the running gear, will not last. Harness should be oiled and blacked as frequently as is necessary to keep it in good condition. The teamster should be required to give proper attention to these details.

Purchase of property in field.—Every article of property which appears on a voucher as having been purchased and which is not expendable must be accounted for on the returns of the custodian. In cooperative States vouchers for such articles must be submitted for payment on a separate Federal voucher. Those in direct charge of property should be prepared at all times to make a statement to the custodian as to its condition and the amount on hand.

Tents, wagons, and other property of considerable value must not be purchased without special authority from the division geographer.

Lost or stolen property.—When public property has been lost or stolen, without negligence on the part of its user, reasonable charges for recovering it are allowable.

When field property is condemned or has been lost, a certificate to that effect, approved by the Director, must be furnished and filed with the custodian.

STORAGE.

Storerooms.—In arranging for the care of field property at the close of a season, efforts should be made to store it near a main-line of railway, if possible in a brick building or other substantial structure.

Storing and pasturing.—Storing is something more than mere stowing away in haphazard fashion; it should be done with order and system. The materials should be placed in boxes, the boxes numbered, and lists made of the articles in each box. The boxes should be securely packed and nailed, so that, if necessary, they may be in condition to be shipped by rail. In the case of wagon outfits the boxes may be left on the wagons ready to haul away. Precautions must be taken to protect the property against dampness and rodents. Tents, harness, blankets, etc., must be thoroughly dried before packing, otherwise they will be ruined by mildew. Axles of vehicles must be cleaned with coal oil and well covered with axle grease. Cooking utensils and tableware must be thoroughly cleaned and dried and must never be packed unwashed.

No food should be stored.

Chiefs of parties must exercise great care in selecting proper localities and responsible caretakers for public animals to be placed in pasturage. Shelter, water, and character of forage, as well as the reliability of the caretaker, are the factors which should govern selection. All shoes should be removed and an inventory and a complete description of all animals should be made before they are delivered to the caretaker.

Signed agreements must be executed in triplicate with all persons taking charge of Government property. Two copies must be sent to the chief geographer and one retained by the caretaker. Similar agreements should be signed when animals are placed in pasturage. These agreements are effective for a single fiscal year only and must be renewed on July 1 if any property is left with the caretaker.

Employees will be held personally responsible for neglect to comply with these instructions.

Inventories.—When nonexpendable property is stored a detailed inventory, stating the condition of each article, must be made and forwarded to the chief geographer. Similarly, on withdrawing property for field use, each party must take an inventory of the same and promptly forward it to the chief geographer, with the date of withdrawal indicated. The last party to draw upon a storeroom should send to the chief geographer an inventory of the material left.

An inventory or invoice of each shipment of property should be made in duplicate. One copy should be sent to the consignee and another to the chief geographer. These should be mailed promptly, so that one may be used to check the shipment as goods are unpacked.

FIELD NOTEBOOKS AND RECORDS.

Party chiefs will be held strictly responsible for all field notebooks, plane-table sheets, traverse sheets, and other valuable manuscript data until they are delivered to the agent of an express company or the registry clerk of a post office and a receipt is obtained. Notebooks should usually be forwarded to the Washington office by registered mail addressed to the chief geographer. If notebooks contain duplicate data they should be separated and forwarded on different days, so that if either set is lost the other may be used. This rule applies especially to levelman's field books and bench-mark description books, transit books, chainman's books, triangulation notes, and field computations or abstracts of angles. Every effort should be made to prevent the possibility of entire loss of results. Under no circumstances should valuable records be forwarded by ordinary mail.

REPORTS OF FIELD PARTIES.

A monthly report is required from each chief of party on the topographic, primary-control, or level work done under his direction; also, from each levelman in charge of an independent level party. Reports should be made out in duplicate and one copy sent to the chief geographer, the other to the division geographer; and it is absolutely essential that they be complete in every detail. They should be mailed not later than the 3d day of each month, and should in no case reach the Washington office later than the 9th.

The regular monthly form is to be used for topographic, triangulation, and level work. A single blank may include the report for several quadrangles, provided the data for each are given separately. Thus, where a party has worked on three quadrangles in one month, the chief of party should apportion the amount of work and the cost among the three as nearly as practicable, for he can do this better than the division geographer. The total for the three should be accurate, though the details of each may necessarily be approximate.

When a party is engaged in several classes of work, a separate diagram should be used for each. Thus one diagram should show the area controlled by plane-table or traverse (distinguishing between kinds of traverse); another, the area leveled; and a third, the area mapped. The work of the current month should be given most prominence on the diagram; preferably, it should be indicated in ink, different colors being used where necessary. Previous work should be indicated in pencil.

A weekly report must be transmitted by each levelman to his immediate party chief, using the report blanks in card form that are provided for this class of work. As the data from these weekly reports are incorporated by the party chief into his monthly report, levelmen should so time the sending of their last weekly report for each month as to avoid delaying the party chief's monthly report.

An employment report stating the names of the field assistants of grades 1 and 2 employed and the length of their service is required from all party chiefs. This report is to be made out once during the field season, that is, on October 31 for the months of May, June, July, August, September, and October. During the remainder of the year it is to be made out monthly. One copy only, to be transmitted promptly at the close of the month to the chief geographer, is required.

IMPORTANT RULES OFTEN FORGOTTEN.

All official mail or telegrams, except bills of lading, sent to the Washington office must be addressed to the chief geographer or to a division chief. Bills of lading for shipments to Washington must be addressed to the Director with the words "Shipping clerk" written in the lower left-hand corner of the envelope. The original bill of lading must be mailed the same day shipment is made, the weight of each separate package being marked on it.

Monthly reports from all field parties are required, even though no work is done. They must be mailed not later than the third day of the month following, and a duplicate of each report must be sent direct to the chief geographer. (See p. 19.) A report on a separate sheet must be made for each quadrangle.

Reports of employees for the Civil Service Commission are due from each field party at the end of each month, November to April, inclusive, and October 31 for the remainder of the year. (See above.)

The flyleaf of each notebook and the appropriate blank on all control or sketch and traverse sheets should be filled in the first day that the book or sheet is used. (See pp. 52, 90, 106, etc.)

On every page of azimuth-observation records give latitude and longitude of station and statement as to time standard used.

Level bench marks should wherever possible be used as turning points on the main line. (See p. 101.)

Books of field notes should be sent to the Washington office by registered mail. Duplicate notes should be separated, and mailed on different days.

Complete inventories of property in use in the field must be submitted at the beginning and close of each field season and on January 1. (See p. 18.)

The compass needle must always be lifted off the point of the center pin before it is moved.

All contracts for storage or pasturage must be renewed on July 1.

INSTRUMENTS.

DELIVERY AND RETURN.

REQUISITIONS.

Threefold forms are provided for requisitions for instruments; these, when properly filled in and signed by the division geographer, are to be transmitted to the chief geographer. When the instruments called for are shipped, one of the three sheets is retained as the office record; the other two are sent to the consignee, who, upon receipt of the shipment, will sign and return the second sheet to the chief geographer, retaining the third for his own use.

RESPONSIBILITY.

All persons to whom Survey instruments are issued will be held personally responsible for them and will be required to replace or repair loss or injuries resulting from carelessness. In case of loss, a certificate on the proper form must be furnished to the chief geographer.

TRANSFER.

When instruments are transferred from one employee to another, a threefold transfer card must be made out: one card must be sent to the chief geographer, another card mailed to the consignee, and the third card retained as a memorandum by the party transferring. It does not suffice merely to state the number and kind of instruments transferred. *The list number stamped on each piece must also be given.*

RETURN OF INSTRUMENTS.

When instruments are shipped to the office, a letter or card of notification should be mailed to the chief geographer, stating the number of bundles shipped and giving an invoice of the contents of each. *Such invoice is not complete without the number stamped on the instruments.* A tag should be attached to each instrument returned listing defects and repairs needed. Special tags are provided for this purpose.

TYPES OF INSTRUMENTS.

LIST.

The following instruments are kept in stock and will be supplied on requisition.

Alidades, Bulgine, 12-inch ruler.
Alidades, open sight, brass; length, 6 and 10 inches.
Alidades, open sight, Burkland type; on boxwood scales graduated to all field scales.
Alidades, telescopic; length of ruler, 18 inches and 25 inches.
Alidades, telescopic, with Beaman attachment.
Alidades, telescopic, with micrometer eyepiece.
Aneroids, graduated to altitudes of 3,000, 5,000, 10,000, 15,000, and 16,000 feet.
Baldwin solar charts.
Compasses, box.
Compasses, pocket.
Compasses, prismatic.
Counters, hand.
Dies, letters, and figures, standard size for bench-mark tablets.
Glasses, field, for triangulation or level parties.
Levels, circular.
Levels, hand.
Levels, plumbing, for New York rods.
Levels, plumbing, for stadia rods.
Levels, prism.
Levels, Y, 20-inch.
Levels, Y, 15-inch.
Odometers.
Pins, marking, sets of 11, plain or loaded.
Pins, turning point, for precise levels.
Pins, turning point, for primary levels, 6-inch and 10-inch.
Plane-table boards, 24 by 31 inches (full size), with wooden or canvas cases.
Plane-table boards, 18 by 24 inches (half size), with wooden or canvas cases.
Plane-table boards, 15 by 15 inches (traverse size), with oilcloth cases.
Plane-table boards, 9 by 9 inches (for foot traverse).

Rods, precise and primary, marked in yards.
Rods, New York.
Rods, Philadelphia.
Rods, paper stadia.
Scales, boxwood, graduated to 1/50, 1/80, and 1/100 inch; also 1:10,000, 1:20,000, 1:21,120, 1:24,000, 1:31,680, 1:48,000, 1:96,000, 1:125,000, and 1:240,000, in decimals of miles on one edge, in feet on the other; also 1:48,000, in decimals of miles on one edge, chains on the other; 1:20,000 metric scales.
Scales, boxwood, for plotting geographic coordinates (latitude and longitude).
Scribes, timber.
Tapes, invar, 300 feet.
Tapes, metallic, 50 and 25 feet.
Tapes, steel, 300 feet.
Tapes, steel, 100, 50, and 25 feet.
Tapes, steel, 25 feet, meters on back.
Tapes, steel, 6 feet, 2 meters on back, pocket size.
Theodolites, 8-inch micrometer.
Thermometers.
Transits.
Tripods, traverse, Bumstead type.
Tripods, Johnson.
Tripods, for levels, theodolites, transits, etc.

CARE IN SPECIFICATION.

General rule.—Pains should be taken to make requisitions distinct and specific, so there may be no doubt on the part of the custodian as to the class or type of instrument desired. When several types of instruments are available, the particular type desired should be clearly specified, and, if necessary, the use for which it is intended should be stated.

Thus, in ordering open-sight alidades, specify whether the brass or the Burkland type is desired; if the former, state length of ruler; if the latter, state the scale. The vanes of the Burkland alidade are light and are readily fitted to any flat boxwood scale.

Prismatic eyepieces.—Prismatic eyepieces can be supplied for any telescopic alidade if requested before the instrument is shipped from the office.

Aneroids.—In ordering aneroids it should be remembered that they are easily strained and rendered unreliable if carried to altitudes much exceeding the limit for which they are graduated. It is wise to allow a liberal margin.

Plane-table boards.—Plane-table boards 24 by 31 and 18 by 24 inches will be provided with plates to fit the Johnson tripods.

Traverse boards.—Traverse boards 9 by 9 and 15 by 15 inches may be had either with or without box compass attached; also with plates for either Johnson or Bumstead tripods.

Exchangeable parts.—Extra parts for standard telescopic alidades are kept in stock and may be obtained on requisition. To insure proper fit the size of part and the number of instrument should be carefully stated.

Extra bubbles.—Each telescopic alidade, when issued, will be provided with an extra bubble for the striding level. Whenever this extra bubble is put into service on the instrument, requisition should be immediately made for a new one. Before inserting the extra bubble measure its over-all length and diameter, for these two dimensions must be specified in ordering the new one.

Stadia rods.—A few stadia rods with standard saw-tooth graduations are kept in stock at the Washington office for use by near-by parties not in camp. Photographs with specifications of the approved style of rods will be supplied on request. The specifications are as follows:

Rods are to be of clear, straight-grained, well-seasoned white or sugar pine, 4 inches wide, $\frac{7}{8}$ inch thick, and 13.2 feet long, hinged at the 6.6-foot mark with two 4-inch strap hinges bolted or riveted in place. An extra handhold strip $\frac{5}{8}$ by 3 by 27 inches is to be bolted to upper end so as to project 15 inches beyond rod when closed; the ends are to be protected with $\frac{1}{8}$ by $\frac{7}{8}$ inch strap iron screwed on. The entire rod is to be painted with two coats of flat white paint and to be subdivided by saw-tooth marks into tenths; the $\frac{1}{2}$-foot marks being made $\frac{3}{10}$ foot and the tenth marks $\frac{1}{10}$ foot in height. The even foot marks and figures are to be painted with flat scarlet vermilion paint; the other marks with flat black paint. Figures are to be $2\frac{1}{4}$-tenths in height; V is to be used for 5 and X for 10; 6 is to be made with straight upper stem; 9 with curved stem. About $\frac{5}{10}$ foot from the top a piece of thick leather about $\frac{1}{2}$ inch by 2 inches must be attached to keep painted faces from rubbing together when rod is closed. A 14 by $\frac{1}{2}$ inch leather strap with buckle may be attached to back near bottom to hold the parts of rod in place when folded. If desired to fasten rod open, a plate staple may be bolted on the inside of the hand strip near its lower end so as to project through a slot in rod; a wooden pin through this will hold rod open.

For some classes of work rods without hinges are to be preferred.

Full-size paper prints of the stadia-rod face will be furnished on request; these when attached to a piece of board by means of varnish make very serviceable rods.

Plumbing levels should be used when necessary.

ACCESSORY ARTICLES.

LIST.

In addition to the instruments listed on pages 22–23, the following accessory articles may be obtained from the custodian. Requisitions for them must be kept separate from stationery requisitions, as the latter go to another division. (See also pp. 206–217.)

American ephemeris and nautical almanac.
Bags, notebook.
Bench-mark posts.
Bench-mark tablets.
Bench marks, temporary, copper nail and washer.
Branding irons.
Bubbles, level, extra.
Cans, paint, with brush inserted.
Canteens.
Celluloid, white sheets, 15 by 15 inches, or 18 by 24 inches.
Celluloid, frosted or clear, sheets, 18 by 24 inches.
Cement, in half-pint cans.
Circular letters, regulations, and instructions.
Cloth, tracing.
Computation tables, Crelle.
Computation tables, geographic.
Computation tables, Gurden traverse.
Computation tables, logarithmic, 5 place and 7 place.
Computation tables, M and P factors.
Computation tables, natural sines and cosines.
Computation tables, stadia, Anderson or Johnson.
Computation tables, vertical angle elevations.
Crayons (keel), red or blue.
Drafting instruments, triangles, straight edges, ruling pens, plain dividers, spacing dividers, scales.
Flags, United States, Survey ensign.

Paper, manila, cut to plane-table sizes.
Paper, plane-table, double-mounted (24 by 31 inches, 24 by 36 inches, and 18 by 24 inches).
Paper, plane-table, single-mounted, in rolls of 10 yards, widths 58 inches and 72 inches, cut to plane-table sizes.
Paper, tracing (vellum), in 20-yard rolls, *cut as wanted.*
Paper, tracing, in sheets, size 22 by 28 inches.
Paraffin, 1-pound cakes.
Plaster of Paris.
Rope, ⅛-inch, 330 or 528 feet length, paraffined.
Rubber stamps.
Shellac, liquid.
Tables, positions of Polaris.
Tapes, cloth, in 400-yard spools.

BENCH-MARK POSTS OR TABLETS.

When ordering bench-mark posts or tablets to be used in cooperative work, the name of the cooperating State and quadrangle should be given. The same style of tablet or post serves for triangulation stations, primary-traverse stations, and bench marks.

CARE OF INSTRUMENTS.

Too much emphasis can not be laid upon the importance of care in the handling and transportation of instruments. Every employee intrusted with instruments in the field will be expected to keep them clean and in adjustment, to protect them from undue wear, and to return them to the custodian in fit order for use.

Minor repairs.—Each topographer should provide himself with a few simple tools and supplies, such as a small pair of pliers with side wire cutter, screw drivers of two sizes, small flat and round files, a spool of soft copper or brass wire, a few assorted brass nails and screws, a bottle of oil, a bottle of liquid shellac, spider web, and plaster of Paris, all of which may be used for minor repairs to instruments.

Field work should never be delayed by sending an instrument away for repair if the topographer can possibly repair it himself. Even crude repairs may often be made to serve until a new instrument can be procured.

Compasses.—Compasses will usually be out of balance when received from Washington. The slider must be moved when it is so much out of balance that one end of the needle is near the glass cover when the box is leveled. Many complaints have been made that compasses were worthless, when the only trouble was that the needles were so badly out of balance that they rubbed against the glass covers. It should be a strict rule with everyone using a compass to lift the needle from the center pin *immediately after use.* Under no circumstances should a compass ever be carried from one station to another with the needle resting on the center pin. Party chiefs should lay special emphasis on this when instructing new field assistants.

CLEANING.

General rule.—Instruments having working parts exposed to air and dust require cleaning from time to time. Such exposed parts as the threads of tangent screws and the cups of Johnson tripod heads are particularly liable to collect dust and grit and should be wiped frequently with an oily rag, then rubbed dry.

Tapes.—Steel tapes should be cleaned and oiled after use. All moisture or grit must be wiped from them each time they are reeled or they will deteriorate rapidly. Special precautions must be taken in this regard in work on the seacoast or in semitropical regions of high humidity.

Arcs and verniers.—Most graduated arcs and verniers are made of silver and are therefore readily scratched and defaced. They should be cleaned by wiping lightly with chamois skin dipped in weak ammonia. A high polish on either an arc or a vernier is a disadvantage rather than an advantage in reading.

Telescope lenses.—The object glass and eyepiece of every telescope should be periodically dusted with a camel's hair brush or wiped with a piece of silk or soft tissue paper. They should never be rubbed with rough cloth or with the fingers, as the glass may thus be permanently scratched. The lenses should never be removed from the cell that holds them nor separated from one another.

PROTECTION.

When in camp instruments, plane-table boards, tripods, and rods should never be allowed to remain outside overnight, exposed to dew or rain. It should be the regular practice in every field party to place all instruments under shelter as soon as they are brought in at the end of the day.

Pains should be taken to protect instruments from dampness or rain when in use. Cross wires in telescopes may sag when damp, and in that condition may introduce serious errors. Tripods and rods warp or twist and may acquire a permanent set. Though such wooden articles are usually well varnished or painted, some moisture will penetrate these coatings, and too much dependence should not be placed on their protective efficiency.

TRANSPORTATION OF PROPERTY.

Pack trains.—In mountains where pack trains are the sole means of conveyance the triangulator's outfit is most conveniently carried in a pair of canvas pack bags (alforjas), which must be properly balanced. The tripod, umbrella, and wind screens should be placed lengthwise on top, lashed to the saddle, and further balanced by properly disposing them on either side of the center. A canvas pack cover should be thrown over the whole and tucked in on all sides.

A plane-table outfit is best packed by hanging the plane table in its wooden case on one side, flat against the animal, and balancing it with the alidade and smaller articles in a pack bag on the other; the tripod goes on top, lashed to the saddle, head forward. A leather or rope harness, with loops for hanging on the packsaddle, should be provided for the plane-table case. As with the triangulator's pack, a pack cover is a valuable protection.

Judgment should be used in selecting the animal for the instrument pack. It need not be stout (for the pack is seldom heavy) but must be well broken, intelligent, and sure-footed. It is to be kept in mind that the instrument pack is the most important and valuable in the entire pack train; it should be constantly under the eye of a competent packer, and the animal bearing it should be led if necessary.

Freight or express.—In shipping instruments by freight or express, the following rules must be strictly obeyed:

Valuations for express shipments exceeding $50 for any shipment of 100 pounds or less and 50 cents a pound for any shipment in excess of 100 pounds must not be made.

Telescopic alidade, spirit level, transit, and theodolite boxes must be filled in with paper or cloth, so that if any part of the instrument should jar loose during the journey it may not roll around in the box and damage other parts. Heavy articles, such as box compasses, aneroids, or other small instruments should never be inclosed. The micrometers of theodolites should be wrapped tightly with cloth, as they are easily jarred loose. The same precaution should be taken when these instruments are to be transported by pack train.

On no account should any of the above-mentioned instruments ever be shipped by express or freight in its own case only. A wooden box, large enough to permit a generous amount of excelsior, hay, or other padding should always be provided.

Level rods, besides being protected by their canvas covering, should have their targets and clamp screws protected with excelsior or other packing. Strapping them to a board helps materially to prevent them for being strained or bent in transport. Precise-level rods should not be shipped except in the box provided for them.

Tripods should have their heads protected by sacking and by excelsior or hay packing.

All instruments of large size or those which exceed in weight the limits set by parcel-post regulations should be shipped by express or by freight when returning them to the office from distant points in large quantities at the end of the field season. From points near Washington express rates are about as cheap as freight.

Government bills of lading should be used for all shipments by freight or express. The original bill must be mailed to the consignee the same day shipment is made. The weight of each separate package or box must be given and the consignee notified of the contents of each, so that in case of loss proper claim may be made. Any shortage or damage must be noted on the original bill of lading before it is delivered to the carrier.

Instructions as to procedure when an original bill of lading is lost are given on the back of the printed forms. It is required that the consignor certify to the loss on form 9-063, which thereafter takes the place of the regular bill.

In case of loss or delay in receipt of the bill of lading the consignee obtains delivery of the goods on a "temporary receipt—freight and express," which states that the shipment is covered by a Government bill of lading and that charges are guaranteed by the Geological Survey.

A blank form is provided for obtaining delivery to some other person than the one addressed.

Mail.—The penalty label, whether on an envelope or a card, must not be used to avoid payment of postage on private property of any kind, unless it is devoted exclusively to the business of the United States. It must not be used by a cooperating State official or by any person not an officer of the Government for any purpose except the return of data requested for official use; and it must not be used by a dealer in forwarding articles purchased of him for the use of the United States nor for the return of signed vouchers.

Packages of Survey property exceeding 4 pounds in weight may be sent by parcel post, but payment of the postal fees at the usual rate is required. Reimbursement for stamps bought for official use may be obtained by including the charge in the miscellaneous account for the month.

ADJUSTMENT OF INSTRUMENTS.

PRECAUTIONS.

The object glasses and eyepieces of all instruments must be properly focused. The cross wires projected against a distant object should appear immovable when the eye only is moved. Before the adjustments are commenced the instruments must be firmly set up and leveled. An instrument may at times appear to be out of adjustment because some part is loose. The object glass may be partly unscrewed or an adjusting screw may be only partly tightened. Level bubbles or cross wires occasionally become loosened; therefore, before commencing the adjustment of an instrument look out for such defects. When it is thought that an adjustment has been completed, always test it before using the instrument. All adjusting screws should be screwed tight enough to hold, yet not so tight as to injure the threads or put a severe strain on any other part. Especial care should be taken not to strain the cross-wire screws. Adjustments should be made in the order given, for some adjustments depend on the accuracy of others previously made, and a change in any one may affect the others.

GENERAL ADJUSTMENTS.

Setting of bubbles.—For setting level bubbles a small supply of plaster of Paris should be kept on hand. For use the plaster should be mixed with water to the consistency of a thick paste. If plaster is lacking, strips of paper may be used, but these should never be jammed in very tight, as the pressure may distort the glass and thus vitiate the bubble reading by an appreciable amount. A reflecting surface of colored paper should be placed under the bubble in order to make the graduations more readable; a subdued green or blue tint is recommended.

Mounting of cross wires.—For mounting cross wires a small bottle containing shellac dissolved in alcohol, a pinch of beeswax, and a pair of dividers or a forked stick are needed. The best spider web is, of course, a freshly spun one from a small spider, for this will be both clean and elastic; but as spiders are not always available, it is well to keep on hand a spider cocoon. Such a cocoon will furnish webs enough to last for years, although with age the threads become stiff and brittle and therefore more liable to break from a jar to the instrument. Most webs taken from grass or bushes are rough, coarse, and dirty.

To draw the reticule from the instrument, unscrew and remove the eyepiece slide; then take out two opposite capstan-headed screws and loosen the other two. Using the latter two as handles, revolve the cross-wire ring 90°, insert a pointed stick through the end of the telescope tube into a screw hole in the ring, and, using it as a handle, remove the other capstan screws and draw out the ring. To replace it in the telescope, reverse this procedure. When in place the cross wires should be on the side of the ring toward the eyepiece.

Having pressed a bit of beeswax to each prong of the dividers or forked stick, let a small web fall from the end of one of the prongs, or pick with it from a cocoon a single thread, pressing the thread into the beeswax, stretch the thread moderately, and attach to the wax on the other prong. If an old web is used, it should first be dampened by dipping in water for a few seconds. In place of the dividers or forked stick, small sticks or lumps of wax may be attached to the web about 2 inches apart. Place the web across the reticule, using a magnifier to insure its coinciding exactly with the marked lines. Put a small drop of shellac on each end and leave until dry.

Instruments such as the prism level, dumpy level, and transit, which are not provided with Ys, or similar devices for adjusting the cross wires, may be put in close adjustment by means of improvised wooden or metal Ys.

For the prism level, the body of which has a cloth finish, remove the object-glass cap and run the eyepiece slide part way out as though focusing for a near-by object. Provide a Y of wood or metal large enough to go over the object-glass end of the telescope where the cap usually fits. Take a second Y of a size suitable to inclose the eyepiece slide near the main telescope tube. Fasten these Ys securely to a box or some other object, rest the telescope in them, and sight a distant point cut by the cross wires; revolve the telescope and adjust the cross wires in the usual way. A final adjustment *must* be made for such instruments as this by the regular methods. (See pp. 34, 37, and 108.)

Some instruments, such as Y levels, have eyepiece slides separate from the telescope tube, which must be adjusted independently of each other. After the cross wires are adjusted, center the eyepiece on them by turning the four screws under the cover, adjusting by estimation only, an exact centering not being necessary.

TELESCOPIC ALIDADE.

But two adjustments are ordinarily required for the telescopic alidade—for level and for collimation. These should be tested daily.

Level.—Clamp the telescope, bring the bubble to the center of the tube with the tangent screw, lift up the level carefully, reverse, and replace it on the telescope. If the bubble runs away from the center, bring it halfway back by means of the tangent screw and the other half by the adjusting screw under the head of the level tube. Repeat this operation till the bubble stays in the center after reversal.

Collimation.—Test the verticality of the vertical wire by raising and lowering one end of the telescope, the cross wires having been set on a near-by point; loosen the screws and twist the cross-wire ring if necessary, or by a slight shift in the position of the cross-wire ring make the vertical wire parallel to the vertical corner of a building or a plumb line. Point the telescope on a small but well-defined object about half a mile distant, and while watching this through the telescope revolve the telescope 180° in its supporting sleeve. If the intersection of the cross wires remains centered on the object, the adjustment is perfect; if not, change the cross wires for half the error and repeat the operation until they stay on the point selected.

Ruler.—So long as but a single alidade and but one edge of the ruler are used, it makes no difference in the results whether the edge of the ruler is parallel to the line of sight or not, except for use with the Baldwin solar chart, when a correction must be applied if appreciable. (See p. 140.)

Beaman alidade.—The accuracy of the graduations of the Beaman arc can be tested by comparison with the regular arc in the following manner. The angular value of the Beaman divisions is as follows:

Divisions.	Angular value.
1	0° 34′.4
2	1° 8′.8
5	2° 52′.2
10	5° 46′.1
15	8° 43′.7
20	11° 47′.3
25	15° 00′.0
30	18° 26′.1

Set the main arc at 30° with the main clamp and tangent screw. Set the Beaman arc at 50° by means of the attached tangent screw.

The two reference marks are now set in definite relative positions. Without touching the Beaman tangent screw set the Beaman arc on any graduation it is desired to test, using the main clamp and tangent screws only; read the degrees and minutes on the main arc, taking 30° as the reference point. The angle, if for an even five divisions, should correspond with one of those above, which are derived from the stadia formula, H=D (+ constant)× $\frac{1}{2}$ sin $2v$, H being the difference in height, D the observed distance, and v the vertical angle.

Y LEVEL.

All instrumental errors of the Y level can be eliminated by exactly equalizing fore and back sights, but as this is seldom possible the line of collimation and the level should be kept as nearly in adjustment as practicable.

Collimation.—Having the instrument carefully leveled, note a small object about 300 feet distant that one end of a horizontal cross wire touches, turn the instrument on its vertical axis a few degrees, and note whether the other end of the cross wire cuts the point; if it does, and the Ys are not badly out of adjustment, the wire is horizontal. With the clips up, focus on a small object 300 or 400 feet distant; watch this through the telescope while revolving it 180° in the Ys; if the intersection of the cross wires moves away from the point, bring it halfway back by means of the cross-wire adjusting screws; repeat the test and adjustment until there is no movement of the cross wires away from the point.

Level.—Having the instrument carefully leveled, loosen the clips, lift the telescope out of the Ys, reverse it end for end, and replace it in the Ys; if the level bubble has moved away from the center, bring it halfway back by means of the adjusting screws at one end of the level tube and the other half by the lower leveling screws. Repeat this operation until the adjustment is perfect. With the bubble in the center, rock the telescope back and forth in the Ys about 25° around its axis; if the bubble moves away from the center, bring it back with the side adjusting screws.

Object-glass slide.—It is seldom necessary to adjust the object-glass slide, as it is usually fixed by the maker, but when required make the collimation adjustment as above described; then an error in the adjustment of the slide will appear as an error of collimation when tested on a near-by point, say 50 feet distant. To correct the error remove the ring near the middle of the telescope and with a screw driver turn the screws found underneath so as to bring the cross-wire intersection halfway back to the near-by point selected.

Eyepiece slide.—The adjustment of the eyepiece tube so that the cross wires will appear in the center of the field, though not essential to the accuracy of the work, may be effected by means of the screws underneath the ring just back of the cross-wire screws. Loosen one and tighten the opposite one of these screws with a screw driver until the wires appear centered.

Ys.—After each of the foregoing adjustments has been made, the adjustment of the Ys is made by turning the telescope and level 180° on its vertical axis; if the level bubble, which was at first in the center, moves away from it, bring it halfway back by changing the large nuts under one Y.

"*Peg method.*"—In the ordinary Y-level adjustment it is assumed that the two rings on the telescope tube which rest in the Ys are circular and exactly equal by construction.

The level and line of collimation can be made parallel independently of the rings and Ys by the "peg method" described on page 108.

LOCKE LEVEL.

The adjustment of the hand level, or Locke level, is most easily tested by sighting along a horizontal line determined by a Y level or alidade, but when no such line is available a modified form of the "peg method" must be used. Hold the level on a fixed point and sight a second point 300 or 400 feet distant which appears by the level being tested to have the same elevation as this point. Take the level to the second point and with the bubble centered over the cross wire sight the first point; if it appears to be on the horizontal line, the level is in adjustment; if not, correct for one-half the difference by turning the small screw at one end of the level box.

ROD LEVEL.

The leveling or stadia rod to which levels are attached should be carefully plumbed with string and plumb bob. The level bubbles should then be brought to the center by means of the proper adjusting screws.

TRANSIT.

Plate levels.—With lower plate clamped and upper plate loose, level carefully; revolve the instrument 180° on its vertical axis and bring each level bubble halfway back to the center of the tube by means of the screw at one end.

Collimation.—Level carefully, sight on a point about 500 feet distant, raise or lower the telescope slightly, and note whether the vertical wire remains on the point; if not, loosen the capstan-headed screw and turn the cross-wire ring till the vertical wire will remain on the point when the telescope is raised or lowered. Clamp the instrument, set the vertical wire so that it cuts the point selected, transit the telescope by revolving it 180° on its horizontal axis, and select a second point 500 feet distant in the opposite direction from the first. Unclamp the upper plate, turn the transit 180° on the vertical axis, set it on the point first selected, and again clamp the plate. Transit the telescope, and if the vertical cross wire exactly bisects the second point its adjustment is perfect; if it does not, bring it one-quarter of the way back to the second point by turning the two capstan-headed screws on the sides of the telescope.

Standards.—Set up the transit near a tall building or other high object; after leveling carefully, point the telescope so that the vertical wire intersects a definite point about 60° above the horizontal, depress the telescope, and select a second point near the ground. Unclamp the upper plate, revolve the telescope and plate 180° on the vertical axis, clamp the plate with the vertical wire again cutting the upper point, and depress the telescope; if the cross wire intersects the lower point, the standards are in adjustment; if it does not, correct for one-half the error by the screw underneath one end of the telescope axis.

Object-glass slide.—If an adjustment for the telescope object-glass slide is possible, it is made as follows. First make the collimation adjustment for a point about 300 feet distant, then focus on a point 1,000 feet or more distant and again on a point only 10 or 15 feet away, transit the telescope, unclamp the plate, turn it 180° on the vertical axis, and reclamp. If the cross wire still cuts the distant and near points, the slide is in perfect adjustment, but if it does not, correct half the error by means of the side screws which hold the slide ring in place. Next repeat the regular collimation adjustment and again test for the slide error; repeat both adjustments until no errors appear.

Eyepiece tube.—The eyepiece may be put into position over the cross wires by turning the screws which hold the eyepiece ring until the cross wires appear in the center of the field; an exact centering is not required.

Telescope level.—If there is a level attached to the telescope, it may be adjusted by the "peg method" after all the other adjustments are made, as follows. Level the transit and bring the bubble to the center of the tube under the telescope. Take a reading on a leveling rod or pole 300 or 400 feet distant, which is held on a stake set firmly in the ground. Revolve the transit 180° on the vertical axis and after again bringing the bubble to the center set a second stake at the same distance as the first and at such an elevation that the rod or pole reading is the same as on the first stake. The tops of the two stakes will then be at the same elevation. Move the transit 25 or 50 feet back of one stake and on a line with the other. Make the telescope as nearly horizontal as possible by means of the attached level, clamp it, and then take a reading on the rod held on the near stake and another reading on the distant stake. If the two readings agree, the telescope is horizontal; if they do not agree, turn the tangent screw so as to bring the cross wire while set on the distant rod nearly to an agreement; repeat the operation until an agreement is reached. The telescope is then level, and the adjusting nuts at the end of the level tube should be turned until the bubble is brought to the center.

Vertical circle or arc.—The screws holding the vernier for the vertical arc should now be loosened and the vernier moved until the reading is 0° while the telescope is still level.

THEODOLITE.

Striding level.—Place the level in the proper position on the telescope axis. Level carefully with the horizontal plates clamped and rock the level slowly back and forth till the foot pieces strike. If the bubble leaves the center, bring it back by means of the side adjusting screws near one end of the tube.

Reverse the level and bring the bubble halfway back to the center by raising or lowering one end of the tube with the screw at that end and the other half with the leveling screws. Repeat these operations till the adjustment is perfect.

Standards.—After the striding level is in adjustment with the lower horizontal circle clamped, level the instrument in two positions at 90° from each other. Turn on the vertical axis 180° from one position; if the bubble runs away from the center, bring it halfway back by loosening one of the large capstan-headed screws underneath the standards and tightening the other. Test the adjustment and repeat it if necessary.

Plate levels.—Level instrument with the striding level only, then bring the bubbles of the plate levels to the center of their tubes by means of the end adjusting screws; or the method described for adjusting the transit plate levels may be used for the theodolite also.

Micrometers.—Each micrometer consists of three concentric tubes; the upper and lower ones slide in the central one. The lower tube, which holds the object lens when in proper position, is clamped to the middle one by means of the capstan-headed screw in the lower part of the]-shaped support. These two tubes may be moved together or the lower one moved alone by loosening the proper screws. The upper tube contains the eyepiece lenses and is held in place by friction only.

Focus the eyepiece on the two parallel movable threads and do not change it afterward. With the eye in position for setting the micrometer, tighten one and loosen the other of the two screws that hold the]-shaped microscope support to the main frame of the theodolite until the figures and graduations on the plate appear to be in the center of the field.

Clamp the plate and by turning the micrometer screw set the two movable threads over a long graduation. Examine carefully to see whether they appear exactly parallel to it. If they are not parallel, loosen the two capstan-headed screws which clamp the micrometer tube and twist the tube until the threads and mark appear parallel. Clamp the side screws lightly.

Set the movable cross wires on a division to the apparent left of the field of view as for a regular angle reading; read the micrometer head and record the reading. Turn the graduated head about five turns, stopping when the threads are set on the next 10′ division to the right; read and record. Repeat this operation several times. If the mean of the left-hand readings is the same as the mean of the right-hand readings, or within one division of it, the adjustment may be accepted as satisfactory. An actual count of full revolutions should be made at least once; otherwise the adjustment might wrongly be thought perfect for 4½ or 5½ revolutions.

When the space covered by the two parallel micrometer threads, moved by exactly five revolutions of the micrometer screw, appears to be longer than one 10′ space on the graduated circle, to bring it into adjustment make the distance between the micrometer box and graduated plate longer by raising the middle part of the tube; but when the space is shorter than a 10′ space make that distance shorter also—that is, consider as connected or dependent the length of the thread space covered by an even five revolutions of the micrometer screw and the distance between the micrometer box and the graduated plate. When the former is longer than it should be, the latter should be made longer, if an adjustment is desired, and vice versa.

To make the adjustment, loosen the small capstan-headed screws which clamp the microscope tube; then, if the thread space is long, twist the middle part of the tube (including the micrometer box) back and forth and at the same time pull it upward, thus lengthening the distance to the graduated plate. When by estimation it has moved far enough, which can be roughly determined by the amount of blurring that results from the lower lens being thrown out of focus, clamp the upper capstan-headed screw. The lower part of the microscope tube holding the objective lens must now be twisted and gently pushed downward till the graduations again appear in focus. If the movable threads and graduations are not then parallel, the upper screw must be again loosened and the tube turned far enough to make them parallel, after which both screws must be tightened. Test the adjustment by again measuring a 10′ space with the micrometer. If it is still out of adjustment, repeat these operations till it is satisfactory. When the adjustment has been completed, a scratch may be made on the tube below each support and used as a guide in future adjustments.

The opposite micrometers may be placed 180° apart by setting one at a reading of 0° 0′ 0″, with the comb scale exactly centered. Then center the comb scale of the other micrometer over the 180° mark by means of the capstan-headed screw at the left-hand end of its box. Bring the micrometer threads over the 180° mark also; then, while holding the screw firmly in place, turn the graduated ring till it reads zero.

When setting the micrometer wires on a graduation, it is very important that they be moving toward the right when the turning of the screw is stopped. Should they be moved the least bit too far to the right, turn back not less than half a revolution of the screw and then bring them forward again. In general, when a setting is made by means of a screw working against a spring, the spring should always be undergoing compression when the motion stops.

Cross wires.—The vertical wire should be truly vertical; otherwise an exact adjustment of the cross wires is not essential.

After the striding level has been adjusted and the horizontal axis of the telescope carefully leveled, sight a distant point, raise and lower the telescope through an angle of 5° or 10°, and note whether the cross wires follow the point. If not, loosen the cross-wire ring and twist slightly; repeat the adjustment if necessary.

Holding the striding level on the telescope parallel to the optical axis and, with the bubble in the center of the tube, set the intersection of the cross wires on a distant point and clamp both plates; lift the telescope out of its supports and turn 180° around its optical axis; set it again on the selected point. If the striding level when placed on top of the telescope is horizontal and the vertical wire still cuts the point, the adjustment is complete. If not, shift the cross wires in either direction by means of the capstan-headed screws for one-half the apparent error. Repeat the test till the error is nearly all eliminated. Finally readjust the vertical wire, if necessary; or both wires may be put in place by means of temporary wooden Y supports, as explained on page 32.

SUGGESTIONS TO COMPUTERS.

Do not crowd your work; paper is cheap.

Do your work in a systematic manner. If it permits tabular arrangement, always use the forms approved by other computers unless you can convince them that yours are better. The Survey has printed forms for many purposes; these should be used whenever possible, for by their use the work is made more mechanical, and the more mechanically the work is done the less chance there is of error.

A computer who is inexperienced or out of practice should check his work in every way possible. He should check logarithms either of numbers or of circular functions by using first a tabular value for a quantity less than the given one and then a greater tabular value, so that the differences in one case may be added and in the other subtracted. This operation may be reversed when the logarithm is given and numbers or angles are required.

Many errors are made by taking out the first three figures of a logarithm from the wrong line where a dash over the fourth figure indicates that the first three should come from a lower line.

As the algebraic signs of cosines and sines are so frequently required, the rules governing them should be firmly fixed in the mind; as an aid to this remember the general rule that distances measured upward or to the right on the conventional plat of the quadrants of the circle are considered positive, others negative. The wrong use of signs is a very common source of error.

Where the function of an angle over 90° is desired, instead of subtracting 90° or 270° from the angle to find the argument, add the figures in the tens and hundreds of degrees places together and prefix the sum to the unit degree figure, dropping the sum if it is 9. Thus 121° gives $1+2=3$, and 31° is the argument; 184° gives $1+8=9$, drop it, leaving 4° for the argument; 290° gives $9+2=11$, drop 9 from the 11 or add the two figures a second time, giving an argument of 20°.

Each step in a long computation, if it is not at once automatically checked, should be checked by repeating the computation.

Check the copying of angles, distances, etc., taken from adjusted results for use in new computations; also check figures carried from page to page.

Gross errors are sometimes made by using the sine when a cosine is required, or by writing a product in the wrong column, as east for west, in primary traverse computations.

Placing the decimal point in the wrong place is a common mistake. This may in many cases be corrected by a mere inspection of the quantity to see whether it appears of proper value.

Good judgment should be exercised in the degree of accuracy sought for a given result. For the preliminary computation of geographic positions, for example, six-place logarithms will probably suffice; these can be taken from a seven-place table with only a rough interpolation. A four-place logarithm can often be used to advantage. The accuracy of the results obtained should equal the requirements; more than this involves a waste of time.

The foot, yard, and mile are the units adopted for all Geological Survey field work, but for geodetic computations meters are used. The best conversion tables for metric and English measures are those published by the Bureau of Standards, edition of 1914. In using these all changes from one system to another should be checked by reversing the operation. The logarithms for the interchange of these measures are given in "Geographic tables and formulas,"[1] page 301.

When computers are duplicating work and a difference is found, each should recompute the result before correcting either, as errors have frequently been made by changing the correct figures.

When two persons are comparing a copy with the original, if the reader occasionally calls out a wrong figure or word intentionally and notes whether the error is caught up, it tends to keep the listener more intent on the work.

PRIMARY CONTROL.

GENERAL CONDITIONS.

The boundary lines of all regular United States Geological Survey maps are parallels of latitude and meridians of longitude. In order that these shall be properly located and that intermediate points shall be placed in correct positions, some system of horizontal control is required. The method to be adopted for linear control should be fixed by the character of the country, the requirement being that all control work shall be so accurate that no errors will be apparent in maps several times as large as those to be published. In mountainous regions or in hilly, partly timbered areas horizontal control is effected by a system of triangulation, the whole area being divided up into triangles whose apexes are represented by stations established on prominent points several miles apart. The angles between each station and all others visible from it are carefully measured with a

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[1] U. S. Geol. Survey Bull. 234, p. 296, 1904; Bull. 650, p. 364, 1916, reprinted 1918.

theodolite graduated to read angles by micrometer to two seconds of arc or by estimation to fifths of a second. One side of one of the triangles, called the base line, must be carefully measured with a steel tape, account being taken of slope of the line, elevation above sea, temperature of the tape, and other essential details, and for at least one station the exact latitude and longitude, and also the azimuth of one of the lines must be determined by astronomic observations or by a connection with stations previously located.

In heavily timbered areas, where it is difficult to see from any point more than a mile or two in any direction, horizontal control is best obtained from distances actually measured on the ground with a 300-foot steel tape, a record being made of angles measured with a transit at each bend in the line. Such control, called primary traverse, must begin and end at points whose positions have been previously determined and must be carried around the edge of each quadrangle and once across its center east and west.

Because of the great expense involved in base-line measurements and the fixing of astronomic positions, it is generally advisable to connect triangulation systems or traverse lines with positions previously determined, even though they may be a long distance away. There are now but few localities in the United States that can not conveniently be connected with known positions and distances, and therefore, before horizontal control work is begun, the records of the Coast and Geodetic Survey, the Lake Survey, the United States Army Engineers, and other Government organizations should be examined in order to ascertain what positions in or near the area to be surveyed have been determined and are available for use in the work on hand.

Whenever possible, geographic locations should be based on the North American datum (formerly known as the United States standard datum), for there is often a considerable difference between the standard and astronomic data.

The results of triangulation or primary traverse by the Geological Survey can always be obtained by anyone having occasion to use them by applying to the Director, United States Geological Survey, Washington, D. C.

PRIMARY TRIANGULATION.

FIELD WORK

PERSONNEL AND OUTFIT OF PARTY.

Each party usually consists of a chief of party, who acts as observer, and a recorder; also a cook and a teamster (or packer) when camping is necessary. Additional men are required for heliotroping, one for each heliotrope station, and local laborers may be employed to clear timbered summits or to erect large signals.

The following instruments and books are used in primary triangulation:

One 8-inch theodolite, with leather carrying case and shoulder straps.
Two pairs field glasses.
One prismatic compass.
One protractor (6-inch celluloid, full circle).
One boxwood scale, graduated to inches and tenths.
One 50-foot steel tape, meters on back.
Two electric hand lamps.
One 6-foot steel tape.
Heliotropes.
One plumb bob.
Triangulation tablets or posts, according to requirements of country.
Cement, cans.
Signal notices, printed on cloth.
Climbing irons, for use in wooded regions.
Sun umbrella } For use in regions where improvised sun and wind shelters can
Wind screen } not readily be built.
Triangulation field notes (9-912).
Computation of geodetic distances (9-901).
Computation of geodetic coordinates (9-902).
Computation book, blank (9-989).
Polaris positions for year.
Geographic tables and formulas.
Seven-place logarithmic tables.
A good watch must be provided by the chief of party.

The following additional articles may be purchased in the field: Ax, hatchet, saw, nails, tacks, signal cloth, guy wire, stone drills ($1\frac{1}{8}$-inch bit), drill hammer, posthole digger, wire cutter, and brace and bits.

PREPARATORY WORK.

Amount of control.—At least three serviceable stations must be established for each quadrangle and as many more as may be necessary to afford adequate control. In addition, a number of secondary points—such as church spires, windmills, water tanks, trees, and in high mountain regions some of the more prominent summits—must be located by intersection and checked by angles from one or more stations or by the "three-point method." Where no such objects are available, at least two points should be flagged for intersection if practicable. These points are intended to afford supplemental control for the topographer and should be selected with special reference to their usefulness in that connection.

The observer is also expected to locate, when practicable, either by direct measurement from his stations or by the three-point method, conspicuous objects, marks on State and county boundary lines, and township and section corners. Especial attention should be given to township and section corners because of their recognized value in the control of the land-line net.

Reconnaissance.—Stations should be selected and signals built before any observing is done, and to this end the triangulator and his assistant should make a reconnaissance over the area to be controlled. Such reconnaissance should disclose every practical scheme of triangulation, the angles at each point selected being measured with a prismatic compass and platted with the protractor so that the size and proportions of the figures may be ascertained. All preparatory work, such as the setting of tablets and posts, the erecting of signals and scaffolds, the clearing of lines of sight, and obtaining consent of the owner, if on private land, should be completed during this reconnaissance, so that the final observing may be performed with economy and dispatch. The reconnaissance affords the triangulator opportunity to acquaint himself with the shortest routes of travel, the best stopping places, the available camp sites, water holes, pastures, and trails, and the best routes for scaling each peak to be occupied; and it enables him to gain a familiarity with the special character of each station and its signal which will be invaluable to him in identifying the points when he sights them later on. As station names are to be published, efforts should be made to select those which have local significance.

Figures.—The most desirable groups of triangles consist of either quadrilaterals with both diagonals sighted or central point figures with four to seven sides. The triangles composing these figures should be well proportioned, angles measuring not less than 30° nor more than 120° each. The scheme should not be allowed to dwindle down to simple, unsupported triangles, and especial care should be taken to connect the work done with other work by means of well-proportioned triangles. Overlapping figures or an excess of observed lines beyond those necessary to insure a double determination of each length are undesirable, although a diagonal through some figure may occasionally be valuable as a check. Additional lines of this kind only complicate the main scheme without materially adding to its strength, and the numerous observations made for them are discarded by the computers as superfluous. Judgment is to be used in this matter, however, for in many regions the atmospheric conditions are exceedingly uncertain and the observer can not always count on being able to see in both directions over every line that may be essential to the main scheme. In such regions it is well to err on the safe side and to obtain too many data rather than too few.

Angles should be read to all prominent points outside of the area for use in future expansion, even though they are without signals or are not sharply defined.

Secondary points.—In cutting in secondary points for topographic control it should be remembered that locations which depend on two sights only, even if the angles are of adequate size, are likely to be of doubtful value, because of the absence of any check on possible gross errors in observing or computing, or because of mistakes in the identification of the points. An endeavor should therefore be made to obtain at least three sights to every secondary point, even if the triangles are not of the best shape. Observers are especially cautioned not to slight the location of secondary points merely because they happen to be of no importance in their scheme of figures. The topographer may find it expedient to start his control from a secondary point, so that a blunder in the location of such a point may result in his starting with an erroneous base and having to make corrections at a great cost.

Consent of owner.—Before a site for a station on private land is selected, the written consent of the owner should be obtained, if practicable, for establishing a permanent station mark and erecting the required signal. If a summit must be cleared of timber, or if lines of sight must be cut, the value of the timber to be cut should be definitely fixed and agreed upon with the owner before cutting is begun.

Where reimbursement is required on this account, cash payment in full of the amount claimed should be made whenever possible and a subvoucher receipt taken. The subvoucher should read "For timber used in connection with the construction of a triangulation station at .... job, $........" If it is not practicable to make cash payment, a direct voucher (Form 9–012) in which the same wording is used should be submitted.

In order to protect the Survey against any further claims, a written agreement should always be made with the owner according to the following form, the signed copy to be sent promptly to the chief geographer through the division geographer and to be retained in the Geological Survey files as evidence of payment of the claim in full:

Post Office .... County .... State ....

..............................., 191..

Permission is hereby given to the United States Geological Survey (........................, chief of party) to build a triangulation signal and maintain a station mark on my property on .... mountain in the town of .... county of ...., State of ....

It is further agreed that no charge will be made except for timber or other material actually used or destroyed in building and maintaining said triangulation signal and mark.

I hereby agree to accept .... dollars ...... cents as payment in full for damages sustained and material used by .... for the purposes indicated above.

Signed ....

Witness ....

When it is necessary to clear away timber and the owner or agent for the ground can not be reached without great delay, three residents of the locality should be asked to appraise the value of the timber cut and to sign a written statement regarding it. This statement should be forwarded to the office of the Survey for consideration if a claim for damage is filed.

Station marks.—Primary triangulation stations must be permanently marked by either standard iron bench-mark posts or by tablets, each tablet to be set in rock in place or in the top of a concrete or stone pier. (See Pl. I and also second paragraph, p. 100, for instructions in regard to setting tablets.) When practicable, bottles or other imperishable material should be left as subsurface marks.

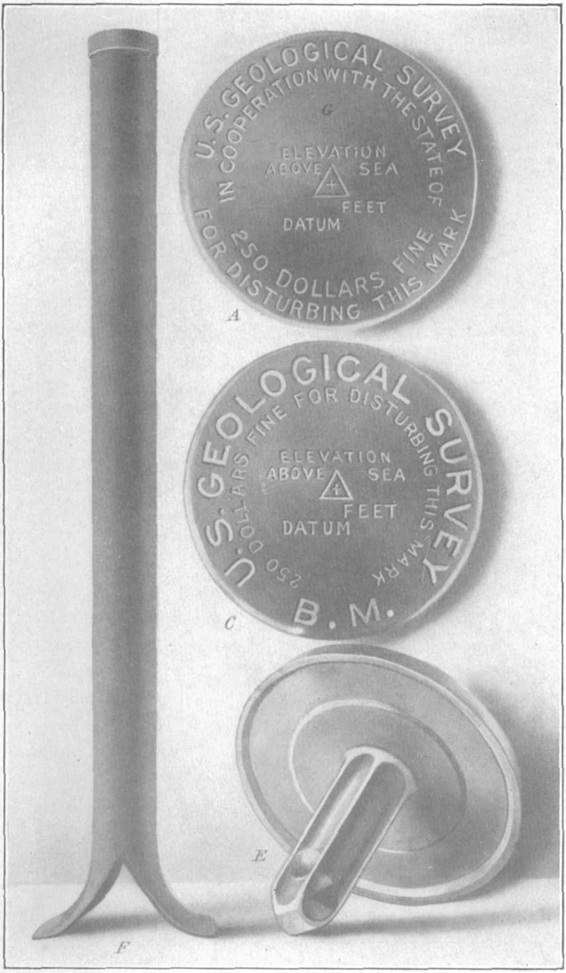
Two or more permanent reference marks should be established about each station mark. These may consist of holes drilled in rock in place, spikes in roots of trees, or large stones set solidly in the ground. The azimuth and the distance to each reference mark must be duly entered in the field record.

When old stations are revisited and any of the marks are found to be defective or to have been destroyed, new marks must be established in their places.

Signals.—Triangulation signals must be built with a view to their permanence as well as to their visibility. They may be of various forms, the form selected depending on the locality and the materials at hand. Thus, a signal on a bare mountain peak may be a rock cairn; one on a partly wooded summit may be a straight tree, the surrounding timber being cleared away; one on cleared land may be a tripod or quadripod.

Rock cairns should be not less than 8 feet high and should be well put together, so that they will withstand strong winds and heavy snows. A pole or a small green tree placed in the top is of advantage in sighting.

Signal trees are most satisfactory if stripped of their branches, except a tuft at the top. They form the best of targets when sighted against the sky, but if they are to be sighted against a dark background, they should carry two triangular targets 3 to 6 feet on a side, placed at right angles to each other and covered with white cloth. Tripods or quadripods should be built of sawed lumber if such mate-



MARKS USED FOR CONTROL STATIONS.

(See pp. 48 and 82.)

A, Tablet used in cooperating States. The State name is inserted at *G*.
A, *C*, and *E*, Tablets for stone or concrete structures.
F, Iron post used where there is no rock.

rial is available. For the legs and center pole 2 by 4 inch scantlings may be used, for the cross braces 1 by 6 inch boards. The base of the pyramid should be large enough to permit a theodolite to be set up under the center pole. In order to increase its visibility, boards may be nailed across the sides about a foot apart and covered with signal cloth, and cross targets may be attached to the center pole above the apex of the pyramid. The best colors for this cloth are white and black or white and red.

Most signals stand in exposed places and should be securely anchored to prevent their being blown over. The legs of tripods and quadripods should be placed in the ground at least 2 feet; each should be fastened to a "deadman" and the holes filled with thoroughly tamped earth or rocks, or else a stake 4 feet long should be driven into the ground at an angle with each leg and firmly spiked to it. If the ground is too rocky to permit the digging of holes, a 4-foot crosspiece should be nailed to each leg at right angles flat on the ground and weighted down with rocks.

Scaffolds.—If it becomes necessary to elevate the instrument, a scaffold must be erected in the form of a tripod, capped with a thick board 12 inches square to support the instrument. Around this scaffold, but entirely independent of it, should be built another, in quadripod form, supporting a platform on which the observer is to stand. If very high, such a scaffold should be composed of successive bents, each 8 or 12 feet, with diagonal bracing. The outer scaffold, further, is to serve as a signal, and for that purpose should extend at least 6 feet above the observing platform and be surmounted by a mast bearing cross targets. Before fixing signals in position the direction in which sights are to be taken should be carefully ascertained, so that no woodwork will interfere with the observations.

The size of the timbers to be used necessarily depends on the height of the structure. The amount of lumber required may be determined by means of a rough drawing of the structure to scale.

Centering of signals.—Great care must be taken to insure perfect centering of signal and scaffold over the station mark, the plumb bob being used for this purpose. Signals should stand over station marks wherever possible, so as to avoid the necessity of computing swings for the angles, but if this is impracticable, as it is with a tree signal, then the distance and bearing of the signal to the station mark must be carefully measured and recorded.

The permanent mark, tablet, or post must always be considered as the station for which the geodetic position will later be computed, and when observations are made for angles the theodolite should be set up over its center if possible. If it is impracticable to center the instrument over the station mark, the distance between the point occupied and the station mark must be carefully measured and recorded. Also one or more sets of angles must be read between the station mark and the other stations, in order of azimuth, preferably with the 0° 0′ 0″ for the pointing to the station mark.

Heliotroping.—The heliotrope outfit commonly used by the Survey is either the Steinheil or a plane mirror with a screw hinged to the back to give it universal motion and improvised diaphragms of tin or wood with round apertures. The plane mirror is generally preferred to a heliotrope of the more elaborate form.

A heliotrope is usually set up by mounting the mirror on a stake or board immediately over the center of the station and the diaphragm on another stake, 10 or 20 feet away, carefully lined in with the distant station. The operator must constantly watch the reflection from the mirror and keep it symmetrically over the aperture. If the sun is back of the observer a second mirror, a foot or two from the first, may be used to reflect the light into the first.

To the observer the flash should appear as a clearly defined point of light; if of appreciable size it will be necessary to bisect it, and an error is thus likely to be introduced. A good rule to follow is to make the diameter of the opening in inches equal to one-fiftieth of the distance in miles for work in the West, and twice this size for work in the East, with a minimum opening of a quarter of an inch.

OBSERVING AND RECORDING.

Time of observing.—As a rule, the best time for observing is the three hours before sunset; the atmosphere is then steadiest and shows no "boiling." The early morning hours are occasionally good but are likely to be less satisfactory. Many cloudy or overcast days are favorable. As a last resort, observations at night may sometimes be necessary, but these require special night signals and assistants to operate them, and because of the additional cost involved are seldom warranted.

Preparation for observing.—Whenever practicable the theodolite must be set over the station mark for reading angles, to obviate reduction to center. In setting up the tripod the head-bolt thumb-screws must be left loose until the legs are firmly placed and then tightened.

The instrument must be sheltered from both wind and sun. If the region affords no material readily available for constructing wind screens and sun shelters, a folding wind screen and a sun umbrella must be carried as a part of the regular outfit.

Before observations are begun at a station all adjustments of the theodolite must be tested and such as are found in error must be corrected, special attention being paid to the micrometers to eliminate errors of run. The stations to be sighted must next be carefully identified by means of the directions shown on the plat or by means of angles previously taken with a prismatic compass. If any of the distant stations can not be seen with the unaided eye, some object in line with each which can be found quickly must be selected, or, if necessary, the direction to each may be marked by some object near by, so no time shall be lost in making the pointings when the angles are being read.

Method of observing.—With micrometer theodolites either single angles may be measured or circle readings (directions) may be made. In using the latter method select for the initial point some station that is especially distinct and easily sighted and use it as the initial point for all sets of readings. The telescope being set on the initial point, read both micrometers, then sight the other stations in succession in the order of their azimuths (clockwise rotations), closing on the initial point. Then reverse telescope, set on initial point, and sight the stations in reverse order. This completes one set of readings with telescope direct and reverse. Now shift the circle about 36° (*examine the plate bubbles after this shift and relevel if necessary*) and begin another set. When pressed for time, it is advisable to shift the circle when telescope is reversed. No angle should be considered as well determined that has not been measured on at least 5 different parts of the circle or 10 times in all, 5 with telescope direct and 5 with telescope reversed. When the telescope is reversed, each end of its axis will rest in the same Y as before. Reversals and releveling are of especial importance when there is an appreciable difference in the elevations of the points sighted.

If the observations are made in the afternoon, it is advisable to take all secondary pointings before commencing the observations to stations, and there should be at least two sets of such pointings; the remaining time for observing can then be devoted to the accurate measurement of the important angles while conditions are the most favorable.

The graduated circle should never be placed so that when pointing at any particular station the micrometers will be set to even degrees except, as before noted, while data are being obtained for "reduction to center."

Field record.—The field record is to be kept in book 9-912. It must be written in a plain neat hand with a No. 4 pencil or in ink, and no part of it must on any account ever be erased. A single line should be drawn through erroneous records, the corrected figures being written above. If deemed necessary, an explanation should be written in the column for remarks. The memory should not be trusted for data of any kind; the record must be faithfully kept in all particulars and be made so complete that it can be understood by another person at any time.

On the flyleaf of each field notebook is a blank in which all information necessary to identify the book may be recorded. This blank should be filled so far as practicable on or before the first date of entry of field notes, and it must be completely filled before the book is forwarded to the Washington office. Any failure to fill in completely the blank on the flyleaf of a field notebook should be reported by the computer to the geographer in charge of the division. One of the blank flyleaves must contain an index of the contents.

The date, name of station, time of observing, and names of observer and recorder should be systematically entered at the head of each page.

The position of the instrument with respect to the center of the station must be clearly defined, and if it is set up off the center a full statement must be given of the distance and the angles measured.

On the page immediately preceding the record of angles should be written a minute and complete description of the station occupied, the station's marks, character of signal, nearest camping or other stopping places, roads, and trails, also a statement regarding the ownership of the land and such other information as will be helpful to the topographer. The description must be written before the recorder leaves the station and should be accompanied by a rough diagram showing directions to other stations and plan indicating location of instrument or signal if it was not centered on the station.

Reading and recording of angles.—When the micrometer wires are set for a reading with the Geological Survey theodolites it is very important that the last movement of the wires be toward the right. The readings on the graduated head are then decreasing and the spring attached to the slide which holds the wires is being compressed. If the cross wires are moved the least bit too far to the right they must not be turned backward merely to the setting, but must be turned backward at least a half turn of the screw, then brought forward slowly to correct setting. When the setting is properly made a division on the graduated plate will appear exactly midway between the two movable cross wires and an equal amount of white space will show on each side of it. A part at least of the micrometer adjustment errors can be eliminated by making the settings with less than five turns of the screw; this can always be done if the right-hand part of the comb scale is sometimes used for comb-scale and micrometer-head readings, the 10-minute space being taken from the left.

For all precision instruments where a tangent screw and spring are used together, the setting should be made while the spring is being compressed, otherwise the "slack" of the screw may cause an error.

The recorder should not only take down the readings called off by the observer but should without delay compute the angles between successive stations and also the mean readings. The following form is to be used for recording angles by the method of directions:

Station occupied, *Ivy*.
Date, *May 3, 1910*.

Observer, *O. J.*
Recorder, *C. P. M.*

Stations sighted.	Microm. A.	Microm. B.	Mean.	Angle.	[In these columns write summaries of the angles measured.]		
Telescope direct.	° ′ div.	° ′ div.	° ′ ″	° ′ ″			
Bald Knob	350 48 02	170 48 00	350 48 02		*Bald Knob–*	*Shumate–*	*Time 4.30 p.m. All*
(Station mark)	000 00 15	180 00 14	(000 00 29)		*Paint:*	*Burning*	*signals distinct.*
Paint	77 54 10	257 54 10	77 54 20	87 06 18	87 06 18	*Rock:*	
Shumate	212 40 05	32 40 04	212 40 09	134 45 49	21	63 25 35	*Eccentric point oc-*
Burning Rock	276 05 24	96 05 20	276 05 44	63 25 35	23	30	*cupied, distant*
Walnut	285 51 19	105 51 17	285 51 36	9 45 52	20	[*etc.*]	*from station mark*
Workman	320 47 10	140 47 09	320 47 19	34 55 43	16		*2.20 meters*
Bald Knob	350 47 29	170 47 27	350 47 56	30 00 37	22		*(7.22 ft.).*
Telescope reversed.					21		
Bald Knob	170 47 18	350 47 20	350 47 38	30 00 39	25		87 06 20.5
Workman	140 46 28	320 47 01	320 46 59	34 55 41	20		134 45 50.4
Walnut	105 51 08	285 51 10	285 51 18	9 45 50	19		63 25 32.0
Burning Rock	96 05 13	276 05 15	276 05 28	63 25 30			9 45 51.6
Shumate	32 39 28	212 40 00	212 39 58	134 45 49	87 06 20.5		34 55 42.0
Paint	257 54 03	77 54 06	77 54 09	87 06 21			30 00 41.0
(Station mark)	180 00 0	000 00 12	(000 00 22)		*Paint - Shu-*		
Bald Knob	170 47 22	350 47 26	350 47 48		*mate.*		359 59 57.5
					134 45 49		
					49		
					51		
					53		
					48		
					46		
					50		
					52		
					54		
					52		
					134 45 50.4		

[NOTE.—Two readings on the station mark only need be taken for reduction to center.]

[Left-hand page.] [Right-hand page.]

Opposite each angle record any necessary information as to visibility of signals or atmospheric conditions.

Field computations.—Angles at each station should be reduced to center in the field in order to test the triangle closures, which for a primary scheme should not exceed 5″.

Arbitrary adjustments and preliminary computations of positions should also be made in the field. Book 9–889 should be used for summary of angles and for miscellaneous computations. Computations for distances should be entered in book 9–901 and for coordinates in book 9–902. For field computations of coordinates where the lines are short, five or six place logarithms will give sufficient accuracy and the computations may be shortened by omitting some of the minor corrections, carrying results to tenths of seconds of latitude and longitude only.

As soon as the preliminary computations are made the record books should be sent to the Survey office by registered mail. The computation books should also be sent by registered mail but on another day.

Triangulation plot.—A careful plot of the work should be kept on the scale of 8 miles to an inch, and each month a reduced copy, on which angles measured are indicated by the usual sign, should be sent in on the monthly report blank. If this plot is carefully made it can be transferred directly to the office State progress map.

In order to use the plot for finding the direction to distant stations place the protractor on it with 0° in line with a station that can be seen clearly, then read in turn the angle to each other station, thus obtaining an observing list.

Azimuth observations.—There must be not less than two azimuth stations in each triangulation scheme, but if the azimuth of any line in a scheme can be computed from former observations then only one azimuth station need be established for each square degree controlled.

The azimuth mark should be placed at least half a mile from the station. It should consist of a vertical slit one-fourth to one-half inch wide and 6 inches long, cut in a small box containing a candle or lantern. To illuminate the cross wires of the instrument and to read the angles, an electric hand lamp is to be preferred.

The observations should consist of not fewer than five direct and five reversed measurements between the star and mark. As the star is at a much higher angle of elevation than the mark it is important that the horizontal axis of the theodolite be adjusted with care and leveled. The ends of the striding level bubble must be read at each setting on the star and a level correction computed if there is an appreciable difference between them, as shown in the example attached.

Observations on Polaris should be made immediately preceding and following elongation, as any error in the time of observation has then the least effect on the resulting azimuth. The time of setting the cross wires on the star must be recorded to the nearest second. The watch error must be known, and to this end the observer should compare his watch frequently with telegraphic time, which is sent over Western Union lines once a day, usually at noon, Washington standard time.

For azimuth observations between 2 a. m. on the last Sunday of March and 2 a. m. on the last Sunday in October in any year use advanced or "daylight saving" time and so state on each page of the notes, remembering to make whatever time correction is necessary in taking positions or time from astronomic tables.

Example of record of azimuth observations.

Station: Canada, Ky. 8-inch theodolite No. 434. One division of micrometer=2″. One division of level=2″ of arc. June 11, 1910. Watch 0m 23sec slow, 90th meridian standard time.[a]

Telescope direct.

Object.	Time a. m.	Level.		Micrometer.		Mean.	Angle.
		West.	East.	A.	B.		
	H. m. s.	*Div.*	*Div.*	° ′ *div.*	° ′ *div.*	° ′ ″	° ′ ″
Mark (1)...	....	......	......	352 54 09	172 53 21	172 54 00	
Polaris (2)..	2 30 50	11.0	10.0	288 35 24	108 35 05	108 35 29	
		9.0	12.0				
		20.0	22.0	....	....	....	64 18 31
		−2.0					

[a] These observations were made before the "daylight saving" law was enacted.

Example of record of azimuth observations—Continued.

Telescope reversed.

Object.	Time a. m.	Level. West.	Level. East.	Micrometer. A.	Micrometer. B.	Mean.	Angle.
	H. m. s.	*Div.*	*Div.*	° ′ *div.*	° ′ *div.*	° ′ ″	° ′ ″
Mark (4)...	....	......	......	172 53 04	352 52 13	352 52 47	
Polaris (3)..	2 36 48	11.0	10.0	108 34 10	288 33 27	288 34 07	
		9.0	12.0				
		20.0	22.0	....	....	....	64 18 40
		−2.0					
Mark (5)...	....	......	......	202 41 13	22 40 22	22 41 05	
Polaris (6)..	2 40 26	10.0	11.0	138 22 24	318 22 06	318 22 30	
		10.0	11.0				
		20.0	22.0	....	....	....	64 18 35
		−2.0					
Telescope direct.							
Mark.......	....	......	......	22 41 07	202 40 17	202 40 54	
Polaris.....	2 46 52	10.0	11.0	318 22 20	138 22 13	138 22 33	
		11.0	10.0				
		21.0	21.0	....	....	....	64 18 21
		0.0					

NOTE.—Four other sets should be taken.

TRIANGULATION COMPUTATIONS.

Preliminary computations of distances from unadjusted angles should be made in the field, as required by the rule on page 55.

The steps in the final adjustment and computation are as follows:

- Closing the horizon.
- Tabulation of angles.
- Reduction to center.
- Computation of azimuth.
- Tabulation of triangles.
- Computation of spherical excess.
- Least-square adjustment:
  - Angle equations.
  - Side or sine equations.
  - Equations of condition.
  - Table of correlates.
  - Normal equations.
  - Solution of normal equations.
- Computation of distances.
- Computation of geodetic coordinates.
- Tabulation of results.

Operations are completed in books 9–912, 9–889, 9–901, and 9–902. The results are tabulated on printed blanks 8 by 10½ inches in size, one blank for each station.

Closing the horizon.—In careful work closing errors will always be small and may be distributed among the various angles in proportion to their number. If any of the angles measured should equal the sums of smaller angles, proper adjustments must be made before the horizon is closed.

Tabulation of angles.—For convenience of reference a rough plot should be made for each station on part of a page in book 9–889, showing the relative size and position of the various angles with names of stations sighted, and on the same or the following page should be given a summary of all the angles at the station, in order of azimuth, with the angles and distances to signals for eccentric stations.

Reduction to center.—For eccentric stations the data for reduction to center should be indicated on the plat and figures given for them in the summary. An illustration of the method of procuring these data is given below. (See also fig. 1, p. 62.) Two sets of angles were read at Elk station (where an eccentric point was occupied), with one of the micrometers set very nearly on 0°, when the telescope was pointing directly toward the center of the signal. The angle to each point in turn is given below. By measuring the angle with this setting the computer is saved considerable trouble, and the possibility of error is lessened. The measured distance between the center of the instrument and the center of the station was 4.7 feet (1.43 meters).

The formula for computing the swing in seconds for any line is—

$$\frac{\text{Distance to signal}}{\text{Sine } 1''} \times \frac{\text{Sine of angle between signal and far station}}{\text{Distance to far station}}.$$

The distance to signal will be a constant for each set up, hence its logarithm may be combined with the sine of 1″ and this constant used throughout the computation. The distances to the distant stations in logarithms of meters are derived from a preliminary computation.

log 1.43	=0.15534
log sin 1″	=4.68557
log constant	=5.46977

ELK STATION.

Station	Dick.	Taylor.	Browning.	Tweedy.
Angle	23° 07′ 10″	68° 43′ 40″	109° 16′ 54″	206° 27′ 10″
Log constant	5.46977	5.46977	5.46977	5.46977
Log single angle	9.59400	9.96935	9.97493	9.64881
A. C. log distance	5.70154	5,59196	5,74781	5,63275
Log correction	0.76531	1,03108	1.19251	0.75133
Correction in seconds	+5.83	+10.74	+15.58	−5.64

The sign for any correction is the same as that for the sine of the angle, therefore for an angle over 180° it will be negative.

The correction for any angle will be the difference between the corrections for the two lines bounding it, always taking the lines in order of azimuth. Thus, for Dick-Elk-Taylor it will be—

$$\begin{array}{r} +10.74 \\ -\ 5.83 \\ \hline +\ 4.91'' \end{array}$$

For Browning-Elk-Tweedy it will be—

$$\begin{array}{r} -\ 5.64 \\ -15.58 \\ \hline -21.22 \end{array}$$

The general rule is, change the sign of first correction (in order of azimuth) and add algebraically to the second correction. The sum will be the correction to the angle. The angles listed on page 64 have all been corrected.

The foregoing formula may be used also when it is desired to compute the "swing" for a line, which is to be applied at a distant station to change the pointing to the marked point—that is, the station center—from that taken to the signal. Whether the computed swing is to be added to or subtracted from a given angle may easily be found by an inspection of the diagram.

Computation of azimuth.—The daily change in Polaris is so slight that for the following computation no account need be taken of a fraction of a day in computing its position:

Computation of azimuth observations.

Canada, Ky., triangulation station. June 11, 2.30 a. m., 1910 (civil date).
Latitude: 37° 35′ 46″. Longitude: 82° 21′ 39″.

	H.	*m.*	*s.*
Watch time of observation $2^h\ 30^m\ 50^s$ a. m. $= 14^h\ 30^m\ 50^s$ of the astronomic day which commenced at noon June 10	14	30	50
Correction from seventy-fifth meridian time to 82° 21′ 39″ correction for 7° 21′ 39″ (p. 124, "Geographic tables and formulas")		−29	27
Watch slow by telegraphic time		+	23
Local mean time (astronomic day)	14	01	46
Correction, mean to sidereal time (p. 126, "Bulletin 650," or Table III, "Nautical almanac")		+ 2	18
Right ascension of mean sun at Greenwich noon, June 10, corrected for $5^h\ 29^m\ 27^s$ to change to noon at 82° 21′ 39″ west longitude ("Nautical almanac," June, Table II; change for longitude made by Table III, last part of almanac)	5	12	44
Sidereal time of observation	19	16	48
Right ascension of Polaris for nearest Washington transit—June 10.8 ("Nautical almanac," circumpolar stars for June)	1	26	12
Hour angle of Polaris at time of observation	17	50	36
Hour angle of Polaris in arc$=t$ (p. 125, "Geographic tables and formulas")	267° 39′ 00″		

The following are the formulas for azimuth and level correction:

$$\tan A = -\frac{a \sin t}{1-b \cos t} \quad a=\sec\phi \cot\delta \quad b=\tan\phi\cot\delta$$

$$\text{Level correction}= -\frac{d}{4}[(w+w')-(e+e')] \tan h$$

in which—

ϕ=latitude of station (37° 35′ 46″).
A=azimuth of Polaris at time of observation.
δ=declination of Polaris at time of observation (88° 49′ 21″).
t=hour angle of Polaris at time of observation (267° 39′ 15″) (both the sine and cosine of this angle are negative for this example).
d=value of one division of level (2.0″).
w, w'=readings of west end of level bubble, direct and reversed.
e, e'=readings of east end of level bubble, direct and reversed.
h=angular elevation of star (at elongation this is equal to the latitude, nearly).

The level correction is used as a correction to azimuth A only.

The following is the computation of the first of the preceding observations (p. 57):

Level correction $=\frac{2}{4}(2\times 0.77)=0.77''$

Log tan ϕ	9.88649		
Log cot δ	8.31290		
Log cos t	8.61282 (negative).		
Log b cos t	6.81221 (negative).		
b cos t	−0.000648		
	1		
1−b cos t	1.000648		
Log sec ϕ	0.10109		
Log cot δ	8.31290		
Log sin t	9.99963 (negative).		
Log a sin t	8.41362 (negative).		
Log (1−b cos t)	0.00028		
Log tan A	−8.41334		
A	1°	29′	01.7″
Level correction			+0.8
	1	29	02.5
Add 180° to refer to the south	180		
Angle star to mark	64	18	31
Azimuth of mark	245°	47′	33.5″

Each azimuth computation should be made in a single column and for convenience the columns should be placed side by side in tabular form.

Tabulation of triangles.—By an inspection of the field plat of the triangulation determine what groups of triangles are so interrelated that a change in one will affect the others and what groups of triangles should be adjusted as a unit. For the triangulation by the Geological Survey, which is not executed for geodetic purposes, it is not advisable ever to include more than 15 or 20 triangles in such a group, because the labor of solving equations for the adjustment of any group increases rapidly with its size.

Four overlapping triangles form the simplest group that may be adjusted by the usual least-square methods.

Assume the group shown in figure 1 for adjustment. Tabulate the angles for each triangle, as shown at (a), (b), (c), and (d) (p. 64). Any angle in any of these triangles may be considered as the difference between the azimuths (directions) of its two sides. For example, angle Dick-Elk-Taylor, or 3.0.2, using for convenience the figures assigned to each angle vertex, would be the azimuth or direction of the line 3—0 subtracted from the azimuth or direction of the line 2—0. Azimuths are always measured in a clockwise direction. Therefore this angle may be indicated as $-3.0+2.0$ or $-3/0+2/0$. In the latter form the denominator is always the figure at the vertex of the angle and with the vertex pointing toward the observer the

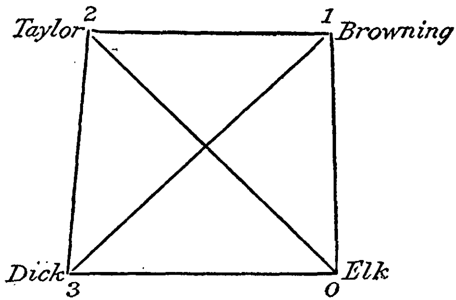


FIGURE 1.—Diagram showing quadrilateral for adjustment by least-square methods.

left-hand direction is always given the minus sign. (Directions will hereafter be referred to as sides.)

Computation of spherical excess.—For any triangle on the earth's surface the sum of the three angles, if correctly measured, will exceed 180° by an amount varying with the area. For use in computing distances the observed angles must be reduced to their plane values by deducting one-third the spherical excess from each. The spherical excess for any triangle between latitude 25° and 45° is approximately 1 second for each 75.5 square miles of area, or exactly equals in seconds ab$m$ sin C, in which a, b, and C are, respectively, the lengths of the two sides in meters and the included angle of any triangle, and m is a constant depending on the latitude.[1] In computing spherical excesses for any figure (as fig. 1,

[1] Logarithms of m are given in Geographic tables and formulas, p. 271; and in U. S. Geol. Survey Bull. 650, p. 294, 1916, reprinted 1918.

for example) arrange the work systematically, the logarithms of each of two sides in meters from a preliminary computation, the logarithm of the sine of their included angle, and the logarithm of m for the mean latitude for each triangle; place in a column. Give the figures for the triangle at the head of the column, as 3.0.2, using the angle 3.0.2 and the sides 3–0 and 2–0 in the computation.

Computation for spherical excess.

Triangles.	3.0.2	2.0.1
Log side a	4.29846	4.40804
Log side b	4.40804	4.25219
Log sin C	9.85406	9.81304
Log m	1.40475	1.40475
Log spherical excess	9.96531	9.87802
Spherical excess in seconds	0.92	0.76

Mean latitude, 37° 35′.

In the same manner compute the spherical excess for each of the remaining triangles. Many such computations can be conveniently made in the book (9–901) used for preliminary distances, in the left-hand column adjacent to each triangle.

As the spherical excess for a given area is constant, the sum of the spherical excesses for the triangles 2.0.1 and 3.0.2 must equal the spherical excesses for the other two. This check should always be applied to the results.

Least-square adjustment.—After deducting the spherical excesses from the sums of angles for each triangle (a), (b), (c), (d) (see below) the differences between the remainders and 180° will be the errors, plus for remainders over 180° and minus for those less than 180°.

The rules for determining the number of angle equations and the number of sine or side equations required for the proper adjustment of any figure are these:

$$L - S + 1 = \text{angle equations}$$
$$L - 2S + 3 = \text{sine equations}$$

where L equals the number of lines in the figure and S the number of stations. A solution of these equations for a quadrilateral shows that three angle equations and one side equation are required. In the present example it is immaterial which three triangles are used for the adjustment.

Angle equations.

	Stations.	Side.	Observed angle.	Correction.	Corrected spherical angle.
			° ′ ″	″	° ′ ″
(a)	Elk	−2/0+1/0	40 33 19.17	+2.12	40 33 21.29
	Browning	−0/1+2/1	95 23 07.62	+0.71	95 23 08.33
	Taylor	−1/2+0/2	44 03 30.52	+0.62	44 03 31.14
			179 59 57.31		180 00 00.76
			.76		Spherical excess.. 0.76
			Error−3.45		
(b)	Elk	−3/0+2/0	45 36 34.90	−2.97	45 36 31.93
	Taylor	−0/2+3/2	50 34 37.57	−0.40	50 34 37.17
	Dick	−2/3+0/3	83 48 53.15	−1.33	83 48 51.82
			180 00 05.62		180 00 00.92
			.92		Spherical excess.. 0.92
			Error+4.70		
(c)	Elk	−3/0+1/0	86 09 54.07	−0.84	86 09 53.23
	Browning	−0/1+3/1	50 10 30.58	−1.47	50 10 29.11
	Dick	−1/3+0/3	43 39 38.99	−0.43	43 39 38.56
			180 00 03.64		180 00 00.90
			.90		Spherical excess.. 0.90
			Error+2.74		
(d)	Dick	−2/3+1/3	40 09 14.16	−0.90	40 09 13.26
	Browning	−3/1+2/1	45 12 37.04	+2.18	45 12 39 22
	Taylor	−1/2+3/2	94 48 08.09	+0.21	94 38 08.30
			179 59 59.29		180 00 00.78
			.78		Spherical excess.. 0.78
			Error−1.49		

To select the sines for the side equation: Consider the figure as a pyramid with vertex at 2; by redrawing the figure with the line 3–1 dotted and the triangle 2–3–0 shaded, it will appear to the eye as such a pyramid. Select for the first set of angles for the sine equations those opening to the front in going around the base of the pyramid from 3 to 0 to 1 to 3; for future reference mark them with solid arcs of circles; the remaining angles around the base make up the other set and are marked with dotted arcs. In selecting the point for the vertex of the pyramid, as a general rule choose the one which includes the smallest angles, but if all the angles are greater than 30° either station may be chosen. Find the sines for each set of angles, recording also the differences for 1″ for each; call the first set of sines plus and the second set minus, find the difference between them, and give it the sign of the greater.

Sine equation.

	Sides.	Angle.	Sine.	Difference for 1″.	Correction in seconds.	Correction to sine.	Corrected sine.
		° ′ ″					
(e) +	−2/3+0/3	83 48 53.15	9.9974645	+02.2	−1.33	− 3	9.9974642
	−2/0+1/0	40 33 19.17	9.8130350	+24.6	+2.12	+52	9.8130402
	−3/1+2/1	45 12 37.04	9.8510731	+20.9	+2.18	+46	9.8510777
			9.6615726	....	....	....	9.6615821
(e) −	−2/3+1/3	40 09 14.16	9.8094543	+24.9	−0.91	−23	9.8094520
	−3/0+2/0	45 36 34.90	9.8540576	+20.6	−2.97	−61	9.8540515
	−0/1+2/1	95 23 07.62	9.9980787	− 2.0	+0.71	− 1	9.9980786
			9.6615906 Error −180				9.6615821

Equations of condition are now made up as follows: For triangle (a), equation (f), error equals −3.45″; this is made up of the errors in the azimuth or pointing of the sides −2/0+1/0−0/1+2/1−1/2+0.2, six in all. In like manner form equations (g) and (h). The sine equation (i) is made up as follows: The error of the sines, being the difference between the two sets, is −180. To correct the sines changes in seconds to be found for the angles must be multiplied by the differences for 1″ in column 4 of (e) for the given angle; hence for the first sine this will be +2.2 multiplied by the corrections to be given the directions −2/3 and +0/3, or if expressed in a simple form it will be −2.2 2/3+2.2 0/3. Treat each side and difference for 1″ in like manner, noting, however, that for the second set of sines, which is considered negative, each sign given for the side will be reversed; for example, the first one is written +24.9 2/3−24.9 1/3.

It will be noticed that in the first form of (i) as written, 2/1 appears twice with like signs, 2/3 appears twice with unlike signs; combine like terms algebraically, thus reducing the equations to the second form of (i). For the convenience of the computer and in order to avoid the handling of large numbers, equation (i) has been divided through by 100; this, of course, does not alter its value.

Equations of condition.

(f) $0=-3.45''-2/0+1/0-0/1+2/1-1/2+0/2$
(g) $0=+4.70''-3/0+2/0-0/2+3/2-2/3+0/3$
(h) $0=+2.74''-3/0+1/0-0/1+3/1-1/3+0/3$

$$
(i)\begin{cases}
0=-1.80''-.022\ 2/3+.022\ 0/3-.246\ 2/0+.246\ 1/0-.209\ 3/1+.209\ 2/1+.249\ 2/3 \\
\qquad -.249\ 1/3+.206\ 3/0-.206\ 2/0-.020\ 0/1+.020\ 2/1 \\
0=-1.80''+.227\ 2/3+.022\ 0/3-.452\ 2/0+.246\ 1/0-.209\ 3/1+.229\ 2/1 \\
\qquad -.249\ 1/3+.206\ 3/0-.020\ 0/1
\end{cases}
$$

There are now four equations to be solved and twelve unknown quantities; the latter are combined and reduced to four in the table of correlates. Column (j) contains the marks for the sides or directions for which corrections are required. Column (k) contains on the proper lines the algebraic coefficients for the various sides from equation (f); for example, $-2/0$, considered as a quantity, might be written $-1\ (2/0)$, and $+1/0$ in like manner written $+1(1/0)$; -1 and $+1$ are therefore the entries for column (k), lines 2/0 and 1/0.

Table of correlates.

(j)	(k)	(l)	(m)	(n)	Correlates after substituting computed values.					
Sides.	1	2	3	4	1 +0.275	2 −0.063	3 −0.589	4 +3.007	Corrections.	Sides.
1/0	+1	.....	+1	+0.246	+0.275	....	−0.589	+0.740	+0.426	1/0
2/0	−1	+1	....	−0.452	−0.275	−0.063	....	−1.359	−1.697	2/0
3/0	.....	−1	−1	+0.206	....	+0.063	+0.589	+0.619	+1.271	3/0
0/1	−1	.....	−1	−0.020	−0.275	....	+0.589	−0.060	+0.254	0/1
2/1	+1	.....	....	+0.229	+0.275	....	....	+0.689	+0.964	2/1
3/1	.....	.....	+1	−0.209	....	....	−0.589	−0.628	−1.217	3/1
0/2	+1	−1	....	....	+0.275	+0.063	....	....	+0.338	0/2
1/2	−1	.....	....	....	−0.275	....	....	....	−0.275	1/2
3/2	.....	+1	....	....	....	−0.063	....	....	−0.063	3/2
0/3	.....	+1	+1	+0.022	....	−0.063	−0.589	+0.666	−0.586	0/3
1/3	.....	.....	−1	−0.249	....	....	+0.589	−0.749	−0.160	1/3
2/3	.....	−1	....	+0.227	....	+0.063	....	+0.683	+0.746	2/3

The formation of normal equations from the table of correlates is as follows: Column 1, line 1, of (*o*) (p. 67) contains the sum of the squares of each quantity in column (k). Column 2, lines 1 and 2, contains, first, the sum of the products of each quantity in column (k) by corresponding quantities in column (l); second, the sum of the squares of each quantity in column (l). Column 3, lines 1, 2, and 3, contains the sum of the products of (k) by (m), (l) by (m), and (m) by (m) (the squares). Column 4 is made up in the same manner, using the quantities and signs as given. If columns 1, 2, and 3 are completely filled out by products found as indicated above, it will be found that the quantities from +6.000 down the column are the same as those from +6.000 along the lines to the right to column 4. But as the former are not needed in the solution they may be omitted; when retained, the equations in full will be as follows, the second member of each equation being zero:

(*o*) *Normal equations.*

1	2	3	4	Absolute term.
+6.000	−2.000	+2.000	+0.947	−3.450
−2.000	+6.000	+2.000	−0.863	+4.700
+2.000	+2.000	+6.000	+0.122	+2.740
+0.947	−0.863	+0.122	+0.51779	−1.800

These are ordinary algebraic equations which may be solved by the usual rules of algebra, but as the solution of 5, 10, 15, or more equations is often required in Geological Survey work, the process should be conducted systematically as shown.

Solution of normal equations.

(p)

	1	2	3	4	Absolute term.
(p_1)	+6.000	−2.000	+2.000	+0.947	−3.450
(p_2)	(0.1667)	+0.333	−0.333	−0.1578	+0.575
(p_3)		+5.333	+2.667	−0.5473	+3.550
(p_4)	(0.1875)		−0.500	+0.1026	−0.666
(p_5)			+4.000	+0.0800	+2.115
(p_6)		(0.250)		−0.0200	−0.529
(p_7)				+0.31060	−0.934
			(3.2196)		+3.007

(q)

	2	3	4	Absolute term.
(q_1)	+6.000	+2.000	−0.863	+4.700
(q_2)	−0.667	+0.667	+0.3157	−1.150
(q_3)		+6.000	+0.1220	+2.740
(q_4)		−0.667	−0.3157	+1.150
(q_5)		−1.333	+0.2737	−1.775
(q_6)			+0.51779	−1.800
(q_7)			−0.14944	+0.544
(q_8)			−0.05615	+0.364
(q_9)			−0.00160	−0.042

(r)

	1	2	3	4
(r_1)	+0.575	−0.666	−0.529	+3.007
(r_2)	−0.475	+0.309	−0.060	
(r_3)	+0.196	+0.294		
(r_4)	−0.021		−0.589	
		−0.063		
(r_5)	+0.275			

The first normal equation is written in full on line (p_1); parts of the other equations are written on lines (q_1), (q_3), and (q_6). The reciprocal from Barlow's tables of the first quantity (+6.000, line (p_1), column 1), is placed at the left. The product of this reciprocal

(0.1667) by the quantities on line (p_1), columns 2, 3, and 4, and absolute are written immediately under each in turn; the quantity +0.333 (line (p_2), column 2) is now used as a multiplier for line (p_1) (omitting column 1), and the products are placed in columns 2, 3, 4, and absolute, line (q_2); in like manner the quantities −0.333 (line (p_2), column 3) and −0.1578 (column 4) are used as multipliers and the products written on lines (q_4) and (q_7). The algebraic sums of lines (q_1) and (q_2) are now written on line (p_3), which is then used as if it were an original equation. The reciprocal of +5.333 is found and used as a multiplier as before and the products written on line (p_4). The next products are written on lines (q_5) and (q_8). The sum of each column of lines (q_3), (q_4), and (q_5) is carried over to (p_5). The process is repeated for each equation until finally the product +3.007 is found, which is the value for unknown quantity numbered 4. This value and also the quantities in the column of absolute terms, lines (p_6), (p_4), and (p_5), are copied in the table (r), line (r_1). With +3.007 as a multiplier products of each quantity in column 4, lines (p_6), (p_4), and (p_2), are found and written on line (r_2), columns 3, 2, and 1. Column 3 of (r) is then summed and the result (−0.589) is the value of unknown quantity numbered 3. This is used as a multiplier and products found with quantities from columns 3 and 2, lines (p_4) and (p_2), and in like manner values for unknown quantities numbered 2 and 1 are found.

The solution of the normal equations and the values found for the unknown quantities may be checked by substituting in the full equations (p. 63).

The next step in the adjustment is to substitute the values for the four unknown quantities in the tables of correlates (p. 66) and to find the correction for each side. The method of doing this can be easily seen by following the process through the right-hand half of that table. For convenience, the value found for each unknown quantity is written at the head of columns 1, 2, 3, and 4. Each of these in turn is multiplied by quantities in columns 1, 2, 3, and 4 of the left-hand part of the table and the products are placed in the right-hand part on the same line with the multiplicand. The final correction for any side is then the algebraic sum of the quantities, which are on line with the side number in columns 1, 2, 3, and 4 (at the right side of the table). Thus the correction 1/0 is made up of $+0.275$, -0.589, $+0.740=+0.426$; this is the correction in seconds to the side. The correction for any angle, then, is the difference between the corrections for the two sides bounding it. For example: Angle at Elk, triangle (a), is:

$$\begin{array}{r} -\text{correction } 2/0 = +1.697 \\ +\text{correction } 1/0 = +\ \ .426 \\ \hline +2.123 \end{array}$$

The correction for any sine is the correction for the corresponding angle multiplied by the difference for 1″ in the sine.

It is desirable to have triangles close without errors greater than a hundredth of a second and sine equations close to the seventh place of the logarithm, but unless the normal equations are carried to three or four decimal places, there will possibly be residual errors of two or three hundredths in some triangle closures. It is, however, considered allowable to make arbitrary changes of not over $\pm 0.03''$ in angles in order to procure consistent results.

The figures for adjustment will generally be larger than quadrilaterals, though they may be made up of quadrilaterals or triangles which do not overlap and are therefore independent each of the other. When they do overlap select for the first pyramid group (p. 61) the one which takes in the largest number of triangles and set down (according to the formula on p. 63) the number of triangle equations required to completely adjust it, remembering that the triangles used must always cover the whole area once but not twice. For the second group set down the number of triangle equations required by the rule, as though they were from an independent pyramid group, but omit from those selected all which would be adjusted in or by the first group, the vertex of the pyramid being so situated that a base triangle will not be included in a former group. In other words, as group by group is added to the first, find for each a single sine equation and as many additional angle equations as are required, including in the number all triangles adjusted by a previous group, excluding those which appear in each or which would appear in each if the vertex of the pyramid were taken in a different place.

In any figure in which each station is sighted from every other one no attention need be paid to the selection of triangles for use in the adjustment, which may be selected at random, provided the number required by the formula is taken.

In order to adjust an extensive triangulation scheme, the strongest groups are adjusted first; then if lines or triangles in them form parts of other groups, their first adjusted values are given infinite weights and thus left unchanged.

In connecting new groups of triangles with those previously adjusted, if more than a single adjusted line is used a condition must be introduced fixing the relative length of the adjusted lines. For example: Let the solid lines in figure 2 represent an adjusted group and the dotted lines part of a new group of triangles to be adjusted. It is evident that the distance *a c* and the angle *a b c* are fixed by the completed adjustment; therefore in adjusting the new work a side equation must be used in order to maintain the relative length of the lines *a b* and *b c*. This may be taken from the quadrilateral *a e c d* with the central point *b*, infinite weight being given to the five adjusted lines.

The accuracy of figure adjustments will be increased if the sines of the smallest angles are used in forming the equations and each figure used covers the largest possible area; but on the other hand labor will be saved if as few angles as possible are involved. These conditions appear when two figures overlap; in such cases a sum angle can be used in adjusting one figure, with a saving of labor, but unless all the triangles are of good shape it is better to take the triangles which cover the largest area. Whether the slight increase in accuracy justifies the extra labor involved depends on the quality of the work.

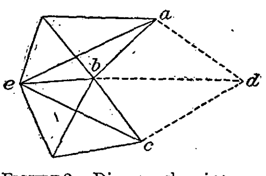


FIGURE 2.—Diagram showing condition to be introduced in connecting new triangles to those previously adjusted.

The angles to be used depend on the position taken for the pole of the assumed pyramid.

Weighted observations.—When the field notes show that certain angle measures are incomplete or uncertain it is generally advisable to introduce weights. These may be in the form of fractions or whole numbers, but in assigning them the field observations and records alone should be considered, not triangle closures. An infinite weight is given when it is desired to hold the value for a direction, as when it is taken from a previously adjusted figure. A weight of ∞ for a side reduces all correlate table products for it to 0—in other words, eliminates its effect on the normal equations.

Weights are used in the table of correlates only. As an example of their use let weights be assumed for directions in the table of correlates on page 68, as follows:

The rule for forming normal equations from weighted correlates is that each product for a given side is to be divided by the weight for that side before combining it to form a term in the equation. For example: The first term in equation 1 is made up as follows from column t of the correlates:

Side 1/0, $(+1)\ (+1) \div$ weight $2 = +1/2$.
Side 2/0, $(-1)\ (-1) \div 1 = +1$.
Side 0/1, $(-1)\ (-1) \div 2 = +1/2$.
Side 2/1, $(+1)\ (+1) \div 3 = +1/3$.
Side 0/2, $(+1)\ (+1) \div 1 = +1$.
Side 1/2, $(-1)\ (-1) \div 1/2 = +2$.

The sum of these quantities is $1/2+1+1/2+1/3+1+2=5.333$.

The fourth term of equation 1 is—

Side 1/0, $(+1)\ (+0.246) \div 2 = +0.123$.
Side 2/0, $(-1)\ (-0.452) \div 1 = +0.452$.
Side 0/1, $(-1)\ (-0.020) \div 2 = +0.010$.
Side 2/1, $(+1)\ (+0.229) \div 3 = +0.0763$.

Combining these quantities gives $+0.123+0.452+0.010+0.0763= +0.661$, which is the coefficient of the term desired. Each other term of the normal equation is found in a similar manner.

These equations after solving by the usual methods give the values at the head of columns 1, 2, 3, and 4 in the right-hand part of the table of correlates. These values after multiplying by the quantities in columns t, u, v, and w are placed in their appropriate spaces and the sum for each line found as described on page 69. Each sum thus found for a side is then divided by the weight for the side, the quotient being the correction for the side, and the corrections thus found, if applied to the triangles (p. 64) and the sine equation (p. 65), will make a complete adjustment for the figure.

Correlates for weighted observations.

	Weights.	t	u	v	w	1 (+0.346)	2 (+0.001)	3 (−0.670)	4 (+3.447)	Sums.	Sums divided by weight.	Sides.
Sides.		1	2	3	4							
1/0	2	+1	....	+1	+0.246	+0.346	....	−0.670	+0.848	+0.524	+0.262	1/0
2/0	1	−1	+1	....	−0.450	−0.346	+0.001	....	−1.558	−1.903	−1.903	2/0
3/0	1	....	−1	−1	+0.206	....	−0.001	+0.670	+0.710	+1.379	+1.379	3/0
0/1	2	−1	....	−1	−0.020	−0.346	....	+0.670	−0.069	+0.255	+0.128	0/1
2/1	3	+1	....	....	+0.229	+0.346	....	....	+0.789	+1.135	+0.378	2/1
3/1	1	....	....	+1	−0.209	....	....	−0.670	−0.720	−1.390	−1.390	3/1
0/2	1	+1	−1	....	....	+0.346	−0.001	....	....	+0.345	+0.345	0/2
1/2	1/2	−1	....	....	....	−0.346	....	....	....	−0.346	−0.692	1/2
3/2	1	....	+1	....	....	....	+0.001	....	....	+0.001	+0.001	3/2
0/3	2	....	+1	+1	+0.022	....	+0.001	−0.670	+0.076	−0.593	−0.296	0/3
1/3	1	....	....	−1	−0.249	....	....	+0.670	−0.858	−0.188	−0.188	1/3
2/3	1	....	−1	....	+0.027	....	−0.001	....	+0.782	+0.781	+0.781	2/3

Normal equations for weighted observations.

1	2	3	4	Absolute.
+5.333	−2.000	+1.000	+0.661	−3.450
−2.000	+5.500	+1.500	−0.874	+4.700
+1.000	+1.500	+4.500	−0.022	+2.740
+0.661	−0.874	−0.022	+0.452	−1.800

In the solutions of the normal equations on page 68 no method was shown for checking the work before the final values of the unknown had been found and substituted in the full equations. There is a simple method for checking a solution frequently, and as it involves but little extra labor it should be adopted when a large number of simultaneous equations are to be solved. The check requires an added term for each equation, the numerical value of which is the algebraic sum of all the coefficients and the absolute term of each full normal equation. The check numbers should be given a sign opposite to that of the sum, so that the equations will still have the form of (a)+(b)+etc.=o.

In the following solution the check is used; the solution differs slightly in form of arrangement from that shown on page 68, and is in some respects simpler. (See p. 76).

The check column is numbered 6; the first term, line (a), is the algebraic sum of each quantity on line (a) with the opposite sign; similarly lines (c), (g), and (k) contain check numbers found from the sum of the quantities in each of the full equations; but as all the terms of each equation are not written down they may be found, because of the symmetry of the equations, from quantities given in other equations. For example, for equation 3 add together the quantities in column 3 of the normal equations (p. 73) and those on the third line: $+1.00+1.500+4.500-0.022+2.740=9.718$, hence -9.718 is the check number. The check numbers are to be treated in the solutions as if they were absolute quantities.

For the first equation the reciprocal of the first coefficient (5.333) with its sign changed is -0.1875; this multiplied by each term of line (a) gives the quantities in line (b). $+0.3750$ (column 2, line b) is next taken as a multiplier for all the coefficients immediately above it and for others to the right on line (a), the products being written on line (d).

Products for equation 3, written on line (h), are found with the multiplier. -0.1875 and the quantities in columns 3, 4, 5, and 6, line (a). All the other numbers on line (b) for any set of equations containing four or more unknown quantities, except those in the absolute column 5 and the check column 6, are used as multipliers, and the products are written under the equations to which they belong. Lines (c) and (d) are next added algebraically and the sums written on line (e).

Line (e) now consists of a complete equation containing but three unknown quantities, an absolute term, and a check term, and the algebraic sum of all the quantities on the line should be zero, reasonable allowance being made for slight errors introduced from the dropping of decimal places beyond the fourth. This constitutes the first useful applications of the check term.

The reciprocal of the first term in line (j) with sign changed is -0.2105; this multiplied by each quantity in line (e) gives the products on line (f); these also if combined algebraically should equal zero, and thus the work is again checked.

Products from multipliers for each unknown (-0.3947 and $+0.1318$) are next found in the same manner as for lines (a) and (b) and written under the equations to which they belong (on lines (i) and (m) in this example). The algebraic sum of each column under equation 3 is next to be found and written on line (j). This is now a complete equation with two unknown quantities, and the sum for the whole line should equal o, this being the third use of the check term. This elimination process is repeated and the check applied until line (p) is reached, the absolute term then being the value of the fourth unknown. This value is written on line (q), column 4, and the absolute quantities from column 5, lines (j), (f), and (b), are written in columns 3, 2, and 1, line (q). The numerical value of number 4 is next to be multiplied by the coefficients of number 4 in column 4, lines (j), (f), and (b), and the products written on line (r), columns 3, 2, and 1, respectively. The sum of the quantities in lines (q) and (r), column 3, is -0.6692, which is the value found for unknown number 3, and this value substituted in column 3 gives products for line (s).

Solution of simultaneous equations.

Reciprocals.	1	2	3	4	5 (absolute)	6 (check).	
	+5.333	−2.000	+1.000	+0.661	−3.450	−1.544	
		+5.500	+1.500	−0.874	+4.700	−8.826	
			+4.500	−0.022	+2.740	−9.718	
				+0.452	−1.800	+1.583	
−0.1875	+5.333	−2.0000	+1.0000	+0.6610	−3.4500	−1.5440	(a)
	−1.	+0.3750	−0.1875	−0.1239	+0.6469	+0.2895	(b)
		+5.5000	+1.5000	−0.8740	−4.7000	−8.8260	(c)
		−0.7500	+0.3750	+0.2479	−1.2938	−0.5790	(d)
−0.2105		+4.7500	+1.8750	−0.6261	+3.4062	−9.4050	(e)
		−1.	−0.3947	+0.1318	−0.7170	+1.9798	(f)
			+4.5000	−0.0220	+2.7400	−9.7180	(g)
			−0.1875	−0.1239	+0.6469	+0.2895	(h)
			−0.7401	+0.2471	−1.3444	+3.7122	(i)
−0.2799			+3.5724	+0.1012	+2.0425	−5.7163	(j)
			−1.	−0.0283	−0.5717	+1.6000	
				+0.4520	−1.8000	+1.5830	(k)
				−0.0819	+0.4275	+0.1913	(l)
				−0.0825	+0.4489	−1.2396	(m)
				−0.0029	−0.0578	+0.1618	(n)
−3.5125				+0.2847	−0.9814	+0.6965	(o)
				−1.	+3.4471	−2.4465	(p)
	+0.6469	−0.7170	−0.5717	+3.4471			(q)
	−0.4271	+0.4543	−0.0976				(r)
	+0.1255	+0.2642	−0.6693				(s)
	+0.0006	+0.0015					(t)
	+0.3459						(u)

Adjusting lines to unoccupied stations.—An adjustment can be made for the three lines to an unoccupied station as follows: Correct the observed angles to the unoccupied point to agree with previously adjusted angles at each occupied station; then form a sine equation, making the unoccupied station the pole of the pyra mid

The swings for the lines to the unoccupied station, which will be the corrections desired, will be the products of the sine differences for 1″ (coefficients of the sine equation) by the absolute term, divided by the sum of the squares of the former.

For each additional line more than three to the unoccupied station an additional sine equation is required, all to be solved in the usual manner.

Computations of distances.—These are to be made in book 9-901. The triangles are arranged in order from a given base or known side, one page or part of a page being taken for each new station. For each triangle the adjusted spherical angles and the spherical excess are given to hundredths of seconds.

Example of computation of distances.

Station.	Spherical angle.	Spherical excess.	Plane angle. 9.8853615	Log sines and distances.
	° ′ ″		° ′ ″	4.2984616
Browning	50 10 29.11	0.30	50 10 28.81	0.1146385
Elk	86 09 53.23	.30	86 09 52.93	9.9990263
Dick	43 39 38.56	.30	43 39 38.26	9.8390917
	180 00 00.90	....	180 00 00.00	....
Miles, 11.106			Browning to Elk.	4.2521918
Miles, 16.050			Browning to Dick.	4.4121264

After adjustment of several overlapping figures has been completed, it is occasionally necessary to find the length of some line joining two points which has not been included in the adjustment. Such lines may usually be computed by the formula for "two sides and the included angle." [1]

[1] Geographic tables and formulas, p. 8; U. S. Geol. Survey Bull. 650, p. 8, 1916, reprinted 1918.

The rule for the solution of plane triangles for which the three angles and one side are given is that the sides are proportional to the sines of the opposite angles. By always arranging the angles in the above form with the new station first, the solution is made somewhat mechanical. The logarithms of the sines of plane angles are, of course, used; that for the angle at the new station from which distances are required to the other two stations is written immediately above the angle; its arithmetical complement (10 minus the sine) is written to the right and on line with the angle. Each of the other sines is placed on line with the angle to which it relates. Immediately above the sines is written the logarithm of the distance in meters between the second and third stations in the triangle; in the example this is 4.2984616 for the line Elk to Dick.

To get the logarithm of the distance from the new station (Browning in the example) to one of the other stations, omit the sine opposite the latter and add together the remaining logarithms in the right-hand column. The distance to thousandths of a mile for each computed line must be found and placed to the left of the names of the terminal stations. The work should be verified by comparing distances for each line that has been computed from two or more triangles.

Computation of geodetic coordinates.—For this work use book 9–902 and check results by computing each position from two stations which form a triangle with the new station. For convenience, only one of the computations is here given:

	° ′ ″
Azimuth a: *Elk-Dick*	*96 56 01.12*
Spherical angle at *Elk*	*86 09 53.23*+
Azimuth a′: *Elk-Browning*	*183 05 54.35*
Δa+180°	*180 00 24.02*
Azimuth (a): *Browning-Elk*	*3 06 18.37*

Geodetic coordinates.

LATITUDE.				LONGITUDE.	
	° ′ ″				° ′ ″
ϕ	37 28 47.32	*Elk.*		λ	82 00 16.16
$\Delta\phi$	9 38.88(+)			$\Delta\lambda$	0 39.40(−)
ϕ'	37 38 26.20	*Browning.*		λ'	81 59 36.76
Computation for latitude:				Computation for longitude:	
log s	4.2521918			log s	4.2521918
log B	8.5110415	Δ *arc and sine*		log sin a′	8.7328074(−)
log cos a′ ...	9.9993647(−)	(*log s*) ...	−06	log A′	8.5091777
		(*log* V) ..	+00	log sec ϕ'	0.1013532
log (I)	2.7625980(−)			Δ a and s	(−6)
			−06	log (V)	1.5955295(−)
log s²	8.50438				39.403−
log C	1.28943				
log sin² a′ ...	7.46561				
				$\Delta\lambda$	39.40−
log (II)	7.25942				
log D	2.3771			Computation for azimuth:	
log [I+II]² ..	5.5252	° ′ ″		log (V)	1.595530(−)
log (III)	7.9023	ϕ 37—28—47.3		log sin $\left(\frac{\phi+\phi'}{2}\right)$	9.785041
		ϕ' 37 43 24.4			
				log sec $\left(\frac{\Delta\phi}{2}\right)$	0.000000
log E	6.0528	72 11.7			
log s² sin² a′.	6.3309	° ′ ″			
log (I)	2.9431(−)	37 36 06		log (VI)	1.380572(−)
log (IV)	5.3268(−)			−Δa	24″.02(−)
−IV	.000(−)			Δa	24″.02(+)
(I)	877.126(−)			Azimuth check.	
(II)	.004 +				° ′ ″
(III)	.018 +	[I+II]	578.891		53 16 47.48
(IV)	.000(+)	log [I+II]	2.762598		3 06 18.37
−$\Delta\phi$	877.104(−)	log [I+II]²	5.525196		50 10 29.11
	′ ″			Spherical angle	
$\Delta\phi$	14 37.10(+)			at *Browning*	50 10 29.11

Computation of Azimuth a, in Book *A1505*, page *26*.
Spherical angle and distance s, in Book *A1570*, page *32*.

Computed by *D. M. E.*

[NOTE.—The signs (+) or (−) placed after logarithms are the signs of the cosines or sines of the azimuth used in the computations.]

In this example the azimuth, 96° 56′ 01″.12, is derived from a previous computation. The spherical angle is that at Elk from the adjusted figure. Whether to add or subtract this can be determined very easily by inspecting a plat of the stations, but when for one of the pair of computations the spherical angle is added, the other is always subtracted. The latitude and longitude at Elk are also derived from a previous computation. Logarithm *s* is the logarithm of the distance in meters between Elk and Browning. The constants B, C, D, and E are from "Geographic tables and formulas"[1] for the known latitude at Elk. Cosine a′ and sine a′ are functions of the azimuth Elk to Browning. The algebraic sign of each of these as fixed by trigonometric rules determines the sign of the resulting quantity. The signs of (II) and (III) are always positive; that for (IV) is always opposite to that of (I). The constant A′ and secant ϕ' in the longitudinal computation are for the new latitude, which requires that the latitude computation be made first. These two factors will be the same for each of the pair of computations for the new position. For short lines, corrections (III) and (IV) will usually be less than 0.01″ and may be neglected.

When the logarithm of distance *s* in meters exceeds 4.0000000, a correction will usually be required for logarithm (V) for the difference between the arc and sine. The constants for computing this are given on page 269 of "Geographic tables and formulas,"[2] the arguments being log distance *s* and log (V). The difference between the values found is to be applied, according to the sign of the greater, to log (V) before finding the value of the latter in seconds.

Six places of decimals will usually give sufficient accuracy for log (VI). The logarithm of secant $\left(\frac{\phi\Delta}{2}\right)$ may be taken from page 268 of the tables. When log (V) is large, say over 3.5000000, a correction in seconds[2] will be needed for Δa expressed by the factor $(\Delta\lambda)^3$ F. The logarithm of (V) is multiplied by 3 and added to the logarithm of F, which is given in the tables; the value in seconds for the resulting logarithm is always to be added to the previously found value in seconds for (VI).

The latitudes and longitudes for each point thus computed in pairs should agree within one or two one-hundredths of a second.

[1] See also Coast and Geodetic Survey Special Pub. 8, 1911.

[2] See also U. S. Geol. Survey Bull. 650, p. 292, 1916, reprinted 1918.

The difference between the two reverse azimuths should also agree with the corresponding adjusted spherical angle within one or two one-hundredths of a second.

The formulas for finding azimuth and distance between points whose latitude and longitude are known and the form for 3-point computations are given in "Geographic tables and formulas." Special blanks for 3-point work may be procured by application to the Washington office.

Tabulation of results.—The final step in the computation of triangulation is the tabulation of the results. A printed blank is used; on it is written the name of the station, the State and county in which situated, the kind of signal and the center mark used, a full description of the station (see p. 53), the latitude and longitude, the azimuth, the back azimuth, and the logarithms of distances in meters and corresponding distances in miles to all other stations from which it is visible; also a statement regarding the datum on which positions are based. Whenever possible this should be the North American datum (formerly known as the United States standard datum).

PRIMARY TRAVERSE.

FIELD WORK.

PERSONNEL AND OUTFIT OF PARTY.

In primary traverse the party consists of an instrument man in charge, a recorder, two chainmen, and two rodmen; also a cook and teamster when camping is necessary.

The following supplies can be obtained on requisition:

One transit, graduated to 30 seconds and furnished with stadia wires.
Two 300-foot steel tapes, graduated to feet throughout.
One 100-foot steel tape.
Two red and white transit rods.
One stadia rod.
Two plumb bobs.
Eleven tally pins.
Three hand recorders.
Two electric hand lamps.
One tape-repair outfit, punch, and rivets.
Three tape clips, temporary repairs.
Two tape holders.
One set steel dies (figures).
One set steel dies (letters).

Three large book bags.
Standard bench-mark tablets or posts (according to the requirements of the country).
Canteens.
Cement (in cans).
Drills, hatchet, hammer, and posthole digger.
Primary traverse field notebooks, 9-928.
Chainmen's notebooks, 9-929.
Blank notebooks, 9-896, or 3 by 5 inch pieces of manila paper.
Book of instructions.
Polaris tables.

The instrument man must carry a reliable watch.

PREPARATORY WORK.

Location of line.—Primary traverses should always be run in circuits or tied to points previously located. In 15-minute quadrangles, in country where routes can be readily planned, traverse lines should follow as closely as possible the borders of the quadrangles to be controlled, not departing from them more than is absolutely necessary to keep on roads. If there is a choice of roads, select the one in unmapped areas. An additional line should be run to bisect the quadrangle.

In areas where the country will not permit this plan to be followed economically and where the selection of routes for the lines must be influenced by the location of highways, it will be necessary to plan the routes to meet the specific requirements.

Permanent marks.—In regions where topographic conditions permit, tablets or iron posts (see *C* and *F*, Pl. I, p. 48) must be set as near as possible to each corner of each 15-minute quadrangle, one on each side halfway between the corners and one in the center of the quadrangle, making nine in all. All such marks must be stations on the line and should be stamped "Prim. Trav. Sta. No. —" (numbered consecutively) and also with the year of survey. In areas which can not be traversed according to the regular plan, permanent marks must be established at intervals not greater than 6 miles.

In cooperating States use the appropriate State post or tablet (*A*, Pl. I, p. 48).

Where level bench marks have been established along the route of survey, they should be tied to and stamped as above and thus made to serve as permanent marks on the traverse line.

At each station where a permanent mark is set, measure bearings with the transit to two or more well-defined and fixed points, preferably 500 feet or more distant, to be used as azimuth reference marks for future work beginning at that station, the bearings, distances, and descriptions being duly recorded in the notebook.

Secondary points.—Besides the permanently marked points, a number of other points should be carefully located along the traverse, and these points should be specifically designated in the field notes. Of special importance are the crossings of boundaries of States, counties, and civil townships, and the locations of the principal crossroads, of railroad stations when the line follows a railroad, and of township and section corners if the region is subdivided by public-land surveys. Note should also be made of less important landmarks, such as road forks, mileposts, railroad switches, road and stream crossings. These points should be so completely described in the notebook as to be readily identified.

TAPING.

Duties of chainmen.—The front chainman carefully marks off each tape length; if on a wagon road, with tally pins; if on a railroad, with keel on the rail. Each time he marks off a tape length he registers it on his hand recorder; each time the rear chainman reaches the mark left by the front chainman he does likewise. When a transit station is established the two chainmen compare their hand records for check on the measurement. Should they differ, the course must be remeasured.

Transit stations should be made at even tape lengths or even 10-foot marks, wherever possible, in order to simplify the work of the computer. They should be selected at points affording not only an unobstructed view back to the transit but also a clear view forward. Each station is to be marked, if on a wagon road, by a 10-penny nail driven into the ground through a piece of paper on which the front chainman has written the number of station and distances; if on a railroad, by a keel cross on rail, with number and distance on nearest tie.

Stations on main lines are to be numbered consecutively, beginning with zero; those on short spur lines to section corners or other points to be computed are to be lettered instead of numbered. Station numbers should never be duplicated in a single locality.

The two chainmen must keep in book 9–929 separate records of the number of stations and distances between them. At noon and at night these records must be compared with the recorder's notes, and should there be a difference, it must be corrected before the line is carried forward, the line being retraversed if necessary.

In locating transit stations the front chainman should bear in mind that it is desirable for the instrument man to be able to sight the bottom of the rod in each direction. This is especially important on short sights, for errors due to sighting the upper part of a rod which may be out of plumb may appreciably affect the accuracy of the line.

Method of measuring.—When measuring along a wagon road the tape must be kept horizontal unless the grade is very slight; on steep slopes a plumb bob must be used either to bring the tape end vertically over an established point or to establish a new one, as the case may be. Judgment should be used in selecting the proper length of tape on slopes; no attempt should be made to use the full 300-foot length; about 150 feet is ordinarily all that a chainman can hold horizontal with the proper tension and plumb at the same time. On slopes that require "breaking" the tape into short sections, the entire tape should first be drawn forward its full length by the front rodman if convenient, or by the front chainman, who then returns to help "break" the tape at the proper places, until the end of the tape is reached. In this manner the distance is measured on the whole tape and does not depend on the sum of the separate horizontal measurements.

Some tension must be put on the tape, but the use of a spring balance has been found by experience to be unnecessary.

Errors in taping.—The errors that most seriously affect the accuracy of taped lines may be classed under two heads.

The errors of one class are due to failure to keep the tape horizontal and to careless plumbing. The instrument man should impress chainmen with the fact that the accuracy of traverses depends on their work more than on the instrumental work, for the latter is checked at every azimuth observation, whereas there is no check on the taping until the circuit is closed.

The errors of the second class are gross mistakes arising generally from carelessness in counting tape lengths. They may be eliminated by checking the count of tape lengths by independent measurements.

To do this, the instrument man should read each distance by stadia on the red and white transit rod on a special stadia rod carried for this purpose. In case the distance is too great to be read by a single sight, he should set up the transit between stations and read both front and rear rods. Stations should in no case be more than 2,600 feet apart, which is about the limit of visibility of the rod. On railroads an additional check on the taping may be had by counting rail lengths. This should be done by both rodmen and by the recorder, or by the instrument man while moving from one station to the next. In other places a check may be had by pacing.

OBSERVING AND RECORDING.

Deflection angles.—At each station, in reading deflection angles, the instrument man should proceed as follows: Sight rear rod with transit circle set at last reading at previous station, transit telescope, sight front rod, and read both verniers. Turn instrument with the two plates clamped, the vernier remaining undisturbed; sight rear rod again and remeasure the angle. If the two results thus obtained differ more than 60″, repeat the operation.

When the transit is carried from one station to the next, keep the upper plates clamped so as to retain the last vernier reading; after setting up the instrument verify the reading and use it as the first back sight reading at the new station. By following this plan a useful check on the readings is procured without trouble, and it also permits easy and quick computation of an azimuth at any station. The approximate azimuth of a line must be known at a station where daylight observations are to be made on Polaris in order to determine the proper pointing for the star.

Computing azimuth.—If the foregoing rule has been adhered to, the azimuth of a line at any station at which the deflection angle is read twice only may be found as follows:

Find the difference between the A vernier reading for the last foresight along a preceding course the azimuth for which is known and the A vernier reading for the last foresight along any following course the azimuth of which is desired; subtract the smaller reading from the larger and divide the difference by 2. Adding the quotient to the known azimuth when the later A vernier reading is greater or subtracting it from the known azimuth when the later A vernier reading is less will give the azimuth desired.

Example:

At station 10 the last A vernier reading of foresight from station 10 to 11 is 120° 42′ 00″.

At station 72 the last A vernier reading on foresight from station 72 to 73 is 94° 20′ 00″

The azimuth of line 10 to 11 is 167° 25′ 00″.

120° 42′ 00″−94° 20′ 00″=26° 22′ 00″.

½ of 26° 22′ 00″=13° 11′ 00″.

Known azimuth 10 to 11	=167° 25′ 00″
	− 13 11 00
Azimuth of line station 72 to 73=	154° 14′ 00″

The half angle is subtracted in this example because the second vernier reading is less than the first.

Azimuth observations.—Observations on Polaris for azimuth must be made each day if the weather permits. On a crooked line with many short courses azimuth stations should be not more than 100 stations apart; on a traverse with long tangents they should fall not more than 15 miles apart. When practicable an azimuth station should be placed at each decided change in the direction of the line. These requirements may necessitate going back over the line in order to make the necessary observations, but if conditions are favorable it is possible to make azimuth observations in broad daylight.

Both the transit and the azimuth mark must be at stations in the traverse not less than 500 nor more than 1,500 feet apart. Each point should be marked by a stake with a tack, or, if on a railroad, by a nail in a tie. The azimuth mark may consist of a vertical slit one-eighth inch wide and 6 inches long cut in the side of a box or tin can containing a candle or lantern, which should be carefully centered over the tack in the stake. In pointing the telescope use the electric hand lamp to illuminate the cross wires, holding it nearly in front of the object glass, or allow it to shine on a piece of paper fastened with a rubber band in front of the object glass and having in it a half-inch hole.

Angles should be read as follows: Set on azimuth mark, then on star; reverse telescope, set on star again, and then on azimuth mark. Each observation should consist of not less than three direct and three reverse measurements, the circle being shifted for each set by about 60°. (See sample page of record below.) Observations may be made at any time the star is visible, but preferably when at or near elongation. The time of setting the cross wires on the star must be recorded to the nearest second. Observations should be made rapidly; not more than 15 minutes need be taken to complete a set. The notes must be kept in the following form:

Date, Sept. 10, 1912. Line from Pikeville west to Dayton, Mo.

Azimuth observation 2.5 miles southeast of Dayton, Mo., evening of Sept. 10, 1912. Mag. bearing sta. 327–328 N. 59° 30′ W. Lat. 39° 00′. Long. 92° 15′.

Instrument at station 327. Mark at station 328. Watch 35 seconds fast, 90th meridian time.

Point.	Vernier A.	Vernier B.	Mean.	Deflection angle.	Azimuth.	Time.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	H. m. s. (p. m.)
Mark	99 05 00	279 06 00	99 05 30	53 55 45	....	8 31 33
Star[a]	153 01 30	333 01 00	153 01 15	53 56 30	....	8 34 48
Star	333 02 30	153 03 00	153 02 45	....	....	
Mark	279 06 30	99 06 00	99 06 15	....	....	
Mark	352 02 30	172 02 00	172 02 15	....	....	....
Star[a]	45 57 00	225 56 30	225 56 45	53 54 30	....	8 40 28
Star	225 57 00	45 57 00	225 57 00	53 54 45	....	8 41 50
Mark	172 02 00	352 02 30	172 02 15	....	....	
Mark	220 54 00	40 54 00	40 54 00	....	....	
Star[a]	274 48 00	94 48 00	94 48 00	53 54 00	....	8 43 55
Star	94 50 30	274 50 30	94 50 30	53 54 30	....	8 44 56
Mark	40 56 00	220 56 00	40 56 00	....	....	....
				53 55 00		8 39 35
				Watch fast	....	35
				Corrected time	....	8 39 00

[a] Reverse telescope between each two readings on star.

The latitude and longitude of each azimuth station, scaled from the best map available to the nearest minute, should be given, together with the date of observation, on the page with the other records, in order to enable the computer readily to convert standard to local mean time.

Sun observations.—When it is impracticable to take observations on Polaris for azimuth, observations on the sun may be taken instead, but such observations should not be taken within two hours before or after noon, or when the vertical angle of the sun is less than 15°.

With the transit in good adjustment and carefully leveled, set cross wires on rod held at a station in the traverse line, read and record both verniers, point telescope to sun, allowing the image to fall on a piece of white paper held 3 or 4 inches from the eyepiece, then focus cross wires on this image. By means of the two tangent screws, move the telescope till the vertical and horizontal wires bisect the image (care being taken to use the middle horizontal wire and not the upper or lower stadia wire), read and record horizontal and vertical angles. Repeat the pointing at least three times and after the last pointing read again on the rod. Reverse telescope and repeat the readings as before.

Time should be recorded to the nearest minute at the first and last pointing and the mean used.

In case unfavorable weather prevents the taking of azimuth, leave adequate marks at a point selected, before proceeding with the line, and return later to make the observations.

Watch error.—The instrument man must carry a reliable watch and keep it in good condition. He should ascertain its error daily by comparison with telegraphic time, which is sent over Western Union lines once a day. In case he has no opportunity to make this comparison while running the line, he should do so as often as possible, figure the rate of error per day, and record the proper correction for each azimuth observation made. A watch error of 20 seconds or less will not appreciably affect the accuracy of the determination. For all azimuth observations between 2 a. m. on the last Sunday of March and 2 a. m. on the last Sunday in October in any year use advanced or "daylight saving" time and so state on each page of the notes, remembering to make whatever time correction is necessary in taking positions or time from astronomic tables.

Magnetic declination.—A careful reading of the needle for magnetic declination should be made at frequent intervals and recorded opposite the proper station number in the notebook. Such determinations should be made at each azimuth station and at favorable points along the line where the needle is not likely to be affected by rails, electric wires, or similar disturbing elements. At azimuth stations determine the magnetic bearing of the azimuth mark at the time it is established. If the line follows a railroad, magnetic determinations should be obtained from a parallel line at a distance of 25 yards from the rails or wires.

Field record.—Complete notes must be kept by the recorder in book 9–928, to be written in a plain, neat hand with a No. 4 pencil. The blanks in the title page should be filled in the first day the book is used. A single line should be drawn through erroneous records, which must never be erased.

The recorder must take down the vernier readings, as they are called off by the transit man, and compute the mean pointings and deflection angles, giving proper signs to the latter. He must keep up with the instrument man in these computations, as they enable him to note by inspection whether the instrument man has made errors in his readings and to call attention to them before the instrument is removed from the station. He should take special pains to see that the degree and minute numbers for the two verniers are consistent and are recorded in the proper columns.

The notes are to be kept in the following form:

Date, Sept. 9, 1912. Line from Pikeville to Dayton, Mo.

Distance between stations.	Vernier A.	Vernier B.	Mean.	Deflection angle.	Azimuth.	Remarks.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Sta. 326: 3 tapes	316 51 30	136 52 30	316 52 00		[a]123 35 00	
	275 06 00	95 07 00	275 06 45	41 45 15		
	233 21 00	53 22 00	233 21 30	41 45 15	....	Stadia 905.
900				−41 45 15	[b] 81 49 45	
					[c] 81 49 47	
Sta. 327:4 tapes +120=	233 21 00	53 22 00	233 21 30	45 43 15	....	Sta. 327–328 N.59° 30′ W. Stadia 1,330.
	279 04 00	99 05 00	279 04 45	45 44 15	....	
	324 48 30	144 49 30	324 49 00			
1320				+45 43 45	[b]127 33 30	
					[c]127 33 34	
Sta. 327+90 feet, stream crossing.						
Sta. 327+430 feet, crossroad at Tanbark P. O.						
Sta. 328........	324 48 30	144 49 30	324 49 00	17 19 30		
	342 08 00	162 09 00	342 08 30	17 19 00		
	359 27 00	179 28 00	359 27 30		....	Stadia 260.
260				+17 19 15	[b]144 52 37	
					[c]144 52 43	

[a] Written in red ink. [b] Written with black pencil. [c] Written in black ink.

The record must contain also a description of the starting and ending points of the line, of each permanent mark established along the line, of each point which is to be computed for the use of the topographer, and of all crossings and other landmarks that may be of value to him. Such descriptions should be concise, yet full enough to leave no possible doubt as to the identity of the points described. Each should be supplemented by an explanatory sketch, if necessary. Commence the description on the next line after the angle record.

Example of description of permanent mark:

Station 1025, bench-mark tablet stamped "Prim. Trav. Sta. No. 4, 1912," set in sandstone ledge, top of Walden Ridge, 3 miles northwest of Dayton, Mo., at junction of Dayton, Pikeville, and Morgan Springs roads, 325 feet west of residence of John Neilson. Reference marks: Cross cut in ledge 60.25 feet N. 25° 30′ E.; spike in root of white-oak tree 14 inches in diameter, 75.60 feet N. 45° 15′ W.

Examples of description of points to be computed and other landmarks:

Station 625+730 feet [center of crossroads at Antioch Church].
Station 720+320 feet, east abutment of bridge over Glade Creek.
Station 732 is road fork at Johnson blacksmith shop.
Station 926+210 feet [center of track opposite semaphore, Lee station].
Station 936+300 feet, road crossing one-half mile east of Sequatchie railroad bridge.

Each point to be computed should be marked with brackets in ink immediately upon its selection by the instrument man.

As soon as the records in a field book are completed, it should, if not needed for reference, be sent at once to the Survey office in Washington by registered mail. Chainman's books should be sent separate from other notes and on another day.

PRIMARY-TRAVERSE COMPUTATIONS.

The steps in primary-traverse computations are as follows:

Computation of azimuths from observations on Polaris.
Computation of the deflection angles.
Adjustment of closing errors.
Computation and tabulation of latitudes and departures which are the north and south distances and the east and west distances, by two computers working independently.
Computation of latitudes and longitudes.
Adjustment of closures in position.
Computation of diagonals.
Tabulation of results by atlas sheets.

The computations are made in books 9-928 and 9-931. The abstracts of results are placed on long sheets of blank paper.

Computation of azimuths from observations on Polaris.—First find the mean of times of observations and corresponding mean of angles measured between mark and star (p. 87). Having given the approximate latitude and longitude of the azimuth station, compute the true azimuth of star by the tables published annually by the General Land Office.

Example of computation: The station (see p. 87) is in latitude 39° 00′ N., longitude 92° 15′ W.

	H.	*m.*	*s.*
Sept. 10, 1912, 90th meridian standard time of observation, p. m. (correction having been made for watch error)	8	39	00
Correction for 2° 15′ longitude west of 90°		− 9	00
Local mean time of observation	8	30	00

The nearest upper culmination of Polaris as given in the tables is that for September 11 at 2^h 9.6^m a. m., Greenwich mean time, civil date. The correction, always negative, to reduce this to local meridian is:

$\frac{92\frac{1}{4}}{360}$ (of the daily change $(3.9^m) = -1^m\ 0^s$.)

	H.	*m.*
Local mean time of upper culmination (Sept. 11, a. m.)	2	08.6
Hour angle, being the interval between time of observation and time of culmination[1]	5	38.6
	°	′
With this hour angle as an argument and the declination for the given date (88° 50′ 15″), find by double interpolation from the table of "Azimuths of Polaris" in the Land Office table the azimuth angle for the latitude and time	1	29.5
Since the star had not reached upper culmination, it is east of north, or, 180° being added, has an azimuth of	181	29.5
Angle between mark and star (p. 87) (star east of mark)	53	55.0
Azimuth at station 327 to 328	127	34.5

A rough check on this azimuth may be found by comparing it with the observed magnetic bearing, allowance being made for declination. To interpolate for hours angles near elongation, use for the latter 5^h 55^m.

[1] The hour angle will always be less than 12 hours and must be found from the nearest upper culmination; when, as in this case, the nearest upper culmination is in the following day, add 12 hours to its time before subtracting the time of observation.

Computation of sun azimuths.—The data required for the computation of sun azimuths are the latitude of the place, which, if not otherwise known, may be scaled from a map; the sun's declination for the day, from the General Land Office tables, corrected for time west of Greenwich, and the observed altitude of the sun corrected for index error of vertical circle and for mean refraction. The refraction may be found on page 334 of Bulletin 650, or its approximate value in minutes is equal to the natural cotangent of the altitude.

The formula for the computation is:

$$(\text{Cot}^2 \times \frac{\text{azimuth angle}}{2} = \frac{\text{sin of (S}-\text{latitude)} \times \text{sin (S}-\text{altitude corrected for refraction)}}{\cos \text{S} \times \cos \text{(S}-\text{polar distance)}}$$

in which S=½(latitude+corrected altitude+polar distance). The polar distance is 90°−declination when sun is north; 90°+declination when sun is south.

Example:

Aug. 25, 1917, at 9.45 a. m., 90th meridian time, latitude 42° 22′ 34″.

Observed altitude (mean of direct and reverse)	49° 33′ 15″
Mean refraction	−49″
Corrected altitude	49° 32′ 26″
Declination Aug. 25, 1917, at Greenwich noon	=10° 52′ 37″ north.
Hourly difference −51.63″.	
Difference for 6^h less 2^h 15^m before local noon or 3^h 45^m after Greenwich noon	= 3′ 14″
Declination required	10° 49′ 23″
Polar distance	79° 10′ 37″

Lat.=	42° 22′ 34″
Alt.	49 32 26
P. d.	79 10 37
2 S=	171° 05′ 37″
S=	85 32 48

Log sin (S−latitude)	=	9.83516
Log sin (S−altitude)	=	9.76928
A. C. log cos S	=	1.10988
A. C. log cos (S−polar dist.)	=	0.00269
Log cot² ½ azimuth	=	0.71701
Log cot ½ azimuth	=	0.35850
½ azimuth	=	23° 39′ 15″
Azimuth of sun	=	47° 18′ 30″

The sun being east of south this angle must be subtracted from 360° to get the geographic azimuth, which gives 312° 41′ 30″. Add (or subtract) the observed angle between the mark and the sun and the result will be the azimuth of the line to the reference mark.

Each azimuth computation is to be made in the field notebook on the same page with the observations and the results written in red ink in the azimuth column of notebook (see p. 89) on the line with the station occupied.

Daylight azimuth observations.—On a clear day, if the approximate pointing in azimuth and altitude are known and the telescope is properly focused, Polaris can usually be seen at any time within two or three hours after sunrise or before sunset and often near midday. The proper focus should be found at night and a mark made on the telescope tube as a guide for future reference.

Field computation of azimuth.—Azimuth notes must be computed as soon as possible after observations are made and the results applied to the deflection angles. These computations must be made at odd times when they will not interfere with other work. (See p. 91.) Errors of closure in azimuth should not be distributed until checked by a second computer either in the field or in the office.

Computation of deflection angles.—The mean deflection angle is combined according to its sign with the azimuth from the preceding station and the result placed in pencil opposite the deflection angle used. This process is repeated until the next computed azimuth, written in red ink, is reached.

The last azimuth in pencil will probably not agree with the observed azimuth. For any line not running due north or south there will be a discrepancy between observed and computed azimuths, due solely to convergence of meridians, which for latitude 30° will be 0.5′ for each mile run east or west. For latitude 49° the amount will be 1′. For any latitude the convergence in minutes of arc will be the difference in minutes of longitude between ends of line, multiplied by the sine of the middle latitude. For lines running east the computed azimuth should be less than the observed. For lines running west it should be greater.

Adjustment of closing errors.—If no large errors appear in the results, the discrepancy between computed and observed azimuths at the closing station is to be divided by the number of stations and a proportional correction applied to each penciled azimuth, the corrected figures being written in black ink.

Computation of latitudes and departures.—Latitudes and departures are to be computed in book 9–931, as shown below:

Line from Pikeville to Dayton, Mo.

Station.	Azimuth.	Distance.	Sine.	Cosine.	North.	South.	East.	West.
	° ′ ″	*Feet.*			*Feet.*	*Feet.*	*Feet.*	*Feet.*
326 to 327......	81 49 47	900	0.990	0.142	....	128	....	891
337+430.......	127 33 34	430	.793	.610	262	....	....	341
					262 128	128	....	1,232
327+430 to 328.	127 33 34	890	.793	.610	134 543	....	....	706

Natural sines and cosines for the azimuths given are written in the appropriate columns. By means of Crelle's tables the products of these by distances are found and placed in the proper columns. The sines multiplied by the distance give departures east or west. When the sine is positive, the new point is west; when negative it is east. Cosines multiplied by distances give latitudes north or south. When the cosine is negative, the new point is north; when positive it is south. The direction of the new point can readily be determined by noting the azimuth, remembering that 0° azimuth is for a line running due south, 90° for a line due west, 180° for a line north, and 270° for a line east. In the example 81° 49′ 47″, being for an azimuth between due south and due west, will be to a point southwest. Four decimal places in sines and cosines should be used when distances are greater than 1,000 feet.

When traverse tables for distances 1 to 100 for single minutes of arc are available, the latitudes and departures may be written in the north, south, east, and west columns direct for each azimuth and distance.

Whenever a point is reached for which the latitude and longitude are desired, as at 327+430 in the example, leave six blank spaces for the computation. The data for the computation for such a point are found from the record on page 89, as follows: For the crossroad at Tanbark post office, which is on line between stations 327 and 328, the azimuth is the same as to station 328. The distance by measurement is that given, 430 feet from station 327. In order to make the computations continuous, station 328 is taken as 1,320−430=890 feet from the intermediate point used, the azimuth being the same for both points.

Computation of latitudes and longitudes.—The next step in this work is the computation of latitudes and longitudes. These should be determined for important points a mile or less apart. Assume, for illustration, that for station 326 (p. 94) the coordinates have been computed, and that 327+430 is the next location desired. Each of the four columns—north, south, east, and west—is summed, and the difference between the sums of the north and south columns is placed in the column of the greater. Likewise, the difference between the east and west columns is placed in the column of the greater. The computations of latitude and longitude and the descriptions of the points are placed on the right-hand page of the book opposite the group of stations.

The logarithms of the geodetic constants for metric measures, called "the A, B, C factors," are on pages 196 to 267, inclusive, of "Geographic tables and formulas."[1] Factors A and B are used to five decimal places only. These will be practically constant for a distance of 10 or 15 miles north and south, the value for the middle latitude being used.

For the example on page 94:

Log distance 134 (north)	2.12710
Log to reduce feet to meters	9.48402
Log B for latitude 39° 00′	8.51093
	0.12205

The sum, 0.12205, is the logarithm of change in latitude in seconds between station 326 and 326+430=1.32″ (north).

For change in longitude:

Log distance 1,232 (west)	3.09061
Log to reduce feet to meters	9.48402
Log A for latitude 39° 00′ 00″	8.50914
Log secant of middle latitude	0.10950
Log of change in longitude in seconds	1.19327
New point west	15.61″

[1] See also U. S. Geol. Survey Bull. 650, pp. 219–290, 1916, reprinted 1918.

These differences are to be added to the latitude and longitude of station 326.

When the Survey tables of M and P factors, prepared by D. H. Baldwin, are available, the computation of changes in latitude and longitude may be materially shortened by adding log M to the log of distance north or south for change in latitude, and by adding P to the corresponding distance east and west for the change of longitude.

The foregoing computation would then be written as follows:

For the latitude change:

Log distance 134 (north)	2.12710
Log M for latitude 39° 00′	7.99495
Log of change in latitude in seconds	[1] 0.12204

For the longitude change:

Log distance 1,232 (west)	3.09061
Log P for middle latitude	8.10266
Log of change in longitude in seconds	1.19327

To check the plotting, the distance between successive positions must be computed. As the lines are seldom as much as 1 mile in length and never over 2 miles, the latitude and departure can with sufficient accuracy be taken as the base and perpendicular of a plane triangle. The distance sought will then be the hypothenuse and its square will be equal to the sum of the squares of the base and altitude. For distance less than 10,000 feet Barlow's tables should be used in finding squares or square roots. The distance should be written in red ink, inclosed in a circle, on the right-hand page of the computation book in the blank space between the two stations referred to. After the record is complete its accuracy should be tested by computing a side from the given distance (hypothenuse) and the other side.

Adjustment of closures.—These operations are repeated for each selected point until the traverse line closes back on itself or ties to another point previously determined. The errors of closure for a

[1] The difference in the fifth place is the result of carrying forward decimals from the sixth place in the first computation.

15′ quadrangle, if not in excess of 1″ in latitude or 1¼″ in longitude, may be distributed proportionately between initial and closing points.

Where so many operations are involved, errors are very likely to creep into the computations. Therefore each step of the work should be checked as well as possible. The azimuth computation should be compared with the observed magnetic bearings; but because of the possibility of local variation little dependence can be placed on this comparison as a check. If the computed and observed azimuths for a line differ about 10′, look for an error of that amount in the deflection angle or in the adding and subtracting of deflection angles to azimuths. If the difference is larger, it is very likely that a wrong sign has been used for a deflection angle. To find the error, divide the difference by 2 and look for a deflection angle with an incorrect sign equal to the quotient. Errors of about 180° occasionally result from the recorder placing the vernier readings in the wrong columns. By a careful inspection of the records it is sometimes possible to detect such an error. The latitudes and departures, as well as the other steps in the work, should be computed by two persons working independently of each other; after each has completed his work the results should be compared and differences corrected and verified. Errors are often due to incorrect multiplication by the distance, to the decimal point being in the wrong place, or to the product being written in the wrong column—in the north column when it should be in the south column, etc.

PRIMARY AND PRECISE LEVELING.

RESPONSIBILITY.

Unless specific instructions are issued to the contrary the topographer mapping a given area will be held responsible for the proper conduct of the level work in that locality, and to this end each topographer should be as familiar with the requirements as the men who are actually running the lines. Such close attention should be given to the work as will insure care and accuracy from the start and prevent gross blunders due to the misinterpretation of the rules or to a neglect to obey them.

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TYING NEW WORK TO OLD.

It is essential that the initial elevation of a new line be derived from two bench marks whose elevations agree within the limits of error permitted by the formula. (See p. 104.) If the two at first selected do not agree within these limits, continue the line until two are found that are in accord. In order to facilitate such connections a good secondary mark should be established near every probable tie point.

A tie to one bench mark will be sufficient for the end of the line, provided the closing is within limits; otherwise run to a second mark.

DISTRIBUTION OF PRIMARY-LEVEL CONTROL.

A sufficient amount of accurate spirit leveling should be done to insure the placing of at least two standard bench marks in each township or equivalent area surveyed, except in forest-clad or mountain areas, where at least one such mark should be placed in each township.

Permanent bench marks should be established along level lines at intervals of approximately 3 miles, unless otherwise instructed, and in no case should the distance between bench marks exceed 4 miles.

BENCH MARKS.

Permanent bench marks.—Bench marks should be established, if practicable, at the township corners of the public-land surveys, near all important lakes and reservoirs, at the crossings of important streams and divides, in every city or town passed through, and in the vicinity of important mines. They should be so located as not to be liable to injury or disturbance, yet should be so prominently situated as to be easily found. Along a railroad or highway bench-mark posts, if used, should be placed either outside of and close to the right of way or on the right-of-way line. They must not be set close to trees, telegraph poles, or fence posts.

Each levelman should have in mind plans for future extensions and whenever practicable should place bench marks where they will be conveniently situated for such extensions. A bench mark placed near the corner of a quadrangle will serve as a tie point for either of the three adjacent quadrangles.

Levelmen and primary-traverse men working in the same locality should arrange, if practicable, to tie to each other's permanent marks.

Each should ascertain whether there are any marks already set by the Geological Survey or other Government organization in the area assigned him for work.

Standard bench marks consist either (1) of tablets fastened with cement into solid rock in place or into masonry structures, such as the foundations of buildings or bridge piers, (2) of iron posts set in the ground so as to project not more than 6 inches from the top of a conical mound of earth about 3 feet in diameter and 6 or 8 inches in height (see Pl. I, p. 48), or (3) of tablets set in the top of concrete posts.

Tablet bench marks set in rock in place or in large boulders are always to be preferred to iron posts.

When there is a good-sized tree or building or rock in place within a few hundred feet of a permanent bench mark, a secondary mark should be left which may be used as a reference mark; all such marks should of course be turning points in the main line. A copper washer and nail in the root of a large tree or wooden structure or a cut on a rock will make a good secondary mark.

Tablets set in concrete posts make durable marks. Suitable posts may be made by contract in a town where materials are available or may be made by the levelman at the place where they are needed. They should be not less than 4 feet in length, square or round in sections, the sides tapered, the top at least 6 inches across, and the bottom about 12 inches thick. The post should be reinforced by four or five pieces of heavy galvanized-iron wire. The concrete should be 1 part cement, 2 parts sand free from loam or clay, and 3 parts coarse gravel or broken stone. The upper 12 inches of the post should be made of a mixture of 2 parts sand to 1 part cement, without adding any gravel or stone, and the tablet should be set so that its lettered surface is flush with the top of the post. The mixture should be made up with only sufficient water to moisten it thoroughly, but it must be well tamped in the mold. An excess of water is harmful. The post, when completed, should be sheltered from the sun for several days, and wetted frequently if practicable.

If made in a town concrete posts may be cast in wooden molds and when well hardened transported to places where they are needed.

When built in place a square or round hole at least 4 feet deep should be dug which will serve as a mold for the concrete and which, after reinforcing wires are in place, should be filled within 1 foot of the surface. Place on top of this a tapered section of sheet-iron pipe 6 inches in upper diameter and 20 inches long to serve as a form for the cement, a piece being used for each mark and left in place until it rusts off.

Portland cement in air-tight cans is furnished from the Washington office for use in setting tablets. If good clean sand is available, it can be mixed with the dry cement in equal parts. The drill hole for the tablet must be well cleaned and wet. The cement and sand, or cement alone, if pure sand can not be conveniently procured, should then be thoroughly mixed with water to a thick paste and the drill hole filled with it. Into this the tablet should be pressed, the excess cement being forced out, so as to completely fill the space under the tablet face. In order that the cement may set well, it should be kept damp and protected from the sun for at least a day, and it must not be allowed to freeze for 12 hours. Dry earth or a piece of sacking will probably be sufficient protection. When a tablet is set in a vertical wall, it may be necessary to hold it in place by a prop of some kind for a few hours.

The intersection of the cross lines on either style of mark is the reference point. Before a tablet is set the figures indicating the elevation (to the nearest foot only) are to be stamped into the metal before the word "feet." Posts should be stamped (to the nearest foot only) after they are in place. All such stampings should be checked by a second member of the level party. If a post or tablet is wrongly stamped, the level-man or topographer who discovers the error should immediately correct it by cutting out the erroneous figures with a chisel and stamping in their place the correct ones. The facts should be promptly reported to the chief geographer.

In cooperating States the name of the State must be stamped or cast on standard bench marks.

If a tablet is inconspicuously situated, a mound of rock should be erected near it, the rock about it marked with paint, or a near-by tree blazed as a witness tree.

The steel tape instead of the leveling rod can often be usep to devantage for determining the elevation of a tablet set in a vertical wall.

All standard bench marks should be used as turning points in the line, but where this can not be done *the elevation of each must be determined by two readings from different set-ups from two temporary bench marks.*

When a levelman finds a previously established standard bench mark broken or in bad order he should replace or reset it, after which its elevation must be redetermined and immediately reported to the chief geographer.

Intermediate or temporary bench marks.—Intermediate or temporary bench marks must always be turning points in the main line and should be set at intervals ranging from half a mile to 1¼ miles. They may consist (1) of chiseled marks on solid rock or masonry, or (2) of copper nails (with washers) or spikes driven in telegraph poles, mileposts, fence posts, or trees. The copper nails with lettered washers must be used when practicable. Where there are no natural objects for temporary bench marks, pieces of iron pipe about 20 inches long may be used. Select a place where the mark will not be likely to be disturbed and yet can be readily found, preferably near a road junction, so that it may afford a convenient tie point for other levels or traverses. The location should be conspicuously indicated by large figures in white or red paint, thus:

U S
[elevation]
B M

A substantial mark should be placed near every important post or tablet and its elevation accurately determined.

Useful elevations.—Besides the bench marks a number of intermediate elevations are required for the use of the topographer, and these also should be selected with a special view to their usefulness in topographic mapping. The levelman should bear in mind that his work is not an end in itself but a preparation for the work of others, and that the accuracy with which his circuits check, though of paramount importance, is not the only thing that determines its utility.

Ground elevations (to the nearest foot only) should be painted conspicuously along the side of the road, on fences, telephone poles, trees, or rocks. If practicable, they should all be marked on the same side of the road, preferably on the north or east side.

The points at which elevations are particularly desired are the top of the rail at railroad stations, junctions, sidings, and crossings, the ground at crossroads, road forks, and bends; on summits and ridges; near schoolhouses and other public buildings, lone houses, and important mines, quarries, and oil, gas, and artesian wells; on some permanent part of a bridge other than a wooden floor; the water surface of streams under bridges, at stream crossings, and above and below dams; and water surfaces on lakes and reservoirs. Where water-surface elevations are recorded, always give the date.

The number of these elevations should be varied with the nature of the country and the contour interval; thus in rugged regions mapped with 50 or 100 foot intervals relatively few elevations are required (mostly on summits and in hollows); but in areas of gently rolling relief they should be more numerous. In flat areas where 5 or 10 foot contours are used, each contour crossing should be marked with a stake or otherwise. This is important, as in such areas a difference in elevation of a few tenths of a foot may mean a difference of several hundred feet in the location of a contour.

Descriptions of bench marks and useful elevations.—Complete descriptions of all bench marks and useful elevations must be made in the notebook and copied in the description book (9–916) at the close of each day's work. A sketch must accompany the description of each standard bench mark, showing directions and distances to near-by objects.

Descriptions should be written with items in the following order:

1. Name of the nearest post office, town, village, or other well-known locality, with direction and distance from it to the bench mark in miles and tenths; or township, range, and section in which bench mark stands, with direction and distance from nearest corner. When changing to a new reference name give the distance to the former point as well as to the new one, thus affording data for total mileage.

2. Position with reference to buildings, bridges, mileposts, street or road corners; if along a road state on which side. Always give compass directions, do not use "right" or "left."

(Items 2 and 3 should be written in direct form of speech.)

3. Description of object on which the bench mark is placed—tree, boulder, bridge, etc.

(The above three items answer the questions *where* and should be followed by a semicolon (;) and by item 4, which answers the question *what.*)

4. Nature of the bench mark—copper nail with washer, bolt, mark on rock, tablet, post, etc.—and how marked or stamped. Old bench marks which are tied to must be fully described.

Descriptions should be kept in the order in which the bench marks occur. If standard bench marks are not established when the line is first run, spaces should be reserved in description books for them in their proper order. A brief description of the line should be given at short intervals, especially when changing direction. When circuits are closed, complete descriptions of closing points, closure error, old and new elevations, and page reference to connecting points should be given. A plot of all lines or circuits must be made on a page near the back of the description book for each group of circuits and the names of enough places to identify the line readily should be added. Boundaries of quadrangles should be shown, and also, if the area is covered by public-land surveys, the position of the line with reference to township and section lines. Alongside of each line reference to the page of the description book where the record is made should be entered. The records in this book are incomplete without this diagram.

PRIMARY LEVELING WITH Y LEVEL.

Personnel and outfit.—A primary-level party consists of a levelman, one or two rodmen, and in some cases a bubble tender.

The instruments required are as follows:

One 20-inch Y level.
One or two New York rods.
One or two plumbing levels.
Two steel turning pins.
One set dies (figures and letters).
One 25-foot steel tape.
Bench-mark tablets or posts.
Copper nails and washers for temporary bench marks.
Cement in cans.
Paint can.

Level notebooks 9-903 (those in black covers to be used by levelmen; those in yellow covers by rodmen).
Bench-mark description book 9-916.
Two book bags.

Other accessories to be purchased in the field:

One or two hatchets.
One drill hammer.
One posthole digger.
Stone drills ($1\frac{1}{8}$-inch bit).

Character of lines.—Primary levels should be run as single lines in circuits wherever practicable, otherwise checked by rerunning, preferably in the opposite direction. No work is completed until it is checked in some way. Lines should be connected with near-by bench marks of railroads, cities, and other organizations.

Accuracy.—The closure error of a circuit in feet should not exceed

$$0.05\sqrt{\text{length of circuit in miles.}}$$

If it is greater than this, the facts must be reported to the geographer in charge immediately.

Check leveling.—When a line is rerun in order to locate an error of circuit closure and a discrepancy between the new and old work is found, this part of the new line must be again rerun in order to make sure that the new work is correct.

Adjustment of instruments.—The adjustment of the level must be tested daily and corrected whenever it is found in error; the adjustments of the line of collimation and of the level tube are especially important.

The tripod clamping screws must be loosened before the instrument is set and tightened after the legs are firmly placed. After setting the target and before the "all right" signal is given the level bubble should be examined, and if found to be away from center it must be corrected and the target reset.

Equalization of fore and back sights.—In order to eliminate instrumental errors and errors caused by curvature and refraction, it is very important that the length of fore and back sights be equalized, but when this is impracticable because of some obstacle, enough unequal sights to balance should be taken as soon as the obstacle is passed, provided this can be done before a readjustment of the level is made. When the adjustment of the level is changed, further attempts to eliminate instrumental errors by the balancing of previous sights are useless. The failure to balance sights is one of the principal sources of error.

Maximum length of sight.—The maximum length of sight permissible under the most favorable conditions is 300 feet, except when crossing rivers or deep ravines. In such places proceed as follows: Establish a turning point on each side; set up the level about 20 feet from each point in turn, taking in the first position a back sight to the near point and a fore sight to the distant point; then cross the stream or valley and take a back sight to the distant point and a fore sight to the near point. For very long sights several readings should be made on the distant rod; the mean of these determinations of elevation may be accepted as correct.

Measuring of distances.—Distances may be measured by stadia readings on the rod, by counting rails if along a railroad, or by pacing. The distances in miles or feet of both fore and back sights must be recorded in notebooks in the proper columns.

Unfavorable conditions.—Work on primary lines should not be carried on during high winds or when the air is boiling badly. During very hot weather an effort should be made to go to work early and remain out late, rather than to work during midday.

Inspection of rod.—When the rod is lengthened beyond 6.5 feet, both the rodman and the levelman must examine the setting of the target as well as the reading of the rod vernier. When the rod is closed they should see that the rod vernier indicates 6.5 feet, not depending on the abutting ends to bring it back to place. The lower end of the rod and the top of the turning point must be kept free from mud and dirt.

Plumbing levels must be tested at intervals and kept in adjustment.

Turning points.—The regular steel turning-point pin should be used wherever no rock or other suitable points are available. A marked point on the top of the rail may be used when running along railroads, but care must be taken to use the higher edge of the rail.

Reading of target.—Both the levelman and the rodman must read each target setting independently and keep separate records. They must not compare figures until their respective records for a given sight are completed. If the difference exceeds 0.001 foot, each must read the rod again before comparing anything but results.

Records.—All level notes must be recorded directly in book 9–903. Under no circumstances should separate pieces of paper be used for figuring or for temporary records. Use ink or No. 4 pencil, make all figures distinct, and do not crowd them. When two important bench marks come close together provide ample room for placing their written descriptions opposite the appropriate figures by dropping the figures for the record one or more lines down the page. For a given H. I. (height of instrument) the rodman's notes must be at least two lines lower down the page than the levelman's and they must not turn over a leaf at the same time. Erasures with rubber or knife are not permissible under any circumstances; a single line should be drawn through an erroneous record and the corrected figures written above it. The flyleaf of each notebook must be properly filled in when the book is first used.

Both the levelman's and the rodman's books must be balanced daily. At the bottom of each page and at the end of each day's work the difference between sums of columns of fore and back sight readings must be determined and recorded, and this difference should agree with the difference of elevation previously determined. The sums of the distance columns should also be recorded for each page of notes. This check must never be omitted. Side sights which are not a part of the continuous line should be recorded in an extra column or within brackets.

When field work is completed notebooks should be forwarded promptly to the Washington office of the Survey by registered mail, the levelman's books in one package and the bench-mark book and rodman books in a spearate package and on another day.

PRIMARY LEVELING WITH YARD ROD AND PRISM LEVEL.

Personnel and outfit.—A prism-level party consists of one levelman, two rodmen, a recorder, and an umbrella man.

The instruments and outfit consist of the following:

One prism level.
Two yard rods, each to have plumbing level and thermometer attached.
One steel tape (25 feet).
Two steel turning-point pins, hollow head.

One Locke level.
One umbrella with staff.
One set dies (figures).
Bench-mark tablets or posts.
Copper nails and washers for temporary bench marks.
Cement, paint can, keel, and other accessories.
Two book bags.
Prism level notebook 9–940.
Bench-mark description book 9–916.

Character of lines.—Primary levels executed with a prism level need be run in one direction only, but must be in circuits or otherwise checked.

Accuracy.—Circuits must close with an error in feet not exceeding

$$0.04 \sqrt{\text{length of circuit in miles}},$$

which is equivalent to

$$0.056 \sqrt{\text{distance between bench marks in miles}}$$

for forward and backward lines. If errors greater than this limit occur report the facts to the geographer in charge immediately.

Graduation of rod.—The rod used is graduated to yards, tenths, and hundredths, and is read by estimation to thousandths. Each yard has a different and distinctive color, which must be recorded for each reading. One edge of the rod has also graduations in feet and tenths for use as a check on yard readings.

Locke level.—In a hilly country time can often be saved by supplying each rodman with a Locke level, by means of which the rodman can select the places for setting up the level and for turning points.

Ratio of wire intervals.—The rod is read for each of the three horizontal wires in the instrument. The mean of the two wire intervals in thousandths of a yard as read upon the rod should equal the distance to the rod in feet, but this should be tested. As the upper and lower wires are not always equidistant from the middle wire, the ratio of the wire intervals must be determined from the first day's level notes for use as specified in the next paragraph.

Methods of reading.—The program at each set-up is as follows: After the tripod is firmly set and the clamp screws tightened, level approximately by the circular level, which has been adjusted by comparison with the long level. Point the instrument toward the rod and clamp; bring the level bubble to the center of the tube by means of the micrometer screw. Read on the rod, and first call off the color initials for the lesser and greater extreme readings; second, call yards and tenths for each wire, taking the smallest reading first; third, repeat and read yards, tenths, hundredths, and estimated thousandths; fourth, for additional check on the yard number, read the middle wire on the tenths of feet scale on the back of the rod. Before the level is moved the recorder should first see that the color agrees with the yard readings; second, he must compute the two wire intervals and if their ratio one to the other differs more than 1 per cent from the true ratio (see preceding paragraph), the levelman must repeat the readings; third, he must compute the mean reading in feet by summation, and test units and tenths by mentally multiplying the middle reading by 3, also by comparing with the reading on the scale on the back of the rod. An agreement must be reached before the next sight is taken. The temperature must be recorded for each hour.

Level adjustment.—When the work is commenced, and at least once each day thereafter, the adjustment of the level must be tested by the "peg method" as follows:

At some convenient set-up, after the usual back-sight and fore-sight readings have been recorded, copy the fore sight on a separate line as a new fore sight apart from the leveling record, leave the fore-sight pin in place, and set a second turning pin about 30 feet back of the instrument; read rod on it for a new back sight; find from these the mean readings in feet as usual. Move the level forward to a set-up about 30 feet back of the fore-sight pin and take readings on the fore-sight pin and then on the back-sight pin. The constant "C," which is a factor of the adjustment correction, must then be determined thus: Sum of readings on near rods minus that on far rods, corrected for curvature and refraction in feet, divided by three times the difference between the sum of the greater and that of the lesser rod intervals in yards.

The rod interval for any sight is the difference of extreme wire readings.

Example of computation of C.

[To be made in the field.]

Determination of C, 8.20 a. m. August 28, 1910.

Thread reading.	Thread interval.	Sum of thread reading.	Height of instrument.	Sum of thread reading.	Thread interval.	Thread reading.
1.515	0.013				0.105	0.357
1.528	.014				.104	.462
1.542	.027	4.585		1.385	.209	.566
2.252	.105				.012	1.276
2.357	.105				.013	1.288
2.462	.210	7.071		3.865	.025	1.301
	.209	1.385		4.585	.025	
	.419	8.456		8.450	.027	
	.052	−0.0005		8.4555	.052	
	.367 yds.	8.4555	1.101)—.0055—(0.005			
	3					
	1.101 ft.					
The fraction $\frac{.419}{.002}$=210 feet=sum for far-rod distance.						

For correction to be applied to the sum of readings on distant rods for curvature and refraction, see table in back of field book 9–940.

When the sum of the readings on the near rods is the greater, the sign of C will be plus, and vice versa. Great care must be taken in pointing off decimals and in giving proper signs.

Adjustment of bubble.—If the resulting value for C numerically exceeds 0.005, an adjustment should be made by changing the position of the level bubble only, as follows:

Point to a distant rod with the bubble in the middle of the tube and read; move the telescope (by micrometer screw) so as to raise the middle cross wire by an amount which in yards is equal to C times the extreme wire interval. While holding the telescope in this position, bring the bubble to the middle of the tube by raising (or lowering) one end of the level vial with the adjustment wrench; if C is negative, the middle wire must of course be lowered on the rod. After the adjustment has been made, its accuracy should be tested by redetermining the value of C.

In case the cross wires break and the level-tube adjustment has not been disturbed, insert new spider threads and determine value of C, as above directed. Compare with the last determination of C, and adjust for the difference by changing the position of the cross-wire ring only—not the level bubble.

When both level and cross wires have been disturbed the latter can be put in proper position by means of improvised wooden wyes in which the telescope is turned while watching a clearly defined point through it, the operation being the same as for the collimation adjustment for a Y-level.

Care of instrument.—When the level is on the tripod, be sure that the central tripod clamp screw is tight. Keep the telescope off the micrometer-screw bearing while carrying it between stations. Leave the three tripod wing nuts loose when carrying; clamp tight when tripod is in place for work. The micrometer screw should be cleaned and oiled slightly every two or three days.

The level must be shaded by an umbrella when in use and by a cloth hood when carried between stations. In rough country the place to set up the rod or level can be quickly found by means of a hand level.

Leveling of instrument.—The length of the air bubble in the graduated level vial can be regulated by means of the air chamber in one end of the glass tube. There is a small passageway in the lowest part of the tube between the air chamber and the main level tube; when one end of the telescope is held considerably lower than the other, with the leveling screws uppermost, if the air chamber end is then the lower, bubbles will be seen rising through the liquid; these added to the large bubble will make it still larger, but if no bubbles appear and the large bubble grows smaller, it indicates that the air chamber is in the upper end. Note the effect at the first trial and act accordingly in future. When the level is being carried from station to station, if the tripod is held nearly vertical the bubble will not change in length.

When leveling up at the beginning of a day's work, set the telescope parallel to two leveling screws and level; turn it 90° and again level. Turn the level 180° and then 90° and test in both positions. If the bubble moves away from the center, bring it halfway back by means of the leveling screws and the remainder by the micrometer screw. When the leveling is perfect adjust the circular level to agree with the other level and note the reading of the micrometer head. The reading should be maintained for the day as nearly as possible to that thus found. The instrument should be so carefully leveled with the leveling screws at each set up that there will be no material difference between the readings of the micrometer head for fore and back sights; a failure to observe this precaution may introduce uncompensating errors.

Care of rods.—The rods must always be kept covered when not in use. The painted sides must never touch the ground. Should difficulty be found in holding a rod steady because of wind, two pieces of bamboo or other light poles, 8 feet long, may be held by the rodman against the rod, so as to make a triangular brace against the wind. Plumbing levels must frequently be tested and kept in adjustment.

Testing of rods.—At the beginning and end of the season and at least twice each month during the progress of the leveling the intervals between the metallic plugs on the face of each level rod must be measured carefully in feet to the nearest thousandth, always with the same steel tape, kept for that purpose. The temperature must also be recorded and the number of the tape.

Length of sights.—The length of fore and back sights must be equalized with the prism level as with the Y level. The maximum length of sight with the prism level is 360 feet except at river crossings. Sights across broad river crossings should be taken in the following manner:

Mount the instrument and place stakes so that the center wire will fall near the middle of each rod; if the distance is too great to read the three wires, use improvised targets of cardboard held in place by rubber bands or other simple device, and make several settings by raising and lowering them an equal number of times. Rodmen should be provided with field glasses if necessary to read signals. From bench marks on each bank the elevation of the adjacent water surface should be determined as an additional check.

Record.—The notes are to be kept in ink in book 9–940, as for precise leveling (pp. 116–117), except that each H. I. (height of instrument) and level should be computed. No erasures are permitted, either with rubber or knife; a single line should be drawn through erroneous records. Extra fore sights when made should be recorded in the special column on the right-hand page, opposite the H. I., and recorded with "backward," "forward," "right," or "left" added to show the direction to the rod from the instrument.

Check computations.—The check of the means of columns 3 and 5 and of their sums for each page of notes must be made each night, or oftener if convenient, by both levelman and recorder independently. At the bottom of columns 2, 3, 5, and 6 the total sums for the page are required, but for columns 1 and 7 find the sums of the center-wire readings only. At the bottom of column 1 it must be shown that three times the sum of the center-wire readings plus the algebraic sum of the excesses of the lower over the upper thread intervals in column 2 is equal to the sum of the mean feet readings in column 3. A similar computation must be shown at the bottom of column 7 with respect to columns 6 and 5. No other computation than these need be made in the field except those required to carry forward the elevations of temporary and standard bench marks.

The difference (column 3 minus column 5) should be written at the bottom of column 4 and should equal the difference obtained by subtracting the first from the last elevation, which should be written in the upper space at the bottom of column 4.

C is the constant which results from the "peg method" test of adjustment. The formula 3 C (column 2—column 6), etc., at the bottom of the right-hand page is for computing the correction to the elevations for combined errors of level and collimation. This computation need not be made in the field. By "(column 2—column 6)" is meant the difference of the continuous sums of the rod intervals of columns 2 and 6.

On primary work the algebraic sum of the page excesses of back sights or fore sights for each day should be written in the lower right-hand corner of the right-hand page.

Double graduations.—The foregoing instructions for the use of yard rods for primary leveling are to be modified if the rods have two sets of graduations of single and double yards. The two columns marked "Thr. int." are used for the double-yard readings—back and fore sights. The single-yard readings are to be entered in the columns "Sum t. r." Only a single-thread reading is to be made on each graduation, and before moving the level the recorder must check each entry by multiplying double-yard readings by two; the product should not differ more than a thousandth from the corresponding single-yard reading. Detailed instructions for the double-yard check method are given in the back part of level book 9–940A.

Distances are to be determined by stadia while the instrument is being leveled, and colors must be recorded as usual. All entries in the middle column of the left-hand page of the notebook are in yards. Computations of bench-mark elevations in feet are to be placed on the right-hand pages.

PRECISE LEVELING.

Observations.—For precise leveling the instrumental outfit and the number of men in the party are the same as for primary leveling with prism level, but the following modifications of methods must be made:

Lines must be run independently in both the forward and the backward direction. The allowable error in feet is

$$0.017 \sqrt{\text{distance between bench marks in miles}},$$

and when this limit is exceeded on any section the forward or backward measure is to be repeated until a pair run in opposite directions is obtained between which the divergence falls within the limit. It is especially desirable to make the backward measurement in an afternoon if the forward measurement was made in the forenoon, and vice versa. The observer should make the two measurements under atmospheric conditions as different as possible without materially delaying the work for that purpose. At alternate stations the fore sight is to be taken before the back sight—that is, always take readings on the same rodman first.

The maximum allowable difference between a back-sight and the corresponding fore-sight mean thread interval is 0.033 yard (33 feet distance). The continuous sums of rod intervals for the section between bench marks must not be allowed to differ more than 0.132 yard (66 feet distance), and they should be kept as nearly equal as possible.

The last set-up of one running must not be copied nor used as the first set-up of a return running—that is, the instrument must be moved so that an independent reading can be obtained.

If any measure over a section differs more than 0.02 foot from the mean, that measure must be rejected: No rejection shall be made on account of a residual smaller than 0.02 foot.

Whenever a blunder, such as a misreading of 1 yard or one-tenth or an interchange of sights, is discovered and the necessary correction is applied, such measure may be retained, provided there are

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at least two other measures over the same section which are not subject to any uncertainty.

When commencing work for the day and at the beginning and ending of each section, record the time. Record the temperature for each set-up also, using thermometer readings alternately for each rod.

It is not necessary to complete the H. I. and elevation column, but the difference of elevation for each section should be computed.

The field abstracts for precise leveling must be made as the work progresses, on form 9–932a, provided for this purpose. When original records are completed in the field send the books immediately to the chief geographer, Washington, D. C., by registered mail, retaining the corresponding forms, which are to be forwarded by registered mail on another day.

Records.—The following special instructions are necessary in regard to the use of prism-level notebook 9–940 when used for precise leveling record:

The blanks on the flyleaf must be filled in the first day the book is used.

The blanks at the head of each page must be filled in each day. Bench marks run between must be indicated by their letters or numbers.

Each horizontal space between two red lines is for a single set-up of the level.

The notes for each section of line on precise work must be complete in themselves and commence on a new page. Every primary line record must begin on a new page, and the initial bench mark must be fully described.

The columns being counted from the left, each is used as follows:

Column 1 is for the readings on the rod in yards for the three threads, each set of readings to occupy a separate space between red lines, the first recorded reading being for the wire giving the smallest value. The color letter is to be placed beside the first and last readings. The recorder should notice whether the color as recorded corresponds with the unit called out by the levelman. Each day the levelman should verify the comparison and, if a discrepancy exists, rerun the section.

Column 2 is for the thread intervals for the thread readings in column 1, the upper ones being the difference between the lowest readings and the middle ones, the lower being the difference between the middle and the greatest readings of each set. (See also next paragraph.)

Column 3 is for the sums of the three-wire readings of each space in column 1, between the horizontally ruled red lines, these sums being equal to the mean in feet of the three readings on rod.

Column 4, with the exception of the last line, is not intended for use in precise leveling but can be used to compute approximate elevations, being filled out only at bench marks. On primary work the first entry on the page at the left of the words "Elevation brought forward from page —" should be the elevation from a previous page or from another book. In the latter case, give book number and page, and always carefully verify the copying. The second entry below the red line and above the short black line is the height of the instrument as found by adding the first entry in column 3 to the first elevation in column 4. The third entry in column 4 is the elevation computed by subtracting the first fore sight from the H. I. In each case the H. I. will always be above a short black line and the elevation always just above a red line.

The records in columns 3 and 5 should be placed on line with the H. I.

Columns 5, 6, and 7 are for fore-sight readings, corresponding with 3, 2, and 1 for back-sight readings.

Column 8 is for the record of temperature and time.

Column 9 is for the correction of curvature and refraction for unequal sights and need not be filled out in the field.

Column 10 is for extra fore sight at points which are not turning points, also for their sum.

Column 11 is for description of bench marks, for elevations from extra fore sights, for transcripts of bench-mark elevations, and for general remarks or explanation.

In columns 2 and 6 write next above the red lines the continuous sums of the rod intervals for the section. The mean of the last pair of continuous sums in columns 2 and 6, multiplied by 1,000, will be equal to the distance in feet for the page; its equivalent in miles and tenths can be obtained from the table in the back of the book. The total mileage from the beginning of the section on precise work and of the line on primary work must be given at the bottom of each right-hand page.

A sample page from a field book follows:

Date: *July 6, 1910, A. B. C.* Lev., *D. E. F.* Rec. Line from *B. M. 53* via *Forward* to *B. M. 54*.

Back sight. Thr. rdg.	Back sight. Thr. int.	Back sight. Sum t. r.	H. I. feet. Elev. feet.	Fore sight. Sum t. r.	Fore sight. Thr. int.	Fore sight. Thr. rdg.	Temp.	Dif. cor. C. & R.	Extra fore sight.	Descriptions, elevations by extra fore sight, and transcript of other elevations.
			1150.634	Elevation brought forward from page 74.						
R 1.323 *1.569* *1.814*	*.246* *.245* *.491*	*4.706*		*3.807*	*.242* *.242* *.484*	*R 1.027* *1.269* *R 1.511*	*25A*			*10.20 a. m. Strong wind.*
R 1.018 *1.259* *R 1.501*	*.241* *.242* *.974*	*3.778*		*4.413*	*.240* *.240* *.964*	*R 1.231* *1.471* *R 1.711*	*25B*			
R 1.382 *1.624* *R 1.865*	*.242* *.241* *1.457*	*4.871*		*4.797*	*.241* *.241* *1.446*	*R 1.358* *1.599* *R 1.840*	*25A*		*B*	
R 1.382 *1.586* *R 1.790*	*.204* *.204* *1.865*	*4.758*							*R 1.840* *1.888* *R 1.936* *5.664*	*18.113* *18.681* *—0.568=53 to road crossing, top of rail.*

				6.174	*.209* *.209* *1.864*	*R* *1.849* *2.058* *G* *2.267*	*24B*			*No. 54=railroad spike driven in south side of telegraph pole 0.35 mile east of milepole 303.*
										1150.634= No. 53. 10.35 a. m. *−1.078* *1149.556= No. 54.*
Sums for page.			Elev.—Elev.	Sums for page.			Mean.	Sum.		
6.038 *3* *18.114* *−1* *18.113*	*1.865*	*18.113*	B.S—F.S. *−1.078*	*19.191*	*1.864*	*6.397* *3* *19.191*	*25*		*3.729* (Col. 2+Col. 6)÷.002=*1,864* feet=*0.35* mile; *3* total miles. 3 C (Col. 2—Col. 6)=........ cor. for level and collimation in feet.	

COMPUTATION AND ADJUSTMENT OF LEVEL CIRCUITS.

General corrections.—In the computation and adjustment of level circuits the notes are first examined for errors in field computations or records. Corrections are next made for rod errors, including those due to changes in temperature, these being products for each difference of elevation by the rod error. Corrections are applied if required for curvature and refraction for unbalanced sights; also for systematic errors for which the law is known.

Orthometric correction.—On long lines at high elevations a correction is required to take account of the fact that level surfaces along meridians at different altitudes are not parallel curves except at the Equator and at the poles. This correction, which depends on meridional distance, latitude, and altitude, may be found from the following formula: [1]

$$C=\frac{h_m(\phi_n-\phi_s)\sin(\phi_n+\phi_s)}{659{,}000}$$

in which

C= correction in feet.

h_m= mean height of line in feet.

ϕ_s and ϕ_n= the latitudes of the south and north ends of section, respectively.

$(\phi_n-\phi_s)$= difference of latitude in minutes of arc.

In applying the formula the lines must be divided into sections of not over 100 miles each, and a division should be made where the general direction changes materially. The corrections thus found are applied to the several sections so as to lower the elevations at successive division points going northward. Although orthometric corrections may at times lead to apparently absurd results, such as giving a lower elevation for the north end than for the south end of a large lake having no outlet, yet in order to insure agreement between different lines and to obtain results of the greatest theoretical accuracy, they must be applied when appreciable.

After all the foregoing corrections are made to the original results, the remaining closure errors are those which are to be removed by adjustment.

Adjustment of precise leveling.—Weights are first assigned for each class of levels, and observation equations are formed and solved by

[1] Coast and Geodetic Survey Rept. for 1899, p. 875, 1900.

"least squares." In this manner every line helps to establish the elevation for each junction point. When all the junction points are fixed the corrections are distributed over the lines in proportion to distance.

Adjustment of primary leveling.—The Geological Survey in adjusting primary levels has adopted a method which may be described as follows:

All adjustments are to be made in the bench-mark description book 9-916, in which abstracts from the field books, which include the description and elevation of each point as determined by the levelman, are written by him in regular order for each line as run.

All the level lines associated with one another should be considered at one time, and in order to better comprehend their arrangement they should first be platted on the office progress maps as accurately as possible and from these tracings should be made on paper, to be used in the adjustment and later filed with the description book as part of the record. The plat should show the approximate relation of all the lines, including the precise or previously adjusted lines forming the base of the system, and the work of different grades or different men should be represented by differently colored inks or pencils or in some other manner, a suitable explanatory legend being attached. The names of a sufficient number of towns should be given to identify the location readily, and beside each line reference should be made to the page in the description book where the bench-mark elevations for that line are given. On each line a $>$ is to be placed to show the direction in which it was run. For small areas the diagram of routes prepared by the levelman in the description book will probably answer in place of the tracing.

The field notes should be examined to see whether the work was in accordance with the instructions; whether fore and back sights were equalized, rod readings properly summed, balances checked, and elevations properly copied from page to page. The entries in the description book should be systematically checked to see that all elevations, including those at starting, junction, and closing points, and all breaks and second runnings are properly copied. Where two runnings of equal weight are made over one course, the mean result should be accepted for adjustment and written in red ink with the appropriate statement in the "unadjusted elevation" column, the divergence being given in the margin.

At each junction point on the diagram should be written the difference between the recorded elevation by some one of the lines and those recorded in the description book for each of the other lines for the same bench mark, with an arrow alongside and plus or minus signs added to indicate that the elevations as brought by these lines are greater or less than the assumed one. Also, as an additional aid in the adjustment, the closure error for each circuit should be written in the center of its plat on the diagram, each amount and sign being computed in counter-clockwise order. Next ascertain by inspection of the diagram which of the unknown junction points may be determined with the greatest apparent accuracy or by the greatest number of independent lines. From two or more lines connecting this point with the points of known elevation obtain two or more possible corrections to the assumed elevation. Estimate and record relative weights for these corrections, the weights to be based on length of lines (usually in inverse proportion to their length), class of leveling instrument used, number of times leveled, and, in rare cases, on relative standing of observers if two are involved. Weights should not be influenced greatly by closure errors. Where corrections from different sources have a line in common, the length of this line should be doubled in fixing the weights of each.

From the weights adopted compute the weighted mean correction to the assumed elevation of the new point as follows: Multiply the correction computed for it through each of the independent lines from known points in turn by the weight of the line; divide the algebraic sum of these products by the sum of the weights. The quotient is the correction to apply algebraically to the assumed elevation; it should be written in the diagram at the proper junction point in a small loop or rectangle with the letters "Cor." and the plus or minus sign. In complicated nets it may be necessary to assign a preliminary correction to a junction point in order to carry a correction from it to some other point; after fixing the correction for the second point from its various lines a final correction is determined and substituted for the preliminary value of the first point.

In this manner weighted values are found for each junction point in turn, and between the points thus fixed corrections are distributed in proportion to the distance. A line or point once thus adjusted should not be readjusted unless readjustment is required by new field data.

Figure 3 is given as an illustration of the method of adjusting a level net. By inspection of the diagram, junction point E seems to be the most favorably situated for adjustment first. The line run from A via B and E to D closed at D 0.250 foot low; from H via I to E

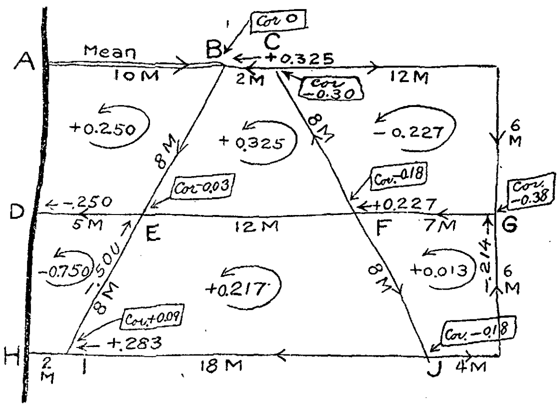


FIGURE 3—Diagram showing method of adjusting a level net.

0.500 foot low. The correction to the recorded elevation for E on the line from A is 0.00 by that line itself, +0.250 computed from D by reversing the closure, and −0.500 from H. The distances to be used in assigning weights are taken as A via B to E$=\frac{10}{2}+8=13$ miles (A to B being a double-run line must be given double weight, which is done by dividing the length of the line by 2); D to E, 5 miles; H via I to E, 10 miles. The weights to be assigned should be in inverse proportions to the length of the lines, or nearly so. To determine the weights, divide a convenient number—as 13 in this example—by the computation distances 13, 5, and 10 each in turn, obtaining 1, 2.6, and 1.3 for the weights of the respective lines. These weights are each to be multiplied by the corresponding assumed corrections 0, +0.25, and −0.50, giving products of 0, +0.65, and −0.65. Divide the algebraic sum of these products by the sum of the weights (4.9); the quotient will be the weighted correction; this is 0 for the point in question, but as there is another line to this point which has not been considered this correction must be accepted as preliminary only. The foregoing data may, if desired, be assembled in tabular form, thus:

From point—	Miles.	Weight.	Correction.	Weight × correction.
A......	13	1.0	0.000	0.00
D......	5	2.6	+ .250	+ .65
H......	10	1.3	− .500	− .65
Sum...	....	4.9	....	.00

Junction point B may be considered next. The preliminary correction for this point is taken as 0, as found from three lines, two lines from A and one from E. A preliminary correction of +0.1 foot for I can be obtained by taking a proportionate part of the closure error at E (one-fifth). Junction point F depends for its elevation on values from several lines. The corrections from E, B, and I are, respectively, 0, −0.32, and −0.18; the corresponding distances are 12, 10, and 26; the weights 2.2, 2.6, and 1.0; the resulting preliminary correction for F is −0.18. A final value for E may now be found from B, D, I, and F; this is necessary to include the effect of F, and by the foregoing method it is found to be −0.03. G is found from lines from B via C, F, F via C, F via J, and I, with the computation distances 38, 7, 44, 28, and 38, respectively; in this case the distances C to G and J to G, which are common to two lines, should be doubled in order not to give them undue weight. The final corrections to the assumed elevations are now found in a similar manner, the computations for B, I, and F being repeated to obtain the effect of the additional lines, and are as follows: B, 0.00; C, −0.30; E, −0.03; F, −0.18; G, −0.38;

I, +0.09; and J, −0.18, two places of decimals only being used for junction points. Each of these corrections is placed in a rectangle on the diagram near the point to which it belongs.

After the corrections for the junction points are fixed, corrections proportioned to the distance are found for intermediate points along the several lines.

Lines on which the closure error is much over the permissible limit must be omitted in adjustment; they may be tied in afterward, but in publishing the results a statement must be made cautioning engineers against dependence on them. If gross errors are evident, the results must not be published until the lines are rerun.

For high altitudes the orthometric correction should be applied. (See p. 118.)

The computer should report to the division geographer in writing any failure on the part of the levelman to comply with instructions; he should also report all circuit-closure errors in excess of the allowable limit. (See pp. 104, 107, and 113.) These data should also be written on the last inside page of the bench-mark book.

SECONDARY CONTROL.

PLANE-TABLE TRIANGULATION.

GENERAL INSTRUCTIONS.

The projection of the sheet under consideration should be made with the utmost care and the points platted thereon tested in every way possible. Both the projection and the platting of the triangulation points should be carefully checked by another topographer.

Before the projection is made a thorough study of all the positions available for the control of the area should be made and the position of the projection on the paper arranged so as to include the greatest number of desirable points.

In the field it is often necessary to construct a projection without the use of a beam compass. A substitute for this is readily made with a wooden strip, into which is inserted a needle large enough to be rigid and a section of pencil.

Seasoned double-mounted paper, attached to the board by brass thumbscrews or tacks, should be used to reduce to a minimum the unavoidable expansion or contraction caused by climatic conditions, and while in use all sheets should be protected with cover paper.

When practicable, the projection lines and as many located points as possible should be platted on the traverse sheet before the work is begun, thus enabling the traverseman to check his work by three-point location or otherwise.

Before commencing work the adjustment of the alidade for collimation and parallax should be carefully inspected. If the hill is high and the weather is at all windy a weight should be suspended from the head of the tripod to steady the plane-table and to prevent accidents. The use of a large umbrella if the sun is bright greatly facilitates the work and protects the eyes and paper. The instruments and the paper should be clean from sand and grit.

Substantial signals, of whatever material is in the vicinity of the stations, should be erected on the main triangulation points and on other prominent hilltops. Unbleached red and white cotton make the best all-around flagging. While placing the signals every opportunity should be utilized to learn the topography of the country, to pick out the best subsidiary stations and to locate them on the guide map, and to fix in one's mind the peculiarities of objects most likely to be seen from the stations thereafter occupied.

CHOICE OF STATION.

In choosing the first station to be occupied it is best to select one of the most prominent triangulation stations, located preferably in the southern part of the sheet, so that when the majority of the sights are taken the topographer will be looking away from the sun. In this way objects may be more clearly seen and peculiarities noted. Clear atmosphere is essential when the first stations on the sheet are occupied.

Where topographic mapping is carried on simultaneously with plane-table triangulation, the availability of vertical control should be considered in the selection of the initial station. In the prosecution of such work the topographer must necessarily locate a sufficient number of points for the control of the contours. The character of the country, the amount of supplementary plane-table traverse, and the scale of the work must be considered in determining the number of points to be located.

OBSERVING AND RECORDING.

After leveling the table place the alidade on a line connecting the station occupied with one of the triangulation points farthest away (the other end of the base) and revolve the table until the farther signal is bisected by the vertical wire of the alidade and clamp table. Verify the orientation by sights to additional visible triangulation stations. Now make the circuit of the horizon systematically and take fore sights to a definite point on prominent objects, such as signals, cupolas, towers, chimneys, flagpoles, monuments, church steeples, schoolhouses, dwelling houses, barns, windmills, trees, hilltops, spurs, etc. These sights and descriptions may be entered in notebook, and brief descriptions should be noted on the sheet itself, along the lines of sight. Draw the lines of sight with a chiseled edge of 9–H pencil at considerable length along the square edge of the alidade, being careful always to hold the pencil at the same angle and see that the contact of the rule and paper is perfect. Get azimuths of long, straight stretches of road and railroad wherever possible.

After all the sights have been made adjust the striding level and read the vertical angles to objects whose elevations are desirable and necessary for vertical control. The stadia rod may be used for obtaining distances and elevations in the immediate vicinity of the station. From time to time, while making observations and upon completion of the work of each station, check original orientation to see if any movement of the table has occurred. In mountainous or hilly sections the topography of the top of the hill should be sketched on the plane-table sheet for identification. After the work on this initial station is completed repeat the operation on the station at the other end of the base.

All triangulation stations should be occupied. Other stations may be made by setting up the table on a foresight, getting orientation by sighting back to the station from which the fore sight was taken, and resecting from another station or located point. This location is checked by sighting to some third located point. All identifiable objects to which lines were drawn from the first station are sighted and intersected. All intersections should be verified by a direction from a third point. A signal should be erected when necessary to mark place of station for future reference. Extreme care should be used in prolonging a short line for orientation.

In areas of great relief and of difficult access advantage should be taken of every opportunity to contour, even approximately, topographic features, such as bottoms of canyons, rock exposures along canyon walls, ground surfaces in heavily timbered, inaccessible mountain gaps, and indefinite slopes of mountain masses which practically can not be occupied.

The stations should be designated by roman numerals I, II, III, etc. Each sight should have a number. All the sights to the same object from other stations should retain the number, and the object should be known by this number during the progress of the work.

After completing the first station the numbers of the sights taken from the second station should follow consecutively and not duplicate those taken for the first station.

After an intersection has been made a cross (×) should be placed opposite its number in the book and its elevation computed. Vertical angles should thereafter be measured to this located point at every station from which it can be seen until its elevation has been satisfactorily determined. It should be remembered that vertical-angle elevations have relative values dependent on the size of the angle measured and the distance between the points.

In areas where the plane-table triangulation is independent of and precedes the mapping the system of symbols provided for plane-table traverse should be used.

THREE-POINT METHOD.[1]

A plan frequently adopted for the location of plane-table stations is that known as the "three-point method," which can be advantageously followed when three or more previously located points properly distributed are visible. When making three-point stations a compass should be used for approximate orientation.

In figure 4 (p. 128) the triangle formed by the three fixed points is called the great triangle and the circle passing through them the great circle. When the table is imperfectly oriented, the lines drawn from the projected points will not intersect at one point except when the table is on or near the great circle but will form a triangle of error.

When the new point is on or near the circle passing through the other points, the location is uncertain. (See fig. 4, case 2.)

When the new point is within the triangle formed by the three points, the point sought is within the triangle of error. (See fig. 4, case 1.)

When the new point is without the great circle, orient on the most distant point, then the point sought is always on the same side of the line from the most distant point as the point of intersection of the other two lines. (See fig. 4, case 4.)

When the point sought falls within either of the three segments of the great circle formed by the sides of the great triangle, the line

[1] For mathematical solution of the three-point problem, see U. S. Coast and Geodetic Survey Rept. for 1880, appendix 13; idem for 1897–98, appendix 13; Geographic tables and formulas, pp. 9–10; or U. S. Geol. Survey Bull. 650, pp. 9–10, 1916, reprinted 1918

drawn from the middle point lies between the true point and the intersection of the other two lines. (See fig. 4, case 3.)

The point sought is always distant from the lines to the three fixed points in direct proportion to the distance of the three points from the point occupied, and, except for case 1, when facing the three fixed points, the true point is always either to the right or to the left of all the sight lines.

When the true point has been estimated and marked on the sheet a new orientation is made. If the lines from the three fixed

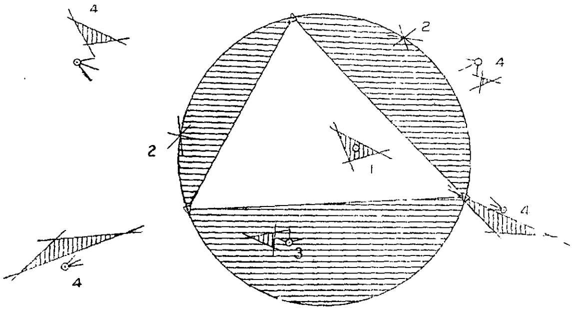


FIGURE 4.—Diagram showing graphic solution of three-point problem.

points now intersect at that point, the position is determined. If a new triangle of error is formed, the operation must be repeated.

PLANE-TABLE TRAVERSE.

METHODS.

Traversing consists of much more than getting direction and distance, though these are absolutely essential features. All the essential topographic features on each side of the line are to be obtained at the time the traverse is made.

Accuracy of plane-table traverse depends on two factors, namely, the obtaining and platting of distances and the orientation of the plane table.

Distances are obtained by stadia, wheel, tape, or pacing, and the orientation is made by magnetic needle, by back and fore sights, by the Baldwin solar chart, or by other approved solar apparatus.

When the needle is used, the accuracy of orientation is dependent on the freedom from local attraction and the length of needle. For these reasons it is well to avoid the use of the compass near railroads, electric-transmission lines, large bodies of steel or iron, and in volcanic regions. No platted line should be greater than the length of the needle.

The method employed in determining distances will be governed by the character of the country and the scale of the work. Traverse lines should be run along roads, ridges, streams, or at intervals in timbered country when necessary; the method in general practice when the needle is used is to set up at alternate stations, using intermediate stations as turning points. Sights should be taken from these stations to prominent hilltops, spurs, houses, windmills, lone trees, and other conspicuous objects, and these should be intersected at subsequent stations. Following this plan, the traverseman should locate all railroads, roads, trails, houses, churches, schools, and bench marks, all State, county, township, and city boundaries, also all cultural features as listed on page 146.

Streams should be mapped near the roads as accurately as the skill and experience of the traverseman will permit. Especially should streams crossing and recrossing roads traversed in ravines or gulches be located and junctions shown with side streams.

In traversing railroads, frequent locations by three-point method should be made if possible and the line extended by means of fore and back sights. If this is not practicable, and it becomes necessary to rely on the needle, it is important to set up the plane table a sufficient distance from the rails to prevent their influence on the needle. The distances can be obtained advantageously by measuring a rail and counting the number of rails between stations.

Where traverse is extended along roads over which levels have been carried, note elevations marked on fences, at summits, bridges, corners, etc., and record same on traverse sheet. Names of villages, streams, hills, etc., should be obtained in the field as far as possible—especial care being taken to get correct spelling—and be written plainly on the traverse.

Traverse should not be made to close, but should show the two tie points by a double arrow between them; such junctions should never occur in towns or villages.

53137—18——9

Traverses should extend a sufficient distance beyond the edge of the sheet to overcome any possible error that may occur in the adjustment.

Single-mounted paragon paper is ordinarily used, though celluloid may be substituted to advantage in wet weather. Before using the sheet the name of the State and quadrangle, the date, the name of the traverseman, and that of the chief of party should be written in the lower left-hand corner.

The proper method of plotting is to place the fractional scale division on the old point and prick the new location with the needle at the even division at end of the scale. This operation should be performed with the greatest care, as more closure errors are to be attributed to careless platting than to any other cause. When aneroids are used the elevations should be recorded on the sheet at road and stream crossings, divides, and traverse stations. To insure accuracy the aneroid should be compared and corrected with bench-mark elevations whenever possible.

STADIA TRAVERSE.

In stadia traverse instrumental measurement of distances and elevations gives sufficient control to permit considerable sketching to be done on either side of the line.

Determination of elevations.—If the elevations are determined by vertical angles, ground elevations may be carried by using a mean height of instrument (4½ feet) as a turning point on the rod, or ordinary level notes may be used with H. I. computations. Accurate distance readings are essential, and sights for turning points should not be over 1,000 feet, unless under exceptional circumstances. In large-scale detailed work 300 feet is a better limit. When the lower hair comes near the ground on long sights serious errors are liable to occur at certain hours of the day through refraction. The Anderson or Johnson stadia tables are probably the most satisfactory for computing differences of elevation and horizontal correction. On scales of 1:48,000, or larger, the horizontal correction can be readily shown in platting. On larger scales it becomes important. Angular measurements exceeding 15° should be avoided.

Whenever possible, as in regions of low relief, elevations should be determined by using the alidade as a level and the rod as a level rod.

Beaman stadia arc.—The use of vertical angles may be avoided by the use of the Beaman attachment to the telescopic alidade. This attachment consists of a stadia arc, which is screwed on the outer side of the old arc and which carries two separate double scales having coincident zero points marked 50 and 0, respectively. Either scale is read by reference to the common adjustable index, which, when the telescope is level, must be set at zero point of scales before the stadia arc is used. The two scales are:

To the right, next index, a multiple scale, with zero point marked 50, which indicates multiples for obtaining differences in elevation. To get desired multiple, subtract 50 from scale reading and use algebraic remainder; for example, if scale reads 56, multiple is $56-50=+6$. If scale reads 47, multiple is $47-50=-3$.

To the left a reduction scale, with zero point marked 0, which gives percentages of correction that may be used, if desired, to reduce observed stadia distance to horizontal.

To determine differences in elevation read the distance subtended on rod and express in feet (for example, $8.7=870$ feet). Clamp telescope and level. Set index exactly at 50, by means of the tangent screw back of arc, and do not touch this tangent screw again.

Then, by means of the customary clamp and tangent movement, raise or lower telescope until there is brought exactly opposite the index such a graduation on the multiple scale as will throw the middle stadia wire somewhere on the rod, it does not matter where. The arc readings, minus 50, multiplied by the observed stadia distance gives the difference in elevation between the instrument and a known point on the rod—that is, the height on rod indicated by middle wire. Settings of both index and arc should be made carefully under reading glass.

Example: Suppose observed stadia distance is 6.3 (630 feet) and that telescope is so inclined that multiple scale reads 58, at which exact setting the middle wire on rod reads 7.2 (7.2 feet above base of rod), then multiple is $58-50=+8$, and computation for a fore sight would be

$$\begin{array}{r} 6.3 \\ +8 \\ \hline +50.4 \\ -\ 7.2 \\ \hline +43.2 \end{array}$$

+43.2 feet = base of rod above H. I.

If middle wire were set on H. I. or top or other fixed point on rod and the arc were read by estimation (for example, 54.2) to obtain a multiple, the result would be approximate only; therefore this method is not to be used with this attachment.

If the half-wire interval is read and this reading is then doubled to get the stadia distance, it occasionally happens that no even multiple arc setting which will throw middle wire on rod can be found. In this case make arc setting that will throw the lower wire anywhere on rod; the middle wire will then be somewhere above the top of the rod. Then take multiple as read on arc, but compute position of middle wire above base of rod by adding one-half the expressed stadia distance (in feet subtended) to the reading of the lower wire.

Example: If the half wires subtend 7.2 on rod, the distance would be $7.2\times2=14.4$ (1,440 feet). If the lower wire cuts the rod 8.7 feet above its base, the computed middle wire reading would be $8.7+7.2=15.9$ feet above base of rod. Then compute as before.

The reading of the left-hand arc from the same arc setting, used to obtain the difference in elevation, will give the correction, expressed as a percentage, needed to reduce observed distances to horizontal.

Example: If a multiple arc setting of, say, 70 has been made for difference of elevation work, the reading of the reduction scale would be 4, or 4 per cent. (Reading to nearest per cent is usually sufficient.)

If the observed distance were 12.0 (=1,200), then 4 per cent of 1,200=48 feet; 1,200−48=1,152=corrected horizontal distance.

Stadia arc notes.—Form 9.913A has been prepared especially for Beaman stadia arc notes. The arc reading or multiple (expressed as above or below 50) is placed under appropriate heading, as in the example below, and all sights are to be regarded as foresights except those taken to determine H. I. Column headed "Product" is for multiple times distance; for example, $4\times4.2=16.8$. Column headed "Rod correction" is for final reading of middle wire on rod.

Date, April 29, 1916. Traverse from Takoma to Sligo.

	Distance.	Beaman arc or steps.	Product.	Rod correction.	Diff. elev.	H. I.	Elevation.
1....	....	....	....	....	....	....	654.7 B. M.
2....	4.2	54 or 4	− 16.8	+ 8.2	− 8.6	646.1	
3....	6.3	48 or 2	− 12.6	− 4.9	−17.5	....	628.6.
4....	9.2	44 or 6	+ 55.2	+ 4.3	+59.5	688.1	
5....	15.8	57 or 7	+110.6	−13.8	+96.8	....	784.9.

The sign to be affixed to "Product" and "Rod correction" are determined according to whether the observation is a B. S. or F. S., by following a rule of universal application, namely:

	Product.	Rod correction.
B. S.	Opposite sign to that indicated by arc reading............	+
F. S.	Same sign as that indicated by arc reading...............	−

Arc reading 54 indicates +; therefore here the sign of product is − for a B. S. and + for an F. S. Note that sign of "Rod correction" is same as in leveling. When line of sight is level arc reading is 50, and therefore only entry is rod reading, entered as "Rod correction," whose signs follow above rule.

Micrometer eyepiece.—A micrometer eyepiece for the telescopic alidade has been used for determining distances, and under some conditions, on small scale or reconnaissance work, it has proved of great value. The principle of this attachment is that if two angles and one side of a triangle are known, the remaining parts may be found. The length of the base is known by previous measurement, it being a known space on a stadia rod, or the distance between two signals left on the ground. The micrometer is used to measure the angles between the lines of sight to opposite ends of the base, and the result is in divisions of the micrometer head. Constants for each instrument are determined [1] and tables prepared to show the number of turns of micrometer head on different bases to give distances in feet or hundredths of a mile. These tables and constants should be tested on measured horizontal bases of different lengths at beginning of season.

Base.—In establishing a base its bearing should be placed on the sheet for future reference. At new station (fig. 5) if the line of sight is not perpendicular to the established base, orient as closely as possible, and draw a line to one of the signals. Plat the base as long as paper will permit. Erect a perpendicular to the line of sight

[1] See formula for computing these constants in Geographic tables and formulas, p. 10, or U. S. Geol. Survey Bull. 650, p. 8, 1916, reprinted 1918.

at one end of base (a). Draw a line parallel to the first line of sight through the other end of platted base (b). Measure the distance of the perpendicular from (a) to intersection with line through (b) on the same scale as base was platted. This distance (a–b') is the corrected length of base to be used; then $a\text{–}b' = ab \sin y$. The solution depends on the fact that the angle between the lines of sight to opposite ends of the base is so small as to be disregarded, and angles V and W are practically 90°. A protractor may be used to make the angle y between the platted base at (b) and the line (bb') the same as the supplement of the angle $V+x$ between the platted base and the perpendicular erected at (a).

The same principle applies to a vertical base which may be above or below the station occupied.

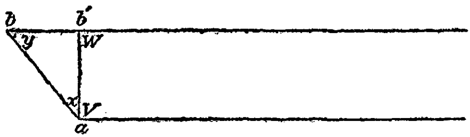


FIGURE 5.—Diagram illustrating correction of base line.

Instruments.—The instruments needed for stadia traverse consist of a telescopic alidade, with compass attached, plane table not smaller than 15 by 15 inches, with Johnson tripod, and standard stadia rod. Establish magnetic north line on the sheet at the beginning of work for future orientation.

It is necessary that the stadia wires give the correct reading on the rod. Therefore, before work is commenced they must be tested on a measured base not less than 500 feet in length, and if an error is found a correction must be applied to each distance measured. It is not desirable to graduate rods to fit the peculiarities of individual instruments.

Correct adjustment for collimation and striding level must be maintained. The eyepiece should give a clear-cut image, free from parallax. To obtain this throw the object glass out of focus and adjust the eyepiece so that cross wires are perfectly distinct and stationary at every position of the observer's eye.

WHEEL TRAVERSE.

Revolutions of the wheel may be used for obtaining distances along the traverse line. Tables are furnished to facilitate reduction. A hand recorder may be used as a check on long sights. A record of distances should be kept until closures are made as a check on plotting.

TAPE TRAVERSE.

In some parts of the country dense forest and undergrowth make it impracticable to carry stadia or wheel traverse, and the lack of open tops puts a narrow limit on triangulation methods. Under these conditions a form of tape traverse depending on aneroid elevations has been devised for obtaining the topography. It is applicable only to scales of 1: 48,000 or smaller.

A plane table 9 inches square, with compass attached, and Bumstead tripod are best for the work. A sight alidade, 528 feet of linen tape or cotton rope, and a pocket compass are the instruments required. The tape or rope should be marked at 100-foot intervals with red ink in a manner to be clearly understood. It should then be run through hot paraffin, and the rear end stiffened to avoid catching and tangling in the brush. It will be necessary to paraffin the tape frequently, especially the rear end, and it should be thoroughly dry to have the best effect. Knots and weak places should be promptly mended with needle and thread.

The chainman should carry a pocket compass, light ax, and marking crayon. He blazes one or more trees at the end of each tape length, and the topographer occupies the point as his next station, thus setting up at every station instead of alternate ones. The sights are taken in the direction shown by the tape and the signal of the tapeman. It is well to number the stations to avoid error in making closures. Lines should follow natural features, such as ridges, valleys, and spurs, rather than gridiron the territory. The greatest error of the lines comes through the tapeman not keeping a straight course.

Adjustment of aneroid elevations should be made daily and the contours altered to agree, care being taken to preserve topographic shape and detail. Adjustment of horizontal errors should not be made on traverse sheets.

FOOT TRAVERSE.

The method of obtaining distances by foot or animal paces is resorted to in timbered countries and mountainous regions without roads. Careful measurements of the average pace of an animal or a traverseman on a level or a slight incline should be made, and a table prepared in hundredths of a mile.

USE OF ANEROID.

In certain classes of work in various parts of the country the aneroid, properly supported by level and vertical angle elevations, is used to great advantage in the completion of topographic detail.

In order to obtain the best results from its use, however, the topographer should realize its limitations as a result of its delicate mechanism and its susceptibility to meteorologic influences.

Aneroid readings should be checked by previously determined elevations whenever opportunity is afforded, as well as at the beginning and end of each day's work. Whenever a station is occupied for a considerable length of time, the usual record should be supplemented by an additional reading made just before departure, for a possible correction. The uncertainty of the aneroid is increased in unsettled weather and it is practically useless immediately before and after a thunderstorm.

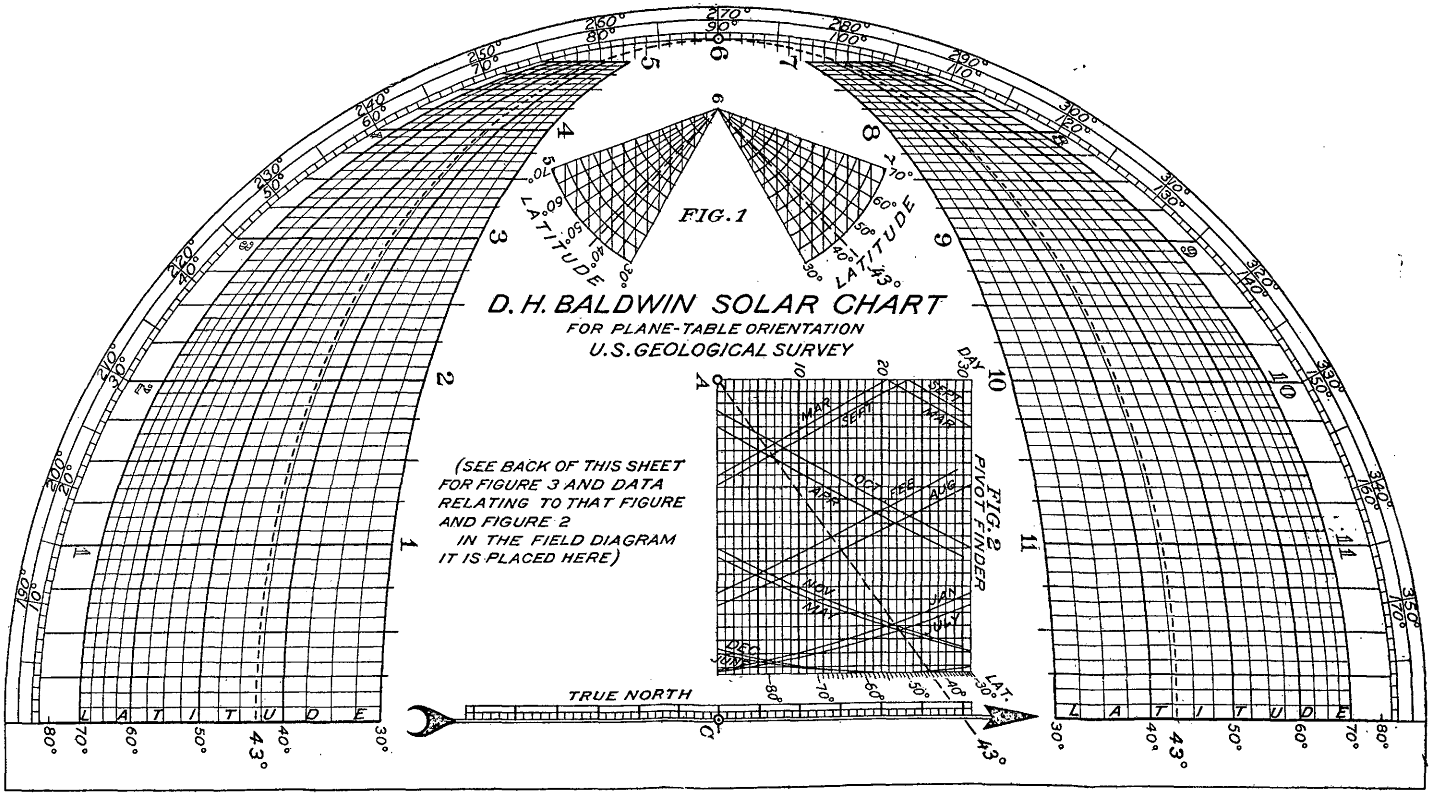
The aneroid should always be transported and handled with care and should be protected from all sudden jars. It should be carried preferably in a closely fitting vest or small pocket secured by a string. The transportation or shipment of aneroids across country, the elevation of which is beyond the limits of the aneroid range, should be avoided whenever practicable.

USE OF BALDWIN SOLAR CHART.

EXPLANATION.

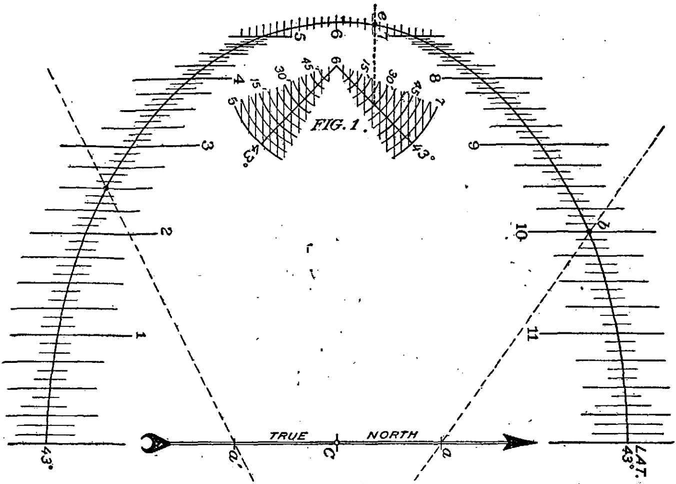
The chart (Pl. II) consists of elliptical lines indicating the sun's path for different latitudes from 30° to 90° N.,[1] intersected by straight sun-time lines at 5-minute intervals; the hour lines are heavy and are marked by their respective hour figures. The intersection of these time lines with latitude ellipses are called sun-time points. Fig-

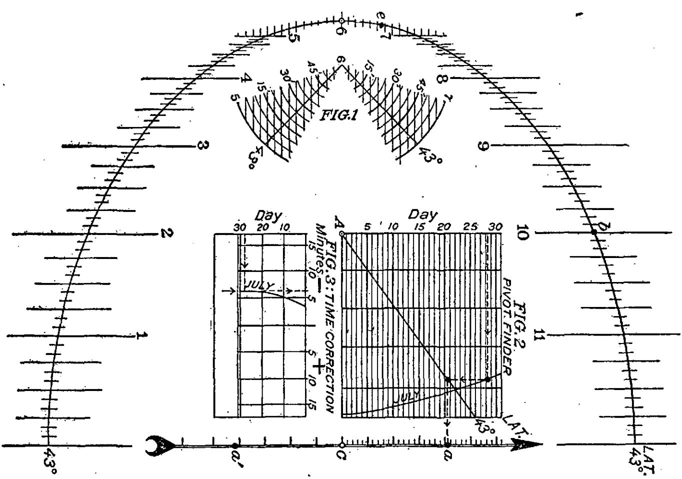
[1] A separate chart is provided for use in latitudes 0° to 30°.



D. H. BALDWIN SOLAR CHART.

(See p. 136.)



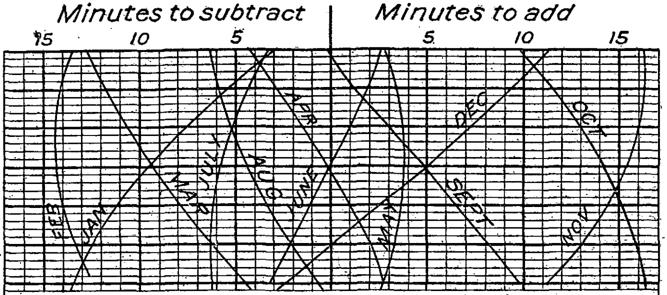


ILLUSTRATIONS OF USE OF D. H. BALDWIN SOLAR CHART.

(See p. 138.)

FIG. 3

TIME CORRECTION



TO CONVERT STANDARD TO SUN TIME FOR USE ON THIS CHART APPLY CORRECTION FIXED BY LOCATION OF DATE POINT OF THIS DIAGRAM (SEE BELOW), AND ALSO ADD OR SUBTRACT 1 MINUTE FOR EACH $\frac{1}{4}$ DEGREE OF LONGITUDE OBSERVER IS EAST OR WEST RESPECTIVELY OF CENTER OF STANDARD TIME BELT USED

DATE POINTS. IN THIS FIGURE AND IN FIGURE 2 ON THE CHART (PLATE II), THE DATE POINT ON ANY MONTH CURVE IS FOUND AS FOLLOWS:

BETWEEN LONGITUDES 0° AND 45° EAST OR WEST OF GREENWICH (AND BEFORE 1929) USE:

DURING FIRST YEAR AFTER LEAP YEAR, DATE-LINE INTERSECTION;

DURING SECOND YEAR AFTER LEAP YEAR, A POINT $\frac{1}{4}$ DAY SPACE EARLIER;

DURING THIRD YEAR AFTER LEAP YEAR, A POINT $\frac{1}{2}$ DAY SPACE EARLIER;

DURING LEAP YEAR, JANUARY AND FEBRUARY, A POINT $\frac{3}{4}$ DAY SPACE EARLIER;

DURING LEAP YEAR, MARCH TO DECEMBER, INCLUSIVE. A POINT $\frac{1}{4}$ DAY SPACE LATER

AN ADDITIONAL CORRECTION MUST BE MADE THUS:

BETWEEN LONGITUDES 45° AND 135°, $\frac{1}{4}$ DAY SPACE $\left\{ \begin{array}{l} \text{EARLIER IF EAST} \\ \text{LATER IF WEST} \end{array} \right.$

BETWEEN LONGITUDES 135° AND 180°, $\frac{1}{2}$ DAY SPACE

BETWEEN YEARS 1929 AND 1961, $\frac{1}{4}$ DAY SPACE LATER ure 1, Plate II, represents the portion of the chart not completely shown in the sections between 5 and 7 o'clock. It is an auxiliary diagram to aid in finding sun-time points between these hours. It is divided into before and after 6 o'clock segments, on each of which the latitude is to be interpolated between the radial lines and the sun time between the circular curves. A supplement to this chart for use in latitudes below 30° is available.

Figure 2, Plate II, is a diagram for finding daily the pivot points on the arrow, the positions for which vary according to the sun's declination and the latitude. Figure 3, Plate II, is a diagram by means of which local mean time may be converted into local apparent time. Below it is the factor required to convert standard to local mean time.

To use the chart some form of stylus or gnomon that will cast a good shadow must be provided on the alidade.

OBJECT OF THE CHART.

The chart is designed to supply a means of obtaining true north in regions where the local conditions will not permit the usual determination by compass. When it is turned so that the proper pivot point on the arrow and the sun-time point on the latitude arc are on a line parallel to the shadow cast by a plumb line upon a level table the arrow will point true north. The chart is intended to be used with the plane table, which may be oriented by its aid.

PREPARATION OF CHART FOR USE.

Two methods may be used to adapt the chart to local use:

1. It will be found convenient in surveying an area of small range in latitude to emphasize, by drawing in pencil or colored ink on the main diagram (Pl. II), the curve for the middle latitude of the area under survey, producing the curve so as to complete the ellipse to the 6 o'clock point. Draw the same latitude lines (radiating from A and 6, respectively) on figures 2 and 1. In Plate II such lines are drawn for latitude 43° N.; new lines should be provided for any material change in latitude. A convenient device may be provided for fixing the daily positions of pivot points by sticking a narrow cardboard strip on the chart with one edge directly on the center line of the arrow, using shellac-alcohol adhesive. The strip should

be placed on the outer side of the arrow for use in spring and winter and on the inner side for summer and autumn, astronomic seasons. Mark on the strip in the form of a scale the positions of pivot points for the latitude of the sheet for selected dates, so that the points for any intermediate dates can be found by interpolation. Cut away the portions of the strip for all elapsed dates and use the corner of the card at the proper date as a stop against which the alidade is placed. When the chart is to be used on the west edge of the plane-table sheet it may be more convenient to turn the chart 180° from its regular position (that is, point the arrow south), so that the arrow will be over the border. The pivot points as found in normal position apply in this position also, but the relative position of pivot point and sun-time point will be reversed.

2. Plate III, upper half, is a working chart constructed from the main chart by drawing only the portions essential for immediate use. It consists of the ellipse for the latitude of the area, the hour lines, and the north-south arrow. As the chart is designed to be used with local apparent time and to provide for daily change in declination, figures 3 and 2 on the main chart (Pl. II) will be used for converting standard time to local apparent time and for fixing from day to day the pivot points a and a^1.

Plate III, lower half, is a special chart constructed from the main chart to illustrate the use of the figures. In figues 2 and 3, Plate III, the day lines intersect the month's curve at date points corresponding with noon values of declination and equation of time, respectively, for the year 1913 at Greenwich, England. For other years and places a date correction must be made, as tabulated on the face of the main chart (Pl. II). Figure 2, Plate III, is used to obtain pivot points on the arrow, two being required for each day. The north one is the a. m. pivot point and the south one the p. m. pivot point, when the day is one included in the half year between March 22 and September 21, inclusive (that is, when the position of the sun is north of the Equator), the relative positions being reversed during the other half of the year. The a. m. pivot point is always directed toward and the p. m. pivot point away from the sun with respect to the sun-time point.

Example: On July 28, 1913, find pivot point (a) and sun-time point (b) at 10 a. m., latitude 43° N., longitude 97° W. At longitude 97° W. the local noon date point on July curve (fig. 2, Pl. II) is about a quarter day space from the 28th toward the 29th day line (97° falling between longitudes 45° and 135° west of Greenwich). From this point project a vertical line to intersect the diagonal latitude line 43°. Draw a horizontal line from this intersection to the arrow. The point of intersection of this line will be the a. m. pivot point (*a*). The same distance below point *C* will be the p. m. pivot point *a*[1]. Transfer these points to Plate III (upper half) if the work chart is to be used. Note that if the date had been between September 21 and March 22 following the first pivot located would have been the p. m. pivot point. To find the sun-time point at 10 o'clock a. m. follow the hour line 10 to its intersection with the latitude ellipse 43°, as shown at *b* (Pl. III); this is the sun-time point.

To find the sun-time point at 6.30 o'clock a. m., same latitude, use the auxiliary diagram (fig. 1, Pl. II). Follow the sun-time curve for 6.30 o'clock to its intersection with latitude line 43°. Project this point horizontally to the ellipse and its intersection is the sun-time point for 6.30 o'clock at (*e*) on the diagram.

Figure 3, Plate II, is used to obtain the correction necessary to convert local mean time to local apparent time. This, combined with the correction for longitude, gives the total correction to convert standard to sun time. To convert standard time to local mean time a correction of 1 minute must be made for each quarter of a degree of longitude east or west of the center of the time belt in which work is situated, to be added if east or subtracted if west.

Standard-time meridians ordinarily are multiples of 15° of longitude east or west of Greenwich, England. Those crossing the United States proper are at longitudes 75°, 90°, 105°, and 120° W., and are the central meridians of the eastern, central, mountain, and Pacific standard time belts, respectively. Hawaiian standard time meridian is 157° 30′ W., and there are some other exceptions.

To convert local mean time to local apparent time, locate on this figure a date point by following the proper day line to its intersection with the proper month curve, and the corresponding time correction can then be read on the minute scale at the top.

Example 1: Plate III (lower half), July 28, longitude 97° W., find the correction to convert standard time to sun time. Longitude 97° W. is 7° west of the center of the central time belt 90°, and this interval equals a correction of 28 minutes to subtract. The July 28 date point on the July curve is opposite 6½ minutes to subtract.

The combined correction is therefore 34½ minutes to subtract from standard time.

Example 2: On November 15, at longitude 106° 15′ W., the correction would be 5 minutes to subtract and 15 minutes to add, on account of longitude and date, respectively, a combined correction of 10 minutes to add.

Standard time can be obtained at most railroad stations or telegraph offices. The watch used should be set each day to apparent sun time by applying the constant correction for longitude and the daily correction for equation of time.

ORIENTATION OF PLANE TABLE.

To orient the plane table by use of the chart, attach the latter to the plane-table sheet so that the arrow will be parallel to the line on the sheet representing the local meridian. The plane table being leveled at a station, select the sun-time point for the instant of observation, place the edge of an open-sight alidade at the sun-time point and the pivot point, and revolve the plane table until the edge of the alidade lies parallel to the shadow of a plumb line, or the shadow of some other gnomon placed on the alidade. The gnomon must be perpendicular to a level line transverse to the alidade edge.

Example: Plate III (upper half), at 10 o'clock, July 28, latitude 43° N., longitude 97° W. Place the edge of a sight alidade at pivot point (*a*) and at sun point (*b*), using the open sight as a gnomon to cast a shadow on the ruler. Revolve the plane-table board until the shadow of the sight is bisected by a line on the alidade parallel to the edge; then clamp the board. The arrow is now in its true north-south position.

To obtain best results it is necessary to use accurate time and to carefully plumb the shadow plane.

In using a telescopic alidade and separate gnomon with the solar chart it is essential that the telescope sight line be parallel with the ruler edge; this may be tested by means of a metal sight alidade or two pins placed against the ruler of the telescopic alidade. The open sights (or pins) are set on a point about 1,000 feet distant; if the cross wires in the telescope also cut the point sighted the line of collimation and the edge of the ruler are parallel. If an appreciable error is found, in order to correct it place the arrow line of the chart parallel to the line joining the pins, then shift the alidade over the chart till the telescope cuts the point sighted and draw a meridian line on the chart along the alidade edge, which will in use be placed parallel to a meridian of the field sheet.

The length of sight on the field sheet should not exceed the distance on the chart between the sun-time point (*b*) and the pivot point (*a*), or the length of the shadow of a vertical gnomon. This will vary with the time of day and the season of the year.

ERRORS.

The error in azimuth caused by errors in latitude, time, and level can be found graphically upon the chart for various conditions, but it is important to observe that the error in azimuth due to error in time is most apt to be serious. At the pole 4 minutes error in time causes 1° azimuth error. Elsewhere, if the sun time used is not over 3 minutes in error, the error in azimuth will usually be less than 1° before 10 a. m. and after 2 p. m.; the error at low latitude being least, but near these hours the error at low latitudes changes more rapidly than at high latitudes and at and near noon is greatest. On June 22, at latitude 30° N., 3 minutes error of time at noon will cause about 6° error in azimuth, but at 10 a. m. and 2 p. m. it will cause only 0.5°. At latitude 40° N. the error at noon will be less than 2.5°, whereas at 10 a. m. and 2 p. m. it will be about 1°. To obtain good results with the chart in secondary traverse, time error should not exceed 3 minutes in most cases, and near noon in low latitudes it should not exceed 1 minute. Fast time increases the measured azimuth of a course, and since the error is greatest at noon a straight course run throughout one day would appear as a slight reversed curve, the morning curve to the right and the afternoon part to the left.

TIME CORRECTION.

Sun time can be found as described in the foregoing text. It can also be found directly from watch time (whether that be fast or slow) if the plane-table can be reliably oriented each morning by known points by placing the alidade edge against the proper pivot point and toward the sun. The edge of the alidade will then cut the true latitude curve at sun time and by subtracting the watch time its correction will be obtained.

MAP CONSTRUCTION.

FIELD WORK.

GENERAL CHARACTER OF ATLAS SHEETS.

Quadrangles.—The topographic maps of the United States Geological Survey are designed to constitute a topographic atlas of the United States for a geologic base. To that end they are issued in standard sheets approximately uniform in size (17½ inches long and 12 to 15 inches wide according to the latitude), representing quadrangles, each bounded by meridians and parallels.

Projection.—All atlas sheets are based on the polyconic projection. Each sheet is laid out independently with respect to its own medial meridian.

Scales.—Standard field scales are 1:192,000; 1:96,000, 1:48,000, 1:31,680, 1:24,000, 1:21,120, 1:20,000, and 1:12,000.

Contour interval.—The relief on all atlas sheets is expressed in con tours. The intervals adopted are 5, 10, 20, 25, 50, 100, 200, and 250 feet.

Contents of the map.—The data shown are essentially the same for all maps of the topographic atlas and differ only with the limitations of the different scales. They comprise all habitations, routes of communication, and other works of man that are permanent in character; the boundaries of civil divisions, reservations, and grants, as well as the lines of the public-land surveys, accurately determined useful elevations; water features, swamp and marsh land; relief features, and the names of all features, cultural and natural.

PRELIMINARY INSTRUCTIONS.

PREPARATORY WORK.

Preparation of field sheets.—Before starting for the field, the topographer should prepare his field sheets in the form best suited to the conditions under which his work is to be carried on.

Drafting of projections.—Coordinates for projections should be taken from the polyconic projection tables.[1] Whenever convenient

[1] Geographic tables and formulas, pp. 38-94; U. S. Geol. Survey Bull. 234, pp. 37-93, 1904. Also Coast and Geodetic Survey Special Pub. 5, 1910.

the platting may be expedited by the use of the Bumstead projector (1: 48,000 and 1: 96,000). Whether this device be used or not, each projection must be subjected to a thorough test by some person other than he who did the platting. It does not suffice that he merely repeat the plattings of the first draftsman with the figures used by the latter. A true check consists of independent computations and measurements throughout. The verifier should therefore enter the tables anew, replat the coordinates, and, as a final test, measure the over-all dimensions of the projection and compare the length of its diagonals.

The platting of primary-control points should, similarly, be checked by independent measurements.

Data from other surveys.—Existing map material of Federal, State, and municipal surveys and other authenticated organizations should be diligently sought. Maps of the General Land Office, the Coast and Geodetic Survey, the Hydrographic Office of the Navy, the Corps of Engineers of the Army, the Mississippi River Commission, the survey of the Great Lakes, the national boundary surveys, State boundary surveys, boundaries of national parks, forests, monuments, game and bird preserves, Indian and military reservations, land grants, surveys made by the Reclamation Service, Forest Service, and Bureau of Soils should be obtained and such of them as prove, on field examination, to be adequate, should be incorporated in the field sheets, with proper recognition. (See p. 180.)

All such material will, upon requisition, be reduced by photography to the field scale.

Sheet borders.—It is of prime importance that contiguous atlas sheets shall join perfectly, so that when they are laid edge to edge the lines on them shall pass without break or offset from the one to the other. In order to insure such perfect joining, compliance with the following rules is necessary:

Before beginning field work on a new sheet, the topographer should procure a border strip from each adjoining sheet already mapped, such border strip to embrace a width of at least 1 mile and to be photographed to the field scale.

Should it appear in the progress of field work that the older sheets contain inaccuracies, or are not up to date as regards developments in culture, the new work shall be considered as standard and the older work be revised for such a distance over the border as may be necessary to effect a good adjustment (generally not over a mile).

Should the older sheets prove so deficient in quality or so far out of date as regards culture that radical revision would be required to make them join to the new work, the topographer must at once report the matter to the division geographer.

Border corrections to be applied to sheets already published should be submitted on tracings upon completion of the inking of the new work.

Wherever the adjoining sheets have not been mapped, the field work should be carried across the border of the new sheet for approximately one-half mile.

Identification of field sheets.—It is of the utmost importance that every field sheet, whether plane-table or traverse, should be marked, before work is begun on it, in a manner that will insure its ready identification. Accordingly, each should bear on its margin in indelible black ink the name of the State, the name of the quadrangle, the scale and contour interval, the name of the person responsible for the mapping, and the year in which the work was done. The latitude and longitude must be clearly marked in pencil at each of the four corners of the projection.

NAMES.

Names to be shown.—The map should show the following names:

Cities, towns, villages, and other settlements, including all country post offices and railroad stations. (Where the name of a railroad station differs from that of the corresponding post office, both names should be shown, the one most widely known being given the greater prominence and the other being followed by "P O" or "Sta," as the case may be.)

Country schoolhouses.

Country churches, when used as locality names.

Isolated ranches constituting important landmarks in sparsely settled districts.

Important public institutions, such as universities and colleges, State hospitals, asylums, and penitentiaries.

Railroads (steam or electric). In addition to the name of the system, it is desirable, as a rule, to give the name of the branch, line, or division.

Highways, turnpikes, and boulevards.

Bridges, ferries, and fords.

Through trails.

Important steamboat routes on large lakes.

Important canals, ditches, aqueducts, etc.

Tunnels, dams, lakes, reservoirs, and other public works.

Lighthouses, lightships, and life-saving stations.

Parks and cemeteries, if scale will allow.

Isolated mines, quarries, prospects, and oil wells.

Isolated furnaces and smelters.

Civil divisions.

Reservations.

Hydrographic features.

Springs, wells, and tanks, especially in arid regions where these features are of vital importance.

All relief features.

Authority for names.—The topographer should utilize local opportunities for obtaining the correct names and spelling of all features shown on the map and not resort to correspondence on this subject after his return to the office. The general policy should be to conform to local usage.

New names.—In unsettled or sparsely settled regions it may often be found desirable to give names to the more important land and water features as a means of reference. Such names must be submitted through the geographer in charge to the chief geographer with full particulars showing their appropriateness for final action. The selection of new names should not be a mere matter of whim but should be made with due consideration of their geographic value and significance. Following are some of the principles adopted by the United States Geographic Board:

(*a*) Names suggested by peculiarities of the topographic features designated, such as their form, vegetation, or animal life, are generally acceptable, but duplication of names, expecially within one

State, should be avoided. The names "Elk," "Beaver," "Cotton wood," and "Bald" are altogether too numerous.

(*b*) Names of living persons should be applied very rarely, and only those of great eminence should be thus honored. No personal names should be attached because of relationship, friendship, or personal interest.

(*c*) Long and clumsily constructed names and names composed of two or more words should be avoided.

(*d*) The possessive form of names should be avoided unless the object is owned by the person whose name it bears.

(*e*) The multiplication of names for different parts of the same feature, such as a river or mountain range, should be avoided. Only one name should be applied to a stream or mountain range throughout its length.

Such names as "East Fork" and "North Prong" for branches of a river should be avoided unless there is a special reason for their adoption. Independent names should be commonly selected.

MAPPING OF CULTURAL FEATURES.

Features to be mapped.—The following cultural features are to be shown on all topographic atlas sheets by conventional signs, as shown on pages A-X:

Aqueducts, water and oil pipes.
Bench marks.
Boundary lines (civil).
Boundary monuments.
Bridges.
Buildings
Canals and ditches.
Cemeteries.
Coke ovens.
Dams.
Ferries.
Fords.
Land corners.
Land grants.
Land-survey lines.
Levees, cuts and fills.
Life-saving stations.
Lighthouses.
Lightships.
Locks.
Mines and quarries.
Oil tanks.
Oil wells.
Power lines.
Primary-traverse stations.
Prospects.
Railroads.
Reservoirs.
Roads.
Steamboat routes.
Trails.
Tramways.
Triangulation stations.
Tunnels.
United States location monuments.
United States mineral monuments.
Wharves, docks, jetties, etc.

Roads.—Under roads are included all streets and roads, public and private. Distinction is to be made between first-class and second-class roads, the former being shown by solid double parallel lines, the latter by broken double parallel lines. Metaled roads, further, are to be distinguished on the engraved map by having one of the two lines accentuated. On the field sheets it may be convenient to represent roads by single lines, but it is nevertheless important that the class of each road shall be indicated on them in some way. A simple method of marking consists of placing a figure or letter on each stretch of road, thus—1 standing for first class, 2 for second class, M for metal. This should be done promptly as fast as the road traverses are run.

The classification of roads is governed by the following criteria:

First-class roads include all State, county, or other public roads in such condition as to be available for travel; all main or through roads in sparsely settled mountain or desert regions, regardless of condition; all city streets and park and cemetery drives.

Second-class roads include all public roads which through disuse or neglect have become impassable or can not be traveled without risk (through roads in sparsely settled regions excepted in accordance with the foregoing paragraph); all neighborhood roads in rural districts (except those of sufficient importance to be regarded as through roads); all private roads, lanes, and stub roads to farms and country houses.

Metaled roads include those first-class roads which are paved or have a dressing of macadam, telford, gravel, or asphalt. Even a thin layer of gravel or broken stone applied without specially prepared subgrade and covering only a strip wide enough for one vehicle is held to constitute "metal."

In areas where public highways generally follow the section lines of the land survey the classification of roads is to be made with reference to ownership and permanency of location, rather than condition or amount of travel. Roads which are considered permanently located include those along section lines and those which leave the section lines for short distances to avoid natural obstacles. Roads thus permanently located, when following a section line for one-fourth mile or more, are to be classed as first-class roads. Diagonal roads following section lines here and there are to be classed as private, unless they constitute the main through routes of travel.

Lumber or wood roads generally are to be omitted, but any principal through lumber roads which may be properly considered permanent cultural features are to be shown by the second-class symbol.

On the 1:192,000 scale no distinctions are to be made between roads of different classes. They are all double parallel lines.

Buildings.—The map must show all buildings of a permanent character, such as dwellings, public buildings, shops, factories, and other industrial establishments; it should be reliable not only as regards their location but also as regards their orientation—that is, the way each building is set with respect to the points of the compass.

Uninhabitable dwellings, whether farmhouses or miner's or lumberman's cabins, are to be shown only when they constitute important landmarks in regions of sparse culture.

The conventional black square is to be used for all buildings except those of larger structures whose dimensions platted to scale actually exceed the size of the symbol. These should be shown with their individual plan outlines. On large-scale maps all houses may have to be thus shown.

On the 1:192,000 scale only isolated houses in the country should be shown; those in towns and cities should be shown by a conventional symbol giving the outline.

Houses should not be shown conventionally contiguous to the roads unless the actual distance that separates them from the edge of the right of way can not be platted on the scale of publication.

Detached houses in residence portions of cities, suburbs, and villages are to be shown separate wherever possible. When the scale does not permit individual houses to be shown (see p. 172), indicate the group by a solid block.

Churches and schoolhouses.—Churches are to be distinguished by a cross and schoolhouses by a pennant; such cross or pennant should be attached to the house symbol, so as to point at right angles to the roadway and not necessarily to the north. In centers of dense culture these distinctive symbols should be omitted. Buildings used both for schools and for religious services should bear the school symbol.

Railroads.—Under railroads should be included all steam and electric railroads. Steam-railroad lines are to be shown by the regular railroad symbol; electric urban, suburban, or interurban lines, and tramways by a symbol on which the crossties are placed closer together; and aerial tramways by broken black line with name.

Double tracks, railroad yards, spur tracks, and switches should be shown so far as the scale will permit. Separate railroad lines in juxtaposition and parallel tracks belonging to the same road should be differentiated by placing the crossties as shown on the symbol chart.

Railroads within a roadway should be shown by fine cross lines not extending beyond the road lines; suburban electric lines, tramways, etc., should be differentiated from long-distance lines by closer spacing of the symbol.

A railway-station building is to be treated like other buildings, except when its symbol is carried conventionally across the tracks to indicate a station locality not otherwise clearly indicated by the position of the station name.

Bridges.—The following classes of bridges should be shown by symbols: All road bridges across double-lined streams; all road bridges across single-line streams in sparsely settled regions or wherever the existence of the bridge is vital to the use of the road; all road bridges over canals and ditches not crossable otherwise; all important viaducts over railroads, railroad yards, roads, or streams.

Drawbridges on roads and railroads should be shown by a separate symbol. Ordinary bridges and trestles on railroads are to be omitted.

The bridge symbol should further be omitted wherever in centers of dense culture its presence would tend to confusion or impair the legibility of the map; also on reconnaissance maps except where it indicates important structures over streams otherwise difficult to cross.

Ferries.—Ferries are to be shown by symbol wherever the stream is wide enough to permit; where it is too narrow (this applies especially to the smaller scales), the ferry is to be indicated by the word. Names of ferries must be put on the map.

Fords.—The symbol for fords is similar to that for second-class roads. On large-scale special maps the route of the ford, if difficult to follow, should be shown, with its characteristic windings.

Trails.—In mapping trails the topographer should consider their relative importance as a means of communication. Thus, in mountain and desert regions, especially in the far West, where travel is largely by trail, he should take pains to map every trail in use, giving its name, if known; in the more densely populated districts, where railroads and wagon roads are plentiful, he should show only such trails as lead up mountains or through unimproved areas not readily accessible otherwise. A mere "way through" not regularly traveled does not constitute a trail.

Steamboat routes.—Only those steamboat routes on lakes and rivers are to be indicated over which a regular public service is maintained by ferries or passenger boats.

Canals and ditches.—Canals, whether for navigation, irrigation, or drainage, should be shown by double-line symbol only when their actual width can thus be indicated on the scale of publication; otherwise, by a single blue line.

The mapping of irrigating ditches is to be restricted to the main feeders; laterals are not to be shown except on large-scale special maps. On smaller scales only those ditches which constitute important landmarks in regions of sparse culture are to be indicated.

Canal locks.—The lock symbol should point upcurrent.

Aqueducts; water and oil pipes.—Only the more important aqueducts and pipe lines should be mapped.

Tunnels.—Tunnels of all kinds, whether on railroads, roads, or canals, should be shown by the tunnel symbol; the route of the tunnel should be indicated by double broken lines (black for railroads and roads, blue for canals).

Dams.—Permanent dams on streams, lakes, or reservoirs should be indicated by a heavy black line. Where a wagon road follows the top of the dam, the road is to be shown in its correct place, the road line on the upstream side being thickened to represent the dam.

Reservoirs.—Artificial reservoirs surrounded by dams on all sides should not be inclosed by the dam symbol but should be outlined in blue like lakes or ponds.

Levees.—Levees and cuts and fills should be represented by the hachure symbol only if they are too small to be shown by contours.

Cuts and fills.—The rule as to hachure symbols for levees applies also to cuts and fills.

Mine dumps.—All mine dumps of sufficient size to deserve mapping should be hachured. Larger ones should be contoured but should also be hachured, so they may not be mistaken for natural hills.

Wharves, etc.—Wharves, docks, jetties, breakwaters, and similar structures should be indicated by heavy black lines with such detail as the scale of the mapping permits.

Lighthouses, etc.—Lighthouses, lightships, and life-saving stations are to be shown by their respective symbols on all maps, whatever the scale.

Cemeteries.—If of sufficient size, cemeteries should be shown with their actual outlines; if too small for this, by a square outline inclosing a cross. Small private cemeteries should be omitted.

Mines, quarries, and wells.—Maps should show the location and, wherever practicable, the elevation of all mines, quarries, open pits of clay, marl, or other material of commercial importance; all mineral prospects exceeding 10 feet in depth, and all country coal banks; and all deep wells, whether drilled for oil, gas, or water, except where such wells are so abundant as practically to be indistinguishable, in which case only the approximate outline of the pool is to be shown.

These are to be recorded in red on the original sheets but are not to be engraved on the topographic maps unless they refer to commercial mines of coal, iron, clay, manganese, or bauxite, to stone quarries, or to exceptionally important and permanent metalliferous mines. Their commercial character may usually, though not invariably, be judged by their possession of railway switches or docks to facilitate transportation, or of equipment permanent in character. Lack of these would exclude from the engraved maps prospect pits, shafts, or drifts and coal mines or clay pits worked only to supply neighborhood demands.

In sparsely settled regions, where there is little culture to be represented, isolated mines, quarries, and even prospects which constitute important landmarks and are widely known should be shown in black with their names and should be engraved.

The above rules apply only to standard-scale maps. On special-scale mining maps all mining features may have to be engraved, even prospects and oil wells. It is for this purpose that the special mine symbols, such as shafts, tunnels, drifts, etc., are provided. On the standard atlas sheets only the crossed pick and hammer symbol for mines and quarries and the sawbuck cross for prospects should be used.

Furnaces and smelters.—No additional conventional sign is considered desirable to represent furnaces, and in many cases it will not be practicable or desirable to name them. In sparsely settled regions, however, the furnaces are frequently the most important and persistent landmarks. They have well-recognized names, which cling to the localities even after the practical disappearance of the furnace itself. In such cases, therefore, it is desirable that the names be given, even if nothing remains but a ruined stack. The same rule applies to smelters, except that those located may be restricted to smelters in active or prospective operation.

Coke ovens.—Only coke ovens connected with mines in operation are to be shown on the engraved maps. Those attached to permanently closed or abandoned mines are to be omitted.

Civil boundaries and boundary monuments.—All civil boundaries, whether national, State, county, district, civil township, reservation (national or State parks, forests, bird and game preserves, Indian, military, or lighthouse), land grants, corporations (city, town, or borough), parks, and cemeteries, are to be shown on the map by their respective symbols. Special effort should be made by field parties to locate such boundaries with accuracy and directly from triangulation or primary-traverse stations if practicable.

Necessary descriptions, survey notes, and plats of all lines of importance should be consulted or procured. Data on national or State reservation boundaries should be obtained at or through the

Washington office prior to the beginning of the field work. Data on minor civil subdivisions can best be procured locally, while the survey is in progress. Many boundaries are obscured or obliterated by natural causes or artificial works; some are indifferently marked to begin with; others have lost some or all of their marks. Information from local settlers may often prove of value and save time and effort in the serach for such obliterated lines. The topographer will do well to avail himself of it; at the same time he should bear in mind that the word of a resident is not to be taken as authoritative, but merely as an aid supplementing information from official sources.

All monuments on national and State boundaries must be located in the field and represented on the map with the appropriate symbol. On other boundaries it is desirable that monuments occupying controlling positions, such as corners or important crossings, be located.

Where lines are found incorrect in azimuth and distance as the result of field errors, it is a fundamental principle that the line marked on the ground is the de facto boundary, and is to be shown on the map in its actual position, regardless of what the statute calls for. This may necessitate in some cases the accurate locating of a number of monuments so that each error in the alinement may be designated at the particular spot at which it exists.

Some civil boundaries are defined by statute to follow natural boundaries, such as streams or divides between watersheds. Those following large rivers should be given special attention, as they may be variously defined as following the "middle" of the stream, its main current, or one of the banks.

Public-land surveys.—All public-land survey lines must be shown on the topographic atlas sheets, and to this end it is necessary that a number of "corners" on them be accurately located in the field and shown on the engraved maps by a black-cross symbol.

In order to expedite the work of locating corners, party chiefs must provide themselves, before taking the field, with copies of plats of the land surveys of the assigned areas. These plats should be assembled in the form of a combined plat, reduced to the scale of mapping, on tracing paper or linen. A detailed description of important corners may prove valuable in recovering them.

The topographer should be familiar with the system of rectangular land surveys and the various intricacies peculiar to it. The more conversant he is in these matters the more intelligently will he be able to make use of land-office data. Acquaintance, further, with the standard monuments used for the various classes of land corners, their marks, and their bearing trees, as well as with the manner in which blazes on trees become overgrown with bark, will prove most useful both in searching for corners and in determining their authenticity where this is in doubt. (For a discussion of the public-land survey system see p. 196.)

United States mineral-locating monuments.—Monuments erected as permanent reference marks for the location of mineral and other claims (often designated as USLM's or USMM's) are important and should be located with the same accuracy as land-survey corners and be shown on engraved maps with their designating numbers.

Triangulation and monumented primary-traverse stations.—Triangulation and primary-traverse stations should be indicated on the topographic maps with the open-triangle symbol only (without name). Wherever practicable, the elevations of these stations should be determined, either by levels, stadia, or vertical angles, and be stamped on the tablet or post that constitutes the permanent mark. If vertical angles have been used, the letters V. A. are to be stamped below the elevation figures.

Bench marks.—All permanent bench marks must be accurately located in the field and shown with their elevations on the engraved maps. Topographic field parties should not rely upon finding bench marks by search simply but must locate them systematically with the aid of the descriptions furnished by the level parties.

Temporary bench marks and other elevation marks.—All temporary bench marks (see p. 101) must be looked for in the field with a view toward their inking in on the final office drawings. Temporary bench marks will be inked with a large red location cross and with black figures of elevation and will be engraved, but whenever interfering with map legibility they may be shown with red figures of elevation and not be engraved. Besides the permanent and temporary bench marks it is desirable that the engraved maps should carry a number of other reliable elevations distributed over the entire area mapped. They should be spaced at intervals of about 1 mile on the 1:62,500 scale and about 2 miles on the 1 : 125,000 scale.

In selecting elevations for publication on the maps, the topographer should bear in mind that it is the policy of this Survey to publish only such elevations as have a definite working value. (See p. 101.)

All elevation data must be assembled on an oversheet tracing in the field, as the small elevation figures which have been placed on the field sheets themselves are ever in danger of being erased or so obscured as to be illegible. On such an oversheet distinction between the different classes of elevations may readily be made by using different inks.

Locations which are to carry names, the letters "B. M.," and elevations, should be designated by an X on the map as heretofore; the figures of elevation and the name should both be placed on the diagram furnished for lettering and neither should be inked on the sheet by the topographer. By this plan the letterer is enabled to arrange the names and elevations properly on the sheet.

MAPPING OF HYDROGRAPHIC FEATURES.

Features to be shown.—The hydrographic features to be shown on all topographic maps are

Shore lines.
Tidal flats.
Tidal (salt) marsh.
Streams: Perennial. Intermittent.
Dry stream courses.
Springs.
Wells, tanks, and reservoirs.
Lakes, ponds, and sinks.
Intermittent lakes.
Dry salt lakes.
Fresh marsh.
Submerged marsh.
Wooded marsh.
Glaciers.

Shore line.—On all topographic maps of the Geological Survey the line of mean high tide is considered to be the shore line.

Changes in shore line.—Reported changes in shore lines should be verified by independent field measurements before being adopted.

Tidal (salt) marsh.—Tidal marshes on low coasts are as a rule traversed by a network of tidal channels. Unlike the rills in mud flats these channels are fairly permanent in location and should be mapped individually so far as the scale permits.

Large rivers.—Broad rivers which are to be water lined on the engraved map offer a perplexing problem to the topographer, as, owing to their periodic fluctuations, their width often varies significantly with their stage. The general rule is that the width shown should correspond to the normal stage.

Bars should be "sanded" on the final map and the limits of the sand area indicated in pencil on the field sheets.

In areas where the flow of streams, though active for brief periods, dwindles or ceases altogether for many months, the normal or prevailing stage is very low. Thus, rivers like the Platte are normally braided streams, and should be represented as such on the map. Many rivers in the desert regions present nothing more than broad sandy washes and should be shown by strips of sanding.

Mapping of river banks.—If the contour interval is too large to permit the delineation of river banks by contour lines, hachures should be used, a single row being sufficient.

Doubled-lined streams.—No stream should be double lined unless its actual width can thus be shown on the scale of publication without need of exaggeration.

Perennial streams.—The topographer will show on his field sheets all perennially flowing streams that the scale of publication will permit; to prevent confusion in inking, his field drafting should clearly distinguish between perennial and intermittent streams.

Intermittent streams.—Intermittent streams are those having alternating pools and dry stretches, or those flowing for only part of the year.

On his penciled field sheets the topographer can not show too much of the intermittent drainage. For the engraving, to be sure, only the more important drainage courses are to be inked, but for the construction of the map all drainage lines are of value. They constitute a controlling element of all normal-erosion topography, and serve as a natural skeleton for the construction of the contours. Indeed, the systematic tracing out of the drainage net can not be too strongly recommended; the earlier the topographer begins to cultivate the habit the more successful he is likely to be in his work. Even in volcanic, sand-dune, or glaciated areas, where the topographic features have been shaped by agents other than running water, the drainage lines will often be invaluable to the topographer in making clear the real nature of slopes and irregular surfaces that are in themselves deceptive to the eye.

Disappearing streams.—Many streams in limestone regions abruptly sink into caverns and continue their courses for long distances through subterranean channels. Special care should be given to the mapping of this type of drainage; the points of disappearance and reappearance should be accurately located.

Springs.—The importance of springs is dependent on their relative usefulness as a part of the water resources of the region in which they occur; and that is the criterion that should govern their mapping. Thus, although it would be entirely proper to omit springs in large numbers from maps of well-watered regions, it would be manifestly improper to omit them from any map, even the merest reconnaissance, of desert regions. There, springs are literally of vital importance, and their omission or erroneous location may have the gravest consequences to those dependent on the map. In such regions it is further desirable to indicate the name by which each spring is known. Intermittent, alkali, or undrinkable springs should be so designated on the map.

Wells and tanks.—The importance of wells and tanks, like that of springs, depends entirely on their relative usefulness as a part of the water resources of the region. In semiarid regions both wells and tanks must be shown. Wells, if artesian, should be so designated.

Lakes, ponds, and sinks.—Wherever doubts arise as to the limits of lakes, ponds, or sinks, the line of the permanent land vegetation should be mapped as the boundary.

Intermittent and dry salt lakes.—Shallow lakes and ponds which are dry for many months each year and dry salt lakes are a physiographic feature typical of some regions, and all those not too small for the scale must be shown.

Fresh-water marshes.—Fresh marsh and swamp land is defined as that not suitable for cultivation without first being drained. All lands of this class should be shown on the published map with fresh-marsh symbol.

Submerged marsh.—Marsh lands that are partly submerged for many months each year are to be differentiated from ordinary marsh and represented by a special symbol combining water and marsh tufts.

Glaciers.—The area of each glacier is to be outlined by a dotted (blue) line, and its surface is to be contoured (with blue lines on the final map) with the same contour interval as that used for adjoining land surface, and with the same degree of accuracy.

MAPPING OF TOPOGRAPHIC FEATURES.

CONTOURS.

For the cartographic representation of land forms several systems are available, but that which has proved most useful and has become the standard in Geological Survey work is that of contour lines. The superiority of this system lies in the fact that not only is the vertical interval between the lines capable of being regulated to suit the character of the relief, but each contour, being a line of constant elevation lying wholly within a "level surface" parallel to the spheroid of sea level, projects upon the plane of the map with a minimum of distortion. It appears for all practical purposes with its true length and true deflections, and consequently represents the contour of the ground at a given level with exactness.

DELINEATION.

Uniformity in practice.—Uniformity in practice in the delineation of topographic features is essential if harmonious results are to be obtained, and although much of the divergence in style of contouring arises from a deficiency in training of eye and hand in the artistic phases of the work, some of it may be attributed to a lack of recognition of basic geometric and physiographic principles. The following suggestions may assist in obtaining the required standard:

Methods of contouring.—In regions where the principal control is obtained by different kinds of traverse generally extended along public highways, the usual procedure is first to contour the country along the route of a given circuit and then to complete the interior of this particular circuit, subdivided by additional control which will be a sufficient base for the accurate delineation of all essential features required by the scale and contour interval. This subdivisional control may consist of one or more of the several kinds of traverse, of intersections obtained from plane-table stations, or of such a combination of methods as will in the judgment of the topographer produce the most accurate and economic results.

The method of contouring regions of bold relief, where all the features are plainly visible, is that of delineating one feature at a time; of drawing all the contours on one land form before commencing on the next. To apply this method with best effect, the topographer should learn, in the first place, to parcel the landscape into its constituent masses or unit forms. The simpler and more easily conceived their conformation the more readily and surely the delineation will proceed. He should therefore deal with each mountain, hill, or spur as a unit. He should, after sufficient control has been established, segregate it from its neighbors by locating the drainage lines that form its natural boundaries, and should, wherever it is practicable, trace out the crest lines and divides. These and the drainage lines together constitute the natural skeleton upon which to place the contours. The skeleton outline once prepared, it is a relatively easy matter to locate the contours themselves. The individuality of each unit should be kept in mind and all the lines expressing its form should be drawn in succession in their correct relations to one another. Each spur on a hill or mountain side should thus be delineated with its own characteristic shape.

It is best, as a general rule, to use convex forms as units, the intermediate drainage lines being used as boundaries.

Use of form lines.—It is realized that practical difficulties often prevent the topographer from adhering rigidly to the method outlined. Incompleteness of control is a common interfering factor. The upper parts of a hill or mountain may be ready for mapping while nothing is as yet available to determine the foot of the slopes. In such cases it may be advisable to extend the sketch beyond the control points and to indicate provisionally by "form lines" the configuration of the lower slopes.

In regions of moderate relief, where each feature takes but a few contours or where the mapping is done at short range, this mode of provisional sketching by "form lines" is unnecessary, but when dealing with intricately sculptured mountains it is often an absolute necessity.

Topographic expression.—The topographer must possess, in addition to his qualifications as an engineer and surveyor, the ability to delineate topographic features with such fidelity as to produce a map which will clearly indicate the physiographic character of the country.

It is most desirable, therefore, that the topographer should have a thorough grasp on his subject. The features of the land must be something more to him than a meaningless jumble of hills and hollows. He must recognize the system that runs through them and understand the significance of their individual shapes. The smaller the scale he is working on the more important will such physiographic knowledge be. Large-scale maps, on the other hand, are less of a problem, as all features not insignificant in size can be adequately shown on them. But in delineating even large-scale maps with abundant control, physiographic knowledge is necessary. Such maps are usually regarded as equivalent to engineering plats in accuracy and are therefore bound to be correct. But, however numerous the locations controlling a given contour, it is always possible, so long as they are an appreciable distance from each other on the paper, to give the line different significant shades of meaning, each equally justified by the control. That line is likely to be nearest to the truth that is drawn most intelligently, with the fullest comprehension of the character of the feature expressed. Geometric knowledge, essential though it be, clearly is not alone sufficient: the most accurate geometric concept of a land form is likely to appear "wooden" or lifeless on a map unless it is vitalized into its real significance by an intelligent insight. It is therefore important that the topographer have sufficient knowledge of physiographic and geologic structure to understand the type of land form with which he is dealing and to realize wherein its peculiar character resides.

MAPPING OF LAND-CLASSIFICATION DATA.

GENERAL REQUIREMENTS.

Each topographer when engaged in mapping in the States of Minnesota, Nebraska, Kansas, Oklahoma, New Mexico, or in States west of them or in areas containing public lands, national forests, or national parks in the States east of them, must make the field observations and local inquiries necessary to enable him to submit to the land-classification board a plat and written report containing such land-classification data as will indicate the possible uses of the lands which he maps.

Such reports will be based only upon facts personally observed by topographers or their assistants or obtained by them through inquiry from known and reliable sources. Both graphic and written reports must be signed and dated by the person or persons preparing them, and must bear the names of the chief or chiefs of party, the names of assistants engaged in collecting the material on which it is based, and the date of the field work.

The general character of the information desired by the land-classification board will appear from the following list of subjects on which it is required to report to the Director for his submission to the Secretary of the Interior:

(*a*) Designations of (1) areas which are not susceptible of successful irrigation at a reasonable cost from any known source of water supply and which can therefore be entered under the general provisions of the enlarged-homestead act (as suitable for dry farming); and (2) lands in certain arid States which do not have an available supply of water (either surface or ground) for domestic purposes such as to make continuous residence on the land possible.

(*b*) Recommendations as to withdrawals of lands for water power, reservoirs, and public watering places.

(*c*) Recommendations for the protection of mineral resources and for other public uses.

(*d*) Reports on the valuable power-site and reservoir possibilities involved in (1) applications for rights of way for railroads or for canals, ditches, reservoirs, etc., included in power and irrigation projects; (2) proposals for alienation of tracts of land in Indian reservations and in the public domain under any of the laws providing for such alienation; and (3) designations by Congress for special alienation or use of whole Indian reservations and other areas.

The board should be notified of the presence of any deposits of coal, oil, gas, or phosphate, the topographer bearing in mind that it is much better to report knowledge already possessed by the Survey than to fail to report facts not on file. The land-classification material thus submitted will be filed with the other records for the area covered and with them will become the basis for recommendations to the department.

For the purposes of the land-classification board it is essential that enough land corners be identified on the ground and located on the map to enable the best possible adjustment of the land-line net to be made. The land must finally be classified by the smallest legal subdivisions, and the immediate availability of the classification data reported depends on its definite application in terms of the land-office surveys to the land described.

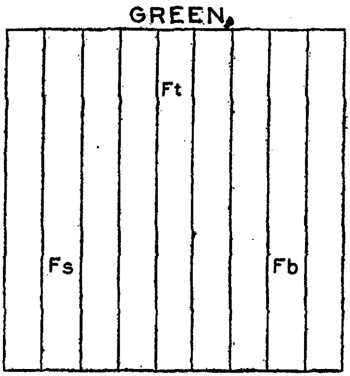


FIGURE 6.—Pattern and symbols for designation of forest land.

AGRICULTURAL DATA.

A sheet must be prepared that will show the classification of the land in accordance with the general outline and symbols described below. The base for this sheet will be the topographic map of the area covered, but the classification will be inked on tracing cloth, on which all projection lines should be fully shown and numbered. When transmitted to the board it should be attached to an undersheet, either a photolithograph or a photograph of the topographic map on the same scale.

An accompanying written description should explain and amplify, where necessary, the information given on the classification sheet and should include all facts which can not be clearly shown graphically, including the character of each examination. The description should, when practicable, be arranged in the order followed in the list of symbols given below and should be arranged in paragraphs, with headings corresponding to those there given, including the index letters. This description should include a discussion of the usual money value of the different classes of land in the locality, so far as known. The description should be appropriately headed and each page should be so designated that if separated from the others it could be quickly restored to place.

The outline and sets of symbols (shown in figs. 6, 7, and 8 and described below) should be used in preparing agricultural data for submission to the land-classification board. The system permits the overlapping of different classes of lands to be shown. For example, land bearing merchantable timber may be good summer grazing land, and these facts may be indicated by vertical lining

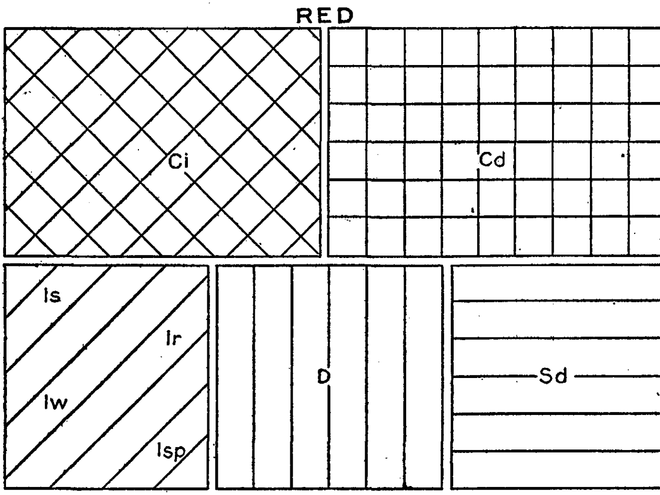


FIGURE 7.—Patterns and symbols for designation of arable land.

and the letters "F t" in green and by horizontal lining and the letters "G s" in yellow.

The boundaries between the four principal divisions as listed below should be inked in black. The boundaries between the subdivisions of a principal division should be inked in the color of that division.

1. *Forest land* (fig. 6; green ruling):

F t Merchantable timber.

F s Small or stunted timber which may be used for posts, firewood, etc.

1. *Forest land*—Continued.

F b Burnt areas.

The kind of timber should always be described in the accompanying text, and where possible its kind should be indicated on the classification sheet.

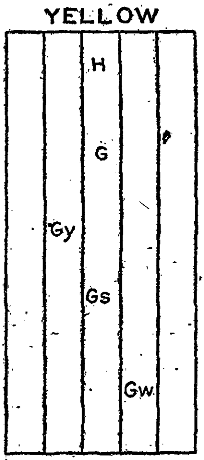


FIGURE 8.—Pattern and symbols for designation of grazing land.

2. *Arable land* (fig. 7; red ruling):

C Cultivated land:

C i With irrigation.

C d Without irrigation.

I Lands not irrigated but which may be irrigated:

I s Irrigable directly from *streams* or *springs*. State unappropriated water rights if known; if unknown, so state.

I r Irrigable from possible storage *reservoirs*.

I w Irrigable from *wells*. Give geologic source if known.

p Irrigable only by pumping from any of the preceding three (insert "p" to other letters; as, I s p).

D Lands cultivable without irrigation (dry farming).

S Swamps:

S e Easily or readily drainable.

S d Drainable with difficulty.

3. *Grazing and natural hay land* (fig. 8; yellow ruling):

H Lands with sufficient natural grass to cut for hay.

G Grazing lands not included under "H." Indicate on classification sheet where practicable the character of the vegetation and the duration of the range:

G y Year long.

G s Summer.

G w Winter.

4. *Barren or waste land* (no pattern):

B a Alkali flats.

B r Rock wastes, escarpments.

B s Sand wastes.

B x Other barrens.

Outlines and symbols for designation of agricultural water supply.

Wells:

Character:

⊕ Flowing.

○ Nonflowing.

Description:

Dug or drilled.

Diameter and depth, indicated thus: 3″ × 168′.

Yield, where well is pumped or where well flows.

Quality of water:

m Mineralized.

du Suitable for domestic use.

st Stock use.

rr Railroad use.

Ownership.

Springs and watering places:

Location.

Description.

Quality of water (as for wells).

Uses (domestic, stock, etc.).

Ownership, public or private. If private, name of owner or occupant.

Area of range controlled.

WATER-SUPPLY DATA.

River surveys in regular topographic mapping.—In connection with or as a part of all regular topographic mapping on field scales of 96,000 or 48,000, river surveys of all important streams will be made on a uniform scale, both in field and office, of 48,000. For this purpose important streams may, in general, be defined as those adapted to the development of power by low or medium heads of

20 to 100 feet. It should be noted that when interpreted on a 48,000 scale the requirements as to detail which it is possible or desirable to show become automatically lessened.

The field traverse sheets when carefully inked should serve as final copy for assembly on the plan-sheets and for data from which corresponding profiles may be made on separate sheets.

When regular field work is executed on 31,680 or 24,000 scale, the river surveys and profiles should be made on the same scale.

In connection with field work executed on the 192,000 scale, only written reports will be required as to water-supply data. Such reports should be based on such general observations and local inquiries as can be made without materially delaying the regular field work.

Written reports.—Signed written reports, accompanied by photographs when practicable, must be submitted iu general conformity with the following instructions, except that map references should be made both to the plan sheets and to photolithographic copies of the quadrangle sheet. Note, therefore, that many desirable facts pertaining to small streams can receive all necessary attention in the written reports.

Special river surveys.—Special river surveys involving the delineation of alinement, water-surface contours, and adjacent topography, and the construction of a corresponding profile will be executed on the scale of 1 to 31,680 (2 inches to the mile). The plane-table method with stadia will be employed.

Topography in all river surveys.—The contour interval on water surfaces will be 5 feet. In addition, the elevations at the head and foot of all falls, rapids, and dams and at the mouths of all important tributaries must be determined. When the stream slope increases so that a 5-foot interval can not be readily shown, the water-surface contour intervals will be increased to 25 feet; beyond this the interval may be increased to 100 feet, but only when demanded by legibility.

The contour interval on land along river stretches will be 25 feet, but wherever a 25-foot office interpolation can be accurately made between the 100-foot contours the 25-foot contours will be omitted and 100-foot (heavy) contours only will be drawn.

The land features, including all culture usually found along streams but excluding large valleys or cities, must be accurately and completely surveyed by additional set-ups, intersections, or side traverses. The work must be executed in such a manner that the data can be readily incorporated in topographic sheets when such areas are regularly mapped.

In the absence of special definite instructions the topography as outlined above should be mapped to an elevation of 100 feet above the stream and sketched for another 100 feet or more if such higher sketching can be done without additional set-ups. Mapped topography should be indicated by full lines and sketched topography by dashed lines, thus enabling them to be clearly distinguished.

Exceptions to the above are (1) wide valleys with low flat floors in which the general height of the floor should be indicated clearly by auxiliary figures of elevation and the general relief features beyond sketched so far as possible without additional set-ups. (2) Reservoir and dam sites. (See below.)

The more important tributaries should be shown with topography for about one-fourth mile and then be sketched as far beyond as possible; for this one or more additional set-ups may be taken if practicable.

Penciled figures of elevation must be placed on the field sheets wherever they will be legible, and frequent contour numbers should be placed on light as well as on emphasized contours.

All gaging stations must be located and the elevation of the zero of the gage given. The ownership, whether United States Geological Survey, Weather Bureau, Army Engineers, or private, must be stated.

Rapids should not be indicated by means of a conventional sign.

Long azimuth lines should be drawn on each separate traverse sheet.

Reservoir and dam sites.—The relations between possible reservoir sites and possible dam sites should be frequently observed as the work progresses in order that these two counterparts when surveyed may serve to illustrate to the fullest the natural storage possibilities. In considering the practicability of a reservoir site the character of the improvements and industries and the amount, kind, and distribution of the timber should be noted and the land values estimated.

The contours within reservoir sites must be accurately determined on a 25-foot interval up to the height of the possible dam. Five-foot intermediate contours must be surveyed (and drawn in close-dotted lines and numbered) wherever an office interpolation would otherwise seriously affect an estimate of storage; that is, wherever an irregular spacing of 5-foot contours extends over a considerable area.

Special surveys of dam sites favorably located in regard to reservoir sites whose existence has been previously ascertained by survey should be made on a scale of 1:31,680, with 5-foot contours up to the height of practicable dam or storage. Depth of water at dam site and character of bottom and abutments should be noted wherever possible.

Land lines.—In sectionized country it is imperative that the land net be placed upon the sheets with an accuracy suitable for 40-acre references. Hence the best judgment must be used before giving up the search for land corners. As aiding toward this accomplishment:

Party chiefs must procure reproductions of land-office plats, which preferably will be photographs furnished on office requisition. They must also obtain a statement if any such plats are under suspension by the General Land Office and must also make inquiry and procure copies of the notes of all such retracements or exterior notes of townships not sectionized as fall within the limits of the river survey. General inquiry should also be made whenever practicable at the local United States land offices.

Existing maps or plats showing corners previously found, such as those of railroad, power, irrigation, and other companies, must be systematically looked for and procured whenever possible.

Diligent inquiry must be made through deputy mineral surveyors, county surveyors, and local engineers as to the existence and location of known corners or ties, and diligent search must be made on the ground for all corners believed to exist near the line of survey. Likewise a reasonable search must be made for such others as fall near or within the work. The time warranted in search for obscure corners will be generally determined by the probable regularity or irregularity of the net and the proximity of corners already found. If no local information is at hand, obviously the greater the necessity for pioneer hunting for the needed land ties.

Stream flow.—An approximate estimate of stream flow should be obtained a short distance below the mouths of all important tributaries. The date of observation and the stage of the water should be noted. Measurements should be made, if possible, at a straight and uniform stretch of water about 200 feet long, free from rapids and cross currents.

The velocity of the current in linear feet per second should be obtained by timing floats (chips) over a measured (stadia) course and using an average of two or more floatings made in or near mid-stream and nearer shore.

The mean cross section in square feet may be assumed to be the mean of the cross sections at the two ends of the stretch. The individual cross sections are obtained separately by multiplying the local width (stadia or intersect) by the corresponding average estimated depth.

The desired stream flow (discharge) in second-feet is obtained by multiplying the velocity in linear feet per second by the mean cross section. Example: Course, 200 feet; floats average 100 seconds in transit; upper and lower cross sections are 300 and 400 square feet, respectively; 2 by 350=700 second-feet of stream flow.

Estimated flow of all important tributaries should be obtained as above.

As the minimum low-water flow denotes the maximum availability of the stream without recourse to storage, and as the high-water discharge in large measure gives its availability for storing, all practicable and reliable information along these lines must be sought, and all information regarding the range of water stages, including data as to past floods or extreme low water, with dates, must be recorded.

Water power.—All dams or other existing natural sites for water-power development must be located and described. If any present development exists, the ownership, character, abutments, possibility of increasing height, and condition of stream bed must be recorded.

The plan and profile sheets of all dam and reservoir sites determined by the river survey should be supplemented by all obtainable facts.

Any favorable stretches of stream which might be of value for power purposes should be noted. The essentials are a diversion-dam site (intake), a site for a waterway alongside (canal or conduit), and a combined site for a relatively short pressure pipe line, and for a power plant on the shore.

Favorable sites for diversion of water for irrigation should be noted.

Information should be collected by observation and by local inquiry as to (1) power development, noting location of existing or proposed power plants, points of diversion, location and capacity of conduit, amount of head available, location of power house, and point of return of water to stream; installation of turbines and generators, including their rating; location and equipment of power-transmission lines, and ownership; (2) reservoirs, noting location, height of dam, capacity, use, and ownership; (3) irrigation works, noting canals and ditches, points of diversion, capacity, location, and ownership; (4) municipal water-supply systems, noting locations of pipes, etc.

Character of adjacent land.—The belt of topography mapped should be classified as to kind, amount, and distribution of timber; extent of cultivated areas; existence of grazing or natural hay lands and duration of range; and extent of barren or waste lands.

OFFICE WORK.

PREPARATION OF TOPOGRAPHIC FIELD SHEETS FOR ENGRAVING.

GENERAL INSTRUCTIONS FOR INKING.

Character.—In inking field sheets the topographer should bear in mind that they are to serve as copy for the engraver. He should therefore execute his inking with neatness and exactness, so there may be no doubt as to the placing and meaning of the symbols and lines; at the same time he should beware of wasting time and effort on artistic effects or needless refinement. The aim should be to give the drafting such quality and clearness as will enable the engraver to work with rapidity and certainty, and anything beyond that is superfluous.

As most manuscript maps are to be reduced and transferred to the copper by photographic processes, it is important that all lines, whatever their color, shall be so inked as to photograph with distinctness.

Inks.—The inks to be used are Higgins's waterproof black, Winsor & Newton's Prussian blue and burnt sienna, and a red ink prepared by the Survey.

Sequence of inking.—Unless special reasons demand otherwise, the features on the map shall be inked in the following order: (1) Culture, (2) drainage, (3) elevations, (4) contouring, (5) lettering (this in many cases is put on a celluloid oversheet).

Symbols and conventions.—The symbols and styles of lettering adopted for the topographic atlas sheets of the United States Geological Survey conform to the standards prescribed for all Government maps. They are to be used in the inking of the manuscript sheets, and all topographers are therefore expected to be familiar with them. (See pp. A–X in connection with sheet of "Lettering and conventional signs" issued by the Survey.)

In addition to the features to be engraved, the manuscript sheets carry many data for special uses. These are to be distinguished by special colors or conventions, as specified in each case.

Woodland and land-classification data are not to appear on the inked manuscript sheets but are to be assembled on separate transparent oversheets.

CULTURE.

Roads.—Roads should be inked with a uniform width which will reduce correctly to the width used by the engraver on the scale of publication. Pikes, drives, and boulevards of special width should be shown to scale whenever they actually exceed the width of the road symbol. On large special scales all roads should be shown with their individual widths wherever they can be platted. Metaled roads should be inked like nonmetaled first-class roads but with the addition of a red overline.

Buildings.—The house symbol on the manuscript sheet should be of such size as to reduce correctly to the size used by the engraver on the scale of publication. Large structures which, platted to scale, exceed the size of the ordinary symbol, should be shown with their individual plan outlines. (See p. 148.)

Railroad crossings.—Wherever railroads and wagon roads cross one another above or below grade—that is, not on the same level—the one passing under the other is to be interrupted at the crossing.

Canals and ditches.—Canals and ditches should not be inked with double lines unless their actual width can thus be shown without exaggeration on the scale of publication.

Civil boundaries.—Where civil boundaries of different classes coincide for a distance the symbol of the major subdivision should take precedence, but in particularly complicated regions, especially among minor subdivisions, it may sometimes be necessary for the sake of clearness to depart from this rule.

Where it is obvious that a civil boundary follows a stream or road for a short distance, the boundary symbol may be omitted to avoid confusion. In some places, however, clearness may be increased by placing the boundary symbol immediately alongside of the stream or road in red.

Public-land surveys.—All land-survey lines should be inked in red so they may not be mistaken for other cultural features; the thickness of the ink line should be commensurate with the importance of the survey line in the system.

Township and range numbers.—Township and range numbers should be placed along the margin of the sheet opposite the middle of each township; the township numbers along the right and left, the range numbers along the upper and lower margins. The numbers should be placed within the townships only where the numbering is *irregular.*

Numbers and names of standard parallels and guide meridians are to be shown.

Section numbers.—On the 1:62,500 scale and all larger scales sections within townships should be numbered.

United States mineral monuments.—Mineral and locating monuments must be shown and accompanied by their numbers, the numbers being placed before the symbol.

United States reservations.—Forest reservations and bird or game reserves must be shown.

BENCH MARKS AND ELEVATION FIGURES.

Permanent bench marks.—Symbols, letters, and figures pertaining to bench marks should, wherever practicable, be arranged with the letters **BM** above and to the left of the cross, and the elevation figures below and to the right. Should they seriously interfere with other features in these positions, this rule may be deviated from at the discretion of the draftsman; in no case, however, should the letters BM appear below or to the right of the figures. All shall be inked in black and figures vertical.

Bench marks in cities.—In case a bench mark is situated in the middle of a city or other center of dense culture, the symbol should be omitted and the letters BM followed by elevation figures, both in parentheses, placed immediately under the name of the place.

Bench marks on triangulation points, land-survey corners, etc.—Bench marks at triangulation and other marked points are not to be shown by symbol, it being undesirable to superpose two different symbols on each other. The letters BM and the elevation figures, however, should appear in the usual place.

Intermediate bench marks.—Intermediate bench marks along routes of primary lines should be shown by a bench-mark cross 0.2 inch in length, inked in red (to be engraved in brown), but should not be accompanied by letters. The elevation figures should be black.

Elevation figures.—Elevation figures, if referring to points not specially marked on the ground but readily identifiable, such as crossroads, road forks, road crossings, and railroad stations, should be inked *in black if to be engraved, in red if not to be engraved.* Wherever the location of the point referred to might remain in doubt, as on flat mountain or hill summits, use should be made of a small brown cross to indicate the exact position.

Water elevations.—Elevations on water surfaces, as in lakes, above and below dams, under bridges, or at fords, shall be in black if to be engraved, in red if not to be engraved, preceded by a small W if necessary.

HYDROGRAPHY.

Water bodies.—Oceans, bays, lakes, ponds, and broad rivers intended to be water-lined on the engraved maps are to be tinted blue (blue tints will not photograph) on the manuscript sheets. As a guide for the engraver, a deeper shade should follow immediately along the shores, islands, rocks, and other features at which the water-lining begins. Bridges and other structures built over the water should not be thus outlined.

Double-lined streams.—Only those streams are to be double-lined whose actual width can thus be shown without exaggeration on the scale of publication.

Perennial streams.—Streams are to be inked with a solid blue line increasing in strength with the importance of the stream, but nowhere so broad as to be equivalent to double lines. Care should be taken not to draw streams to the sheet edge with a width that can not properly be continued on the next sheet. Stream lines should taper off toward the sources of the streams but should remain deep and strong in color to the last. If allowed to become faint the blue will not photograph well.

As a general rule, all perennially flowing streams are to be shown, but the map should not be overburdened with insignificant rills and forks, such as abound in well-watered countries.

Intermittent streams.—The dash and three dots symbol is used to designate intermittent streams. On the penciled field sheets all intermittent stream courses are outlined down to their minuter ramifications, as an aid in contour sketching, but only the more important are to be inked and engraved. The general rule should be to ink no intermittent stream that will be less than three-fourths inch long on the scale of publication. In the more arid districts less intermittent drainage is to be inked, and the minimum length should be increased up to 2 inches or more, according to scale, as may seem appropriate to the degree of aridity. It does not follow, however, that in regions of extreme aridity, such as the deserts of California and Nevada, the map is to carry no intermittent drainage at all. It is to be borne in mind that drainage lines are delineated, not merely because they indicate water features, but because they constitute an important element in the conformation of the land surface and because, especially on contour maps on which lines of greatest declivity are inherently absent, they afford supplementary information of great value in the interpretation of the relief. Whatever the degree of aridity, therefore, a certain amount of intermittent drainage is desirable on the face of the map for the sake of legibility. More especially is this true in delineating intricately sculptured areas, the topography of which in the absence of drainage lines appears chaotic and unintelligible at first glance, and featureless surfaces on which the contours are far apart and the connection between the drainage reentrants is not at once obvious. Aggraded flats and valley floors devoid of well-defined stream channels or scars are not properly shown with drainage lines running through them.

Intermittent streams should not be inked up to or close to the divides. The contours along divides usually suffice to define the location of stream heads, and the symbol should end between one-eighth and one-fourth inch below these.

TOPOGRAPHY.

Strength of contour lines.—Contours should be inked with fine, firm, smooth lines of even strength. Every fifth contour (in the case of 25 and 250 foot intervals, every fourth) must be accentuated and marked with its elevation for aid in reading. The accentuation is to be gained by drawing the lines heavier, not by making them broken or dotted. Their weight should make them stand out from the intermediate contours but should not be so excessive as to cause them to dominate the relief.

The extra weight of the accentuated lines must be considered in the contour spacing, so that they may not cause an apparent increase in declivity

Uniform slopes.—On steep uniform slopes, on which the contours are very closely spaced and no expression is lost, only the accentuated contours should be inked; a much clearer working copy is thus prepared for the engraver, who can readily interpolate the intermediate lines. The omission of the latter, however, is in order only when their parallelism is manifest. Wherever any marked divergence or discordance exists among them, they must all be inked for the guidance of the engraver. As a general rule, the intermediate contours should be indicated on every drainage line and every spur crest.

Bluffs and cliffs.—Extreme care is urged in inking bluffs and cliffs on which the contours can not all be shown. The lines should be as sharp and smooth as they can be drafted, so as to reduce to a minimum the chance of their blurring in transfer to the copper. The general principle should be to ink no more lines than are absolutely necessary for the guidance of the engraver, and to leave the copy as open as the character of the topography permits.

Accentuated contours must not be dropped; they take precedence over the intermediate lines and must be drawn first. The intermediate lines should be inked only where needed to show detailed expression; attempts to fill them in for the mere sake of enhancing the appearance of the manuscript sheet are not permissible.

Depression contours.—Contours inclosing basin-like depressions are to be accompanied by a row of hachures (extending down slope) wherever failure to distinguish them might cause the map to be misread. This applies equally to natural depressions, such as occur in limestone regions, for instance, and artificial depressions, such as are closed in by railroad or road embankments. If the depression takes more than one contour, all should be hachured. In intricate areas it is often desirable to indicate the bottom elevation of the basin by figures, or, if size permits, to mark some or all of the contours with their elevations.

Depressions of large extent covering a considerable area on the map are often readily intelligible without the aid of hachures. Such, however, should be liberally provided with contour figures.

Contour figures.—Elevation figures on accentuated contours should be placed with a special view to their effectiveness as an aid to the map reader. It is desirable, therefore, that they be placed in conspicuous positions; and that they be distributed with some system.

In general, contour figures are most effectively placed on or near the end of spurs and other salients. Broad embankments, long valleys, and other hollow features of importance also require them, but judgment should be used in placing them.

On features taking several tiers of accentuated contours the figures should be placed in orderly series. Such series should follow the features on which they are placed in easy, gentle curves. On very steep slopes, where they would be too crowded, the figures should be omitted on alternate accentuated contours. For most classes of topography series should be about 2 or 3 inches apart on the scale of publication. Each mountain group should have its own series, so that there may be no need of referring to contour figures across valleys or canyons.

In regions of moderate or low relief, where arrangements in series is impracticable, the placing of the figures should be governed primarily by the disposition of the larger topographic subdivision. Each of these should have at least one complete set of figures. In exceptionally intricate topography, as for instance in regions pitted with solution sinks or traversed by high cliffs, the figures on the accentuated contours do not always suffice to make the delineation intelligible. It is proper then to place figures on intermediate contours wherever they will help to remove uncertainty. If need be, elevation figures may be introduced to supplement the contour figures.

Contour figures should not, as a rule, appear in close proximity to bench-mark and other elevation figures. The latter, on the other hand, should not be considered as taking the place of the contour figures.

Finally, care should be taken to select such position for contour figures as will accommodate the engraving on the reduced scale of publication.

LETTERING.

Position.—All names are to be so placed as to be readable from the bottom of the map. Names parallel to a meridian are to read from south to north.

Names of places, public institutions, ranches, mines, and other lesser cultural features are to be placed horizontally and whenever practicable to the right of the feature to which they refer.

Names of ponds, lakes, islands, swamps, and glaciers are to be placed horizontally and to the right, unless the areas of such features are large enough to accommodate the names within their limits.

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Names of oceans, bays, coves, fords, and straits are to be placed across these features in broad curves.

Names of railroads, highways, trails, canals, streams, narrow valleys, canyons, gorges, gulches, arroyos, and washes are to follow the general trend of these features in easy curves. They are to be placed on the upper side whenever practicable.

Names of broad, water-lined streams are to be placed within those features.

Names of mountains, summits, peaks, hills, knobs, etc., are to be placed horizontally and to the right; but if they refer to features of considerable extent, as plateaus, mountain groups, ranges, ridges, basins, or valleys, they are to be spread over same either horizontally or with the trend, as may be most appropriate.

Names of reservations, parks, and forests (National or State), civil townships, and land grants are to be placed horizontally across the areas to which they refer; but when such areas are narrow or winding the names are to be placed lengthwise through them, in sweeping curves, if appropriate.

State and county names are to be placed opposite each other on the boundaries. If a boundary falls on or close to the sheet edge, both names may be placed on the inside of the line, the one referring to the area outside the sheet being given second place.

Punctuation.—Periods are to be consistently omitted on all lettering *within* the margin of the map.

Style of lettering.—All place names and names of country post offices, railroad stations, country schoolhouses, and churches are to be lettered in roman. Where the name of a railroad station differs from that of the corresponding post office, both names are to be shown, the one most widely known being given the greater prominence, the other being followed by "P O" or "Sta," as the case may be. The size of the letters is to be commensurate with the importance of the place. Large cities, State capitals, and county seats take capitals.

Names of routes of communication, such as railroads, highways, trails, canals; of public works, such as bridges, ferries, fords, locks, tunnels, dams, and wharves; of public institutions, such as lighthouses, lightships, life-saving stations, universities, State hospitals, and asylums; and of mining features, such as mines, quarries, prospects, furnaces, and smelters, are to be lettered in small, slanting, block capitals.

Names of civil divisions, such as States, counties, districts, civil townships, and land grants; and of reservations, such as national and State parks, forest and game preserves, Indian and military reservations, are to be lettered in roman capitals.

In inking large roman capitals on manuscript sheets, the shaded parts should be left open wherever there is danger of important detail or dense contouring being obliterated or obscured.

Names of hydrographic features are to be lettered in map italic, except oceans, large bays, straits, rivers, and lakes, which are to be lettered in slanting roman capitals.

Names of topographic features and land features along coasts are to be lettered in upright gothic. Only features of considerable extent take capitals.

Marginal lettering (see also p. B).—All topographic atlas sheets should carry on the margin

The latitudes and longitudes of the projection lines.

At the top the word "Topography."

Above the upper left-hand corner of projection the words

DEPARTMENT OF THE INTERIOR
————, Secretary
U. S. GEOLOGICAL SURVEY
————, Director

Above the upper right-hand corner of projection the name of the State or States within which the area mapped lies, and below this the name of the quadrangle or sheet. If the entire area falls within a single county, the name of that county should appear below the name of the State and should be omitted from the face of the map.

In cooperative surveys, the name of the cooperating State, together with the names and titles of the officials representing it, should appear in the middle of the upper margin under "Topography."

In the middle of the lower margin the scale in the form of a fraction, a bar scale in miles, a bar scale in kilometers, the contour interval, and the datum of elevation should appear in the order named.

Under the lower left-hand corner of the projection should appear the legend stating under whose direction the work was done, by whom the primary control and by whom the topographic mapping was executed, and the date of survey. Credit should be given if appropriated for data used, whether from Federal, State, or private sources. (See p. 143.) In cooperative surveys, the fact of such cooperation must be stated.

Supplementing this legend, and immediately to the right of it, should be placed an "author diagram," showing the area for which each contributor to the work is responsible, with his initials. A diagram showing the mean magnetic declination for the quadrangle should also be given. On maps of 1: 125,000 and smaller scales not carrying section numbers a small township diagram showing the system of numbering sections should appear. Section and township numbers should be given when required by the rule on page 173.

Besides these marginal features common to all atlas sheets, the names of adjoining atlas sheets already published must be placed along the proper sides or at the proper corners of the projection. If he adjoining sheets are executed on scales differing from that of the new sheet, their scales should be given. Lettering should be in map italic.

PREPARATION OF RIVER-SURVEY MAPS FOR PHOTOLITHOGRAPHY.

Size of sheets.—Sheets showing river surveys are of uniform size (18 by 22 inches) with all plan or profile work kept within a 15 by 18 inch neat line, which should be drawn with margins of 1 inch and 2 inches at top and bottom, respectively. Marginal lettering should be kept within a vertical space of 17½ (preferably 17) inches.

Plans.—Plans should be inked in standard colors; all the drainage and culture should be inked, but only so much of the contouring as can be clearly read on a reproduction by a single-color photolithograph.

As it is the readability of the contours from the engineer's point of view that is desirable rather than their graphic expressiveness of relief, the penciling or inking of contours, wherever these closely parallel any shown drainage or culture, should in general be avoided.

Water-surface crossings must be drawn heavy and solid from shore to shore. Every fifth crossing (or intermediate crossings if spaced far apart) must have its elevation placed at the outer end of a black right line drawn out clear of all topography.

Distances along alignments will be indicated in black by figures within small circles placed at the ends of right lines drawn clear of all topography from the center of the stream opposite each platted mile of channel flow. Preferably, they should be numbered upstream.

The mileage must be plotted by pivoting and swinging a scale of miles (drawn as a straight line on tracing paper) within the channel; it must not be stepped off with dividers. The same tracing will pick up the contour crossings for subsequent platting on the profile sheets.

Ink in red for sheet record all water-surface elevations; accompanying reference or direction lines should be inked in red but should be kept clear of all topography. Such data are not for final printing and will be brushed out on the negatives.

Numerous contour numbers and location crosses with figures of elevations should be used for such exterior points as are instrumentally determined.

The plan should be assembled in as few and in as continuous stretches on the same sheet as is practicable, and these stretches should be condensed within the sheet so far as the necessary allowance for outlying section lines, lettering, and other markings will warrant.

Profiles.—Profiles should appear on separate sheets from the plans and should be drawn directly across the sheet, with the separate rows condensed as above. Their direction should be from left to right, irrespective of easting or westing, and this direction of profile should be maintained for all sheets of the set.

For profiles uniform vertical scales must be used so far as possible and profile angles in excess of 45° must be avoided. The profile will be constructed from the water-contour crossings, supplemented by elevations determined at head and foot of falls, etc. (See pp. 167-168.) Profile lines should be drawn heavier than construction lines, and sharp angles should be slightly smoothed.

Key map.—A key map must be prepared for each set of river-survey maps for printing on each sheet of the set. This map should be carefully generalized from the detailed plats and should be drawn on double the publication scale.

Drafting.—Free-hand inking must be in sharp, fine dark lines, suitable for clear reproduction by photolithography (see p. 180), and right lines must be twice lined if fine or in color.

Land lines must be drawn solid and township lines emphasized. Section numbers must be shown only where land has been sectionized; they should be drawn preferably at the centers of sections but should always be offset therefrom if necessary to gain legibility.

Lettering in general should not be placed on or within the inked topography but kept in open places.

PROOF READING, INSPECTION, EDITING, AND TRANSMISSION.

ORDER OF PROCEDURE.

On the completion of the inking, atlas sheets or other topographic-map manuscript prepared either for engraving or for photolithography will be transmitted by the topographer through the division chief in accordance with the following routine:

Border corrections of adjoining sheets.—Whenever practicable, border corrections will be made of previously engraved or transmitted sheets that do not accurately join on to current work. If the previous sheet is still in the editor's hands the original of that sheet should be corrected and the editor informed of the correction; if the previous sheet has been transmitted for engraving, or is engraved, a more elaborate procedure is necessary. If the correction is a small one, it should be submitted in a distinctive color on an engraved or photolithographic copy, provided it can be legibly shown thereon; but if it is extensive or involves close drafting, it should be submitted as an oversheet tracing in standard colors, the scale being immaterial. All corrections to engraved work should be inked in strong photographic colors and should be accompanied by a clear copy for the corresponding take-out on the copper plates.

Lettering.—The final drawing, accompanied by a legible lettering diagram on tracing paper or cloth, is transmitted to the drafting room for lettering.

Land-classification and woodland sheets.—Land-classification and woodland data are to be shown on oversheet tracings made to conform to the usual requirements governing the joining of previous work. (See p. 160.)

Woods.—Tree-covered areas, including merchantable timber and small trees which may be used for firewood or fence posts, should be shown on oversheets in solid green.

Brush.—Areas covered by young and second-growth trees which can not for several years be classified as woods, and shrubs tall enough to hide a man walking, are to be indicated by single hatching in green.

Woods and brush.—Trees and brush when intermixed are to be shown by cross hatching in green.

Proof reading.—Proof reading should be done by a topographer who has not been engaged on the same piece of work. (See p. 184.)

To inspectors for examination.—The original drawing, the border-correction material for adjoining sheets, and the land-classification or woodland sheets are all to be transmitted to the inspection room for examination before being submitted for executive and administrative approval.

Approval.—The sheet must be approved for photolithography, for engraving, or for both, by the division geographer and later by the chief geographer.

Photolithography.—All sheets issued in photolithographic edition should be marked "Advance sheet subject to correction."

Editing.—Sheets approved for engraving should, after the mailing of photolithographic copies from the office, be released from the fireproof safes and referred to the editor of topographic maps for editorial review and examination.

Reference back to the chief geographer.—On the completion of the editing, the original drawing, accompanied by its edited photograph and any other necessary sheets, will be referred back, in jacket, to the chief geographer for reply to queries, approval, comment on editing, and return to the map editor.

Transmission for engraving.—On completion of the map editing the sheet is formally transmitted by the chief geographer through the Director (executive division) to the engraving division.

Engraved proofs.—The first combined engraved proofs, after proof reading by the map editor, are referred to the chief geographer for final approval before the printing of the map edition.

Transmission to land-classification board.—All land-classification and woodland sheets and written reports thereon are to be transmitted to the land-classification board.

Transmission of special reports.—All special reports must be referred to the division geographer for appropriate action.

Filing.—On approval of the final work on any sheet, all remaining map material pertaining to it should be turned over to the custodian of records for safe keeping or appropriate filing.

PROOF READING.

Before being transmitted to the inspectors for examination the original drawing, together with all auxiliary map data (including adjoining border corrections and land-classification sheets), must be submitted, through the division geographer, to a disinterested topographer for careful proof reading as to its completeness, accuracy, and general conformity with Survey instructions. For such proof reading the form printed below (also issued separately) should serve as a guide; it should, however, be regarded as suggestive rather than as complete.

RECORD OF PROOF READING..SHEET.

TOPOGRAPHER CHECK.	PROOF-READER CHECK.	SUBJECT OF EXAMINATION.
		1. Houses, churches, schoolhouses, etc. 2. Roads, first and second class, trails, etc. 3. Railroads, trolley lines, switches, etc. 4. Civil boundaries, State, county, township, city. 5. B. M. symbols, triangulation stations, etc. 6. Public-land lines, township and range numbers, etc. 7. Dams, ferries, bridges, tunnels, etc. 8. Mines, quarries, etc. 9. Streams, double or single line, intermittent, etc. 10. Lakes, ponds, etc. 11. Swamps, marshes, flood plains, etc. 12. Contours, depressions, sand hills, etc. 13. Elevations, contour numbers, B. M.'s, etc. 14. Names of post offices, villages, civil divisions, streams, railroads, etc. 15. Borders and names of adjoining sheets. 16. Marginal lettering, numbers of coordinates, magnetic declination, scale, diagram of township, etc. 17. Forest reserves, Indian reservations.

Each topographer and proof reader should check the following numbers, corresponding to separate five-minute blocks; also place check marks in columns above, opposite each subject, and sign below.

3 2 1	.........................., 19..	3 2 1	.........................., 19..
4 5 6	.... TOPOGRAPHER.	4 5 6	.... PROOF READER.
9 8 7		9 8 7	

As it is a function of the inspectors to advise and instruct regarding this proof reading and by examination to see that it is faithfully performed, not to do it themselves, such work by the proof-reading topographer will be carried out so systematically and so thoroughly as to preclude the necessity for any further similar work by anyone else. This will involve a minute and thoughtful checking up of the entire map through all its features from every point of view that can suggest itself to an experienced topographer.

In order that the proof reader may know that his notations have been attended to, or can be satisfactorily explained by the author or inking topographer, the latter, after due attention and correction, will in all cases return such notations intact to the proof reader for release or further action, pending which the proof reader will withhold his signature from the sheet margin.

In order that the general character and sufficiency of such proof reading may be under the immediate supervision of the inspectors, the division geographers should promptly advise the inspectors of all proof-reading assignments.

EDITING TOPOGRAPHIC MAPS.

The editor of topographic maps examines and edits the manuscript on a photograph made to scale of publication and marks with red ink all corrections, amendments, and changes for the information of the engravers. The jacket, with manuscript and photograph, is then returned to the topographer, that he may answer queries, supply omissions, and review the corrections, interpretations, and rearrangements made by the editor.

When the chief geographer is satisfied that the editing is complete and in proper form he indorses the jacket "Approved for engraving."

At the close of each month the editor of topographic maps advises the chief geographer of the sheets whose editing has been completed, and such are then formally transmitted by the chief geographer to the engraving division (through the Director).

When the engraving of a map is completed and combined proofs printed, the chief engraver refers the complete manuscript, together with twelve engraved copies, to the chief geographer. After further review by the editor, the chief geographer transmits the corrected proofs to the chief engraver, approved for final printing.

In transmitting manuscript maps and proofs from one division to another the officer in charge indorses on the jacket the date of transmittal and the purpose for which the map was referred.

After the completion of the engraving and printing of any topographic sheet, the manuscript drawing will remain in the custody of the editor of topographic maps, and all other engraving material will be filed in the original jacket with the foreman of the plate room in the engraving division.

SUPPLEMENTARY DATA.

MEDICAL AND SURGICAL ATTENTION.

FIRST AID IN EMERGENCY.[1]

Sunstroke.—Get patient into the shade at once. Place on back, loosen clothing, and apply cold water to head and neck. Do everything practicable to reduce temperature of body and rapidity of pulse. In case of exhaustion and threatened collapse, with cold skin and extremities, pale face, and weak pulse, alcoholic stimulants or aromatic spirits of ammonia and heat to the body become necessary.

Lightning.—Dash cold water over person struck.

Frostbite.—Carefully raise temperature of part frozen (which looks white or bluish white and feels cold) by gentle rubbing, preferably with snow or a sponge or cloth dipped in ice water. *Do not* expose to heat or fire. When congestion begins to subside incase in flannel or cotton wool.

Burns and scalds.—Do not break the blisters nor prick them. Cover at once with cooking soda and lay wet cloths over them; or use olive oil and linseed oil mixed or olive oil and limewater if available. Put nothing on a burn that will be difficult to remove afterward.

Drowning.—Get patient into open air; loosen clothing from upper part of body and empty lungs of water by lifting the body by the middle and jerking it a few times. Lay patient on his stomach; raise both arms to shoulder level or higher; turn face to one side, resting forehead on one arm or hand; remove any foreign material from mouth. Kneel astride patient's body at level of hip joint. Place hands, palms down, just over his short ribs, thumbs on each side of spinal column. With arms stiff, lean your weight forward and count six. Then suddenly remove your weight (which relieves the pressure) but not your hands, and count four. Repeat

[1] See First-aid manual for field parties, U. S. Dept. Agr. Forest Service, 1917.

this process in regular rhythm about 15 times a minute, until breathing is restored. Remove lower garments, rub skin dry, rubbing always toward the heart. Above all *don't give up*. Persons have been brought to after hours of persevering, vigorous effort. As soon as breathing begins give stimulants and warm drinks by teaspoonfuls, and get patient to bed as soon as possible.

Mad-dog or snake bites.—Tie cord above wound at once. Suck wound (but be sure you have no cuts or sores in your lips or mouth), cauterize with corrosive sublimate or other caustic, or else with white-hot iron; if none of these means are at hand cut out surrounding flesh with knife. The poison must be prevented from spreading into the circulation.

The bites not only of venomous snakes and mad dogs but of practically all animals are dangerous and liable to produce blood poisoning, as their saliva is at all times charged with septic germs. Every bite, however insignificant, should therefore be very thoroughly disinfected, preferably with a solution of corrosive sublimate.

Venomous insects' stings.—Apply weak ammonia, oil, salt water, or iodine.

Poisoning.—Ptomaines, that is, toxic substances developing in spoiled or decaying food, are the most common source of poisoning. In all cases an effort must at once be made to empty the stomach by vomiting. Tickling the throat with feather or finger and drinking warm water with mustard are the best means to induce it. The bowels should be cleaned out by the free use of Epsom or Rochelle salts, castor oil, or some other laxative. After the poison has been eliminated stimulants should be given and heat and rubbing applied.

Poisoning by drugs or acids requires special antidotes.

For strychnine give mustard and water or sulphate of zinc in 10 to 15 grain doses. Keep the patient absolutely quiet. Plug his ears.

For opium, morphine, laudanum, and other opiates give strong coffee and hot bath. Keep the patient awake and moving.

For any of the foregoing poisons a teaspoonful of tannic acid, followed by an emetic in 15 minutes, is advised.

For arsenic, rat poison, or Paris green give milk, raw eggs, sweet oil, limewater, or flour and water.

For lead, saltpeter, corrosive sublimate, sugar of lead, or blue vitriol give whites of eggs, or milk in large doses.

For chloroform, chloral, or ether dash cold water on head and chest. Give artifical respiration. Put a piece of ice in the rectum.

For mercury and mercury salts give whites of eggs, milk, and mucilaginous drinks.

For carbolic acid give flour and water and mucilaginous drinks; alcohol or whisky can be applied externally or internally with benefit.

For potash, lye, or ammonia give vinegar or lemon juice in water.

Tests of death.—Hold a mirror to mouth; if person is alive moisture will gather. Press a pin head into flesh; in case of death the mark will remain; if it closes life is not extinct.

SURGICAL ATTENTION.

Cuts and flesh wounds.—Reduce the flow of blood at once by applying cold water, snow, ice, or salt; also by elevating the limb or part injured. If an artery is cut and the blood spurts in jets, try to stop the flow by pressing the artery against a bone or muscle with the thumb or forefinger. If the injury is to a limb tie a band tightly around it above the wound—that is, between wound and heart. To tighten, introduce a stick into the band and twist it. Stop turning the moment the flow stops. Remember that too much force may bruise flesh and muscles. Relax the bandage at the end of an hour any way, for keeping up the pressure too long may strangle the limb. Keep bandage in place, however, ready to tighten again if necessary.

Remove all dirt from wound and wash with antiseptic solution, preferably corrosive sublimate (one tablet in 1 quart of water). Avoid using carbolic acid, as it may produce gangrene. Attach a long strip of sticking plaster to skin or on one side of cut, draw the flesh together, and stick down the plaster on the other side.

Deep flesh wounds or holes such as one may get by falling on a pointed stick or by stepping on a nail must be *kept open;* otherwise they will grow over at the surface before they heal inside. Wash out daily with corrosive sublimate and dust with aristol powder or apply aristol and boric acid mixed half and half. Always leave a strip of sterilized gauze in the wound before dressing. It will automatically drain the cavity by capillary action.

Bruises and contusions.—Use cold applications at once. Lead water and laudanum on a piece of cloth frequently renewed will help to allay inflammation. Then apply some soothing ointment or lotion, like arnica or witch hazel, and bandage firmly so as to afford moderate pressure.

Sprains and swollen joints.—Apply lead water and laudanum on a piece of cloth. Bandage tightly and give rest, but keep muscles from stiffening by occasional gentle massage and exercise. Paint with tincture of iodine if available.

Rupture.—Place on back in reclining position, head down and abdomen and legs propped up, so bowels may retract with aid of gravity. Reduce circulation of blood in parts affected by applying cold wet cloths or ice if available. When bowels have ceased to protrude, improvise truss by bandaging tightly about abdomen and thighs. Get patient to skilled surgeon without delay.

Fractures.—Do not waste time making complicated dressings and splints. Broken bones require the most expert surgical skill for their proper setting. Make up your mind that no time is to be lost getting the injured man to a surgeon, and confine your efforts to providing an improvised splint or supporting bandage that will enable him to travel with the least possible suffering and discomfort.

Transportation.—Do not be afraid to transport injured people to camp or town immediately after an accident. They can as a rule stand more hardship and will suffer less in traveling the first few hours after an accident than they will the next day.

MEDICAL AND SURGICAL OUTFIT.

Illness and injury have proved on the whole so infrequent among field men that few parties now carry medical or surgical outfits. It is advisable, nevertheless, to keep a few simple remedies and surgical articles on hand, especially when working in remote areas. The following list may serve as a guide to those most essential in making up a compact outfit:

Pocket encyclopedia of medicine and surgery, by Gould and Pyle.

Quinine, 2-grain compressed tablets (or capsules, but not pills). As a general tonic and preventive against malaria, take 2 grains after each meal.

Quinine sulphate, $1\frac{1}{2}$ grains; arsenous acid, $\frac{1}{60}$ grain; powdered capsicum, $\frac{1}{2}$ grain. One every three hours for malaria.

Compound cathartic, U. S. Pharmacopœia. Extract colocynth, $1\frac{1}{4}$ grains; calomel, $\frac{1}{3}$ grain; resin jalap, $\frac{1}{3}$ grain; gamboge powder, $\frac{1}{4}$ grain. This is a standard cathartic. One or two at night.

Calomel, $\frac{1}{4}$ grain. One every hour until cathartic action is obtained; follow by dose of Epsom salts, castor oil, or sal hepatica. For acute indigestion, biliousness, and torpid liver.

Epsom salts, sal hepatica, castor oil. For cleaning alimentary tract in dysentery, ptomaine poisoning, fermentative diarrhea, etc. Large doses of either salt are debilitating, and must be followed with stimulating but light foods. Castor oil does not require this. Sal hepatica in small doses is excellent for rheumatic troubles.

Sun cholera mixture. Tincture opium, 3 minims; tincture rhubarb, 5 minims; tincture capsicum, 5 minims; spirit peppermint, 5 minims; spirit camphor, 5 minims. For diarrhea, one to two teaspoonfuls every three or four hours as needed. Do not take more than four or five doses.

Limewater tablets. For acidity and nausea. Externally excellent for burns and scalds when mixed with linseed oil. (These tablets often require a long time to dissolve.)

Brown-mixture tablets. Standard remedy for coughs and colds. Extract licorice, 1/20 grain; camphor, 1/50 grain; acid benzoic, 1/50 grain; oil anise, 1/50 minim; opium powder, 1/50 grain; tartar emetic, 1/120 grain. Dissolve one on the tongue every hour until cough becomes free. Do not take for a longer period than 36 hours, but follow with an emulsion of cod-liver oil, teaspoonful three or four times a day.

Boric-acid solution, diluted, for eye lotion.

Tincture of iodine (3 per cent), applied to a wound, is one of the best antiseptics known.

Blue ointment, for chronic ulceration and animal parasitic affections of the skin. Excellent for the prevention of rust on firearms.

Ichthyol ointment. Dilute 25 to 50 per cent with water for skin diseases.

Glycerin. For skin affections, chapped hands, etc. Invaluable for earaches produced by insects, foreign bodies in ears, etc.

Pond's extract ointment, camphor ice (Chesebrough's). For sore lips, chapped hands, or sunburn.

Lead water and laudanum tablets. One tablet to 2 tablespoonfuls of water. Invaluable for sprains, bruises, saddle chafes, etc.

Corrosive sublimate tablets. One tablet to 1 quart of water (or about 1 to 2,000 solution) for washing open wounds. One tablet to one-half pint for cauterizing snake or dog bites. Apply with cotton.

Aristol powder. For flesh wounds, ulcers, etc. Dust on wound or apply with boric acid (equal parts).

Mustard leaves. For plasters, etc.

Arnica and witch-hazel ointment. For bruises, contusions, etc.

Surgical sundries, such as bandages; absorbent cotton; antiseptic gauze; adhesive plaster, in 10-yard spools, 1-inch width; fever thermometer; surgeon's assorted needles; surgeon's silk on cards; glass dropper.

PACK TRANSPORTATION.

In many localities the topographer has to depend solely on pack animals for transportation. Even where wagon roads exist pack animals are often required for side trips or station work. As the party chief frequently has to rely on his own knowledge and resources in instructing assistants in these matters, he must be familiar with details of packing and pack-train management.

PACK-TRAIN EQUIPMENT.

The following list may serve as a convenient guide in the equipment of a pack outfit for a topographic party of six men (two instrument men, two assistants, a cook, and a packer). Riding animals, saddles, and the accessories that go with them are not included.

6 pack animals.
6 packsaddles, with rigging and pads.
6 saddle blankets.
6 pairs pack bags or alforjas.
1 pair small mess chests.
1 stationery case, telescoping.
9 canvas pack covers.
6 lash cinches, each with a 40-foot rope, $\frac{1}{2}$ inch.
6 halters, each with a 7-foot rope, $\frac{3}{8}$ inch.
6 sling ropes, 30-foot rope, $\frac{5}{16}$ inch or $\frac{3}{8}$ inch.
1 stock bell, with heavy leather strap and buckle.

Hobbles and 30-foot picket ropes with swivels, according to the nature of the country and the disposition of the animals.
Horseshoeing kit.
Extra shoes, one set especially fitted up for each animal, if work is to be distant from a blacksmith's shop.
Harness maker's kit.
Extra harness leather, cinches, cinch hooks, lace leather, webbing, buckles, rings, rope, etc.
Liniments, antiseptic washes, etc., for galls.

Experience has taught that the crosstree (sawbuck) saddle is best adapted to the needs of the Survey for pack transportation. It should be rigged with breast straps, breaching, and wide double hair cinches with the large latigo rings protected with leather pads. If possible, the saddle should be fitted to the animal's back and always used on the same animal. Sweat pads, of 12-ounce canvas, renewed when necessary, should be used between the blankets and animal's back as a protection to both.

ORGANIZATION OF PACK TRAIN.

In the pack train the natural leader should be a bell mare, and only one bell animal should be in the train, unless there are other leaders which tend to separate the pack train into small bunches, in which event they should also have bells.

The bell mare should lead the pack train with one member of the party riding her or the animal immediately following, and the animals should be arranged with reference to their likes, dislikes, and gaits. When practicable, distribute the men about four or five animals apart, each man keeping the animals ahead of him in line and preventing lagging. Until the animals are broken in, let each man lead one or, if necessary, a string of animals. Each man should be instructed to watch the packs in front of him and should be held responsible for them. No stops should be made to adjust a pack without signaling those ahead to halt.

CARRYING CAPACITY OF PACK TRAIN.

It is safe to estimate that one pack load is sufficient for one man for 22 days, the load to include portions of the ration, instrument, outfit, and camp equipage. When it is found necessary to transport forage for any length of time the size of the pack train must necessarily be increased. Every attempt should be made to make the loads as light as is consistent with the requirements; tents, kitchenware, stoves, or reflectors, foodstuffs, and other necessities should be selected with special attention to this end.

Loads should average from 150 to 200 pounds, according to the size and experience of the animal and the nature of the journey. Heavier loads may be necessary, but loads within the limits given will be found more expeditious, especially if the animals are just from pasture, when heavy loads and long marches should be avoided until they have had time to get hardened and pack wise. Care must be taken in balancing the heavy load in side packs, with the light or bulky part on top, and in seeing that the pack is cinched tight. Constant lookout must be kept to see that the load does not shift or turn; if it does, it should be immediately straightened to avoid sore backs or mishaps.

MARCHES.

The gait and distance when traveling depend entirely on the character of the country. Over flat country, good roads, and smooth trails, 20 to 30 miles is a good day's journey. Across broken country, over difficult mountain trails, or through fallen timber, 10 miles or less is all that can be made. If the train is to subsist on the country, the different members of the party should be on the lookout for feed.

CARE OF PACK ANIMALS.

In rough country, where pack animals will have hard usage, they should be given every possible consideration. The saddle should not be taken off at once if the back is wet, but should be loosened and allowed to stay on the animal for half an hour. Immediately thereafter the animals should be allowed to roll and cool off around camp, and if any of them has a sore back it should be properly cleansed by washing with castile soap and warm water, then treated with powdered alum or any other astringent powder or wash, such as sugar of lead or sulphate of zinc, 20 grains to an ounce of water. Their feet should also be inspected frequently and shoes fitted and replaced when necessary. In regions infested by mosquitoes a smudge should be built as a protection, and, if possible, shelter should be provided.

HORSE RATIONS.

As a general rule a horse on hard work should not be given more hay than grain by weight. Where corn is available, 10 pounds of alfalfa, 8 pounds of corn, and 2 pounds of oats make an excellent daily ration for a work horse weighing from 1,000 to 1,200 pounds. The amount of the rations may be changed proportionately for lighter or heavier horses. It should not be taken that all horses weighing 1,000 pounds should be given the same ration. Horses vary as to the amount of food required just as persons vary in this respect. High-strung and nervous horses require more food than placid and gentle horses—owing, of course, to the increased wear and tear on their bodies caused by the tension under which they work. The average mule will eat less than the average horse. If corn is not available, fairly good rations may be figured on the basis of 1 pound of oats and 1 pound of alfalfa to each 100 pounds of horse per day.

During winter months or periods of idleness on the part of the horses, a portion of the alfalfa may be replaced by oat straw and the grain ration may be reduced materially or discontinued altogether, the reduction depending upon the length of the idle period.

UNITED STATES SYSTEM OF PUBLIC-LAND SURVEYS.

The following discussion, based on the "United States manual of public-land surveys," to which the topographer is referred for more detailed information, is intended to give the topographer a general outline of the plan and practices of the public-land surveys.

TOWNSHIP UNITS.

The unit of the system is the township, a tract 6 miles square, or nearly so, bounded on the east and west by true north-south lines, and on the south and north by east-west lines, and subdivided into 36 sections, each a mile square, or nearly so.

As true north-south lines (that is, meridians) converge northward to the pole, it is evident that the width of a township decreases slightly from south to north (41.9 links in latitude 30° N. to 86.5 links in latitude 50° N.),[1] and that its shape is really trapezoidal and not square. It is evident also that as the meridian lines are extended northward, townships will become progressively narrower and will be reduced in area. These complexities growing out of the inherent convergence of meridians on a spherical surface like that of the earth were not taken into account in framing the original law, the intent of which was, apparently, to provide for square units of uniform size; nor was any provision made for a system of control lines whereby the narrowing of the townships, on the one hand, and the inaccuracies in the surveying of the subordinate lines, on the other hand, might be kept within convenient limits. However, the first public-land surveys to be executed, notably the classic "Seven Ranges" in Ohio, demonstrated the need of remedying these defects, and as a result there has been evolved by successive legal steps a system of rectangular surveying which "harmonizes the incompatibilities of the requirements of law and practice" and has become the accepted standard for the entire country.

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[1] All public-land measurements are expressed in chains and links. A chain of 100 links is equivalent to 66 feet common measure and 80 chains equal 1 mile.

PRINCIPAL MERIDIANS AND BASE LINES.

All surveys in a given area are referred to two primary lines, a principal meridian and a base line, passing through an initial point; the one is a true north-south line and the other a true east-west line; that is, a parallel of latitude. These two lines constitute the axes of the system, and the township units are numbered with reference to them in consecutive tiers to the north and to the south, respectively, beginning at the base line, and in consecutive ranges to the east and to the west, respectively, beginning at the principal meridian. Any township, accordingly, may be designated by tier and range number, as T. 14 N., R. 7 W. fourth principal meridian, or T. 10 N., R. 28 E. Mount Diablo principal meridian. The principal meridian must be added to each designation; there are about 30 separate systems in the United States, each with a separate set of axes and a separate system of numbers. The number or name of the principal meridian serves to distinguish these from one another.

STANDARD PARALLELS AND GUIDE MERIDIANS.

From the principal meridian, commonly at intervals of 24 miles, auxiliary base lines called standard parallels, or correction lines, are extended east and west. They are numbered each way from the base line, thus, first standard parallel north, third standard parallel south.

From the base line, usually at intervals of 24 miles, auxiliary meridians called guide meridians are run due north. They are numbered each way from the principal meridian, thus, first guide meridian east, second guide meridian west. As they converge appreciably in a distance of 24 miles (the exact amount depending on the latitude), they are not continued beyond the first standard parallel north, but end at *closing* corners on that line and start afresh from *standard* corners a full 24 miles apart. It will therefore be seen that standard parallels have two sets of corners, one set referring to lines north of the parallel and the other being established by township and section lines from the south, closing on the parallel. The process is repeated at the second standard parallel and at all succeeding ones. Each guide meridian thus runs due north from parallel to parallel, and on each of the latter is an offset to correct for convergence.

South of the base line guide meridians are run *not* south but north, so that the blocks inclosed between them and the parallels there are essentially similar to those north of the base line. In case conditions require that a guide meridian be run south it must be begun at a properly established closing corner.

The standard distance of 24 miles between parallels and meridians, it is to be noted, is not always strictly adhered to. Thus, in many parts of the far West there are five tiers of townships (30 miles) between parallels and six, seven, or more ranges between guide meridians. In some places these irregularities in the spacing of the standard lines necessitate the introduction of intermediate meridians and parallels. These are designated by local names.

Certain data are of special importance in the platting of guide meridians and standard parallels, and these the topographer should not fail to procure from the General Land Office. They are the offsets of the meridians on the parallels and their closing distances.

The meridional convergence increases proportionately to the distance from the principal meridian. Therefore the offset of the second guide meridian is double that of the first guide meridian (between the same parallels); that of the third guide meridian is three times as great; and so on in proportion (assuming the intervals to be regular). Again, the convergence increases slightly northward with the latitude. Thus the offset of a first guide meridian in latitude 50° is more than double what it would be in latitude 30°. Of course the actual offsets depart somewhat from the theoretical ones because of inaccuracies in surveying, and this makes it all the more imperative that they be noted on the plats.

It is to be remembered that all errors of closure in distance are thrown in the *last mile* and are *not* distributed over the entire length of the line. The spacing of the corners along the line is thus not affected by the amount of the closure.

TOWNSHIP EXTERIORS.

Whenever practicable the survey of township exteriors within a block bounded by standard lines begins with the southwest township and continues northward until the entire west range is completed; thence it goes from south to north through the next range east, etc. The mode of procedure is first to run the east boundary of a township due north a full 6 miles. Then to run its north boundary on a random or trial line from east to west, correcting back on a true line after the "falling" north or south of the northwest township corner has been ascertained. The closure in *distance*, however, is thrown in the *last half mile* at the west end of the line—that is, between the last quarter-section corner and the township corner. The purpose of this is to throw the meridional convergence and all irregularities arising from inaccurate surveying toward the west boundary of the township. The last quarter-section corner accordingly lies *not* midway in the last mile but always an even 40 chains from the mile corner east of it, whatever the distance between it and the township corner may be.

In getting data for platting township exteriors, therefore, special note should be made of the closing distances at the west ends of the latitudinal township boundaries. The accuracy of the surveys may be gaged from a comparison of the actual closing distances with the theoretical ones, as indicated below:

Theoretical closing distances at different latitudes.

Latitude.	Closing distance.	
	Chains.	Feet.
30°	79.58	5,252
35°	79.49	5,246
40°	79.39	5,240
45°	79.27	5,232
50°	79.14	5,223

In the northernmost tier of townships in a block it is further necessary to take note of the closing distances of the range lines on the standard parallel. Theoretically these distances should be an even 80 chains, but inaccuracies in the azimuth of the standard lines on the one hand and of the township lines on the other hand usually cause discrepancies. It frequently happens that the length of chain used for the one set of lines differs appreciably from that used for the other, and the closure errors may then amount to several chains. Such discrepancies should be marked on the plats.

SECTION LINES.

Each township is divided by section lines into 36 sections, which are numbered consecutively, commencing with No. 1 at the northeast angle of the township and proceeding west to No. 6; thence proceeding east to No. 12; thence west to No. 18; and so on, alternately east and west, to No. 36 in the southeast corner. In all fractional townships the sections bear the same numbers they would have if the township were full.

As townships are trapezoidal and not square, they do not contain a full 36 square miles each, but fall short of that amount by a number of acres. It being undesirable to distribute this shortage among all of the 36 sections, the law provides that it shall be thrown into the westernmost range of sections, and that the other sections shall be laid out so as to contain a full 640 acres each, as near as may be. Accordingly, the longitudinal lines between sections are run *not* due north but parallel to the east boundary of the township. Each bears slightly west of north, according to the latitude of the township and its distance from the east boundary. The latitudinal section lines are run parallel to the south boundary of the township—that is, as a rule they run practically east and west.

The subdividing of all normal townships begins with the southeast section. Its west boundary is run N. 0° 1′ W. a full 80 chains; its north boundary is then run east on a random or trial line, a quarter-section corner being temporarily placed at 40 chains. The "falling" north or south from the appropriate corner on the township boundary having been measured, the quarter-section corner is then shifted proportionately and set exactly midway between the section corners. In many of the older contracts these rules were not faithfully carried out, and in consequence little dependence is to be placed on the position of the quarter-section corners on the latitudinal section lines. The west boundary of the next section north is then run out, and then its north boundary as before, and so on up through the entire east range of sections. The other ranges are taken up consecutively from east to west, each being surveyed from south to north. The range lines of the northernmost tier differ from the others in that they are connected with the corners along the township boundary, and consequently are not always parallel to the east boundary nor measure an even 80 chains in length. Theoretically they should do so, but in practice the inaccuracies in the surveying of the township exteriors on the one hand and of the section lines on the other hand cause discrepancies. Accordingly, these lines are run first on a *random* or trial line parallel to the east boundary and then corrected back according to their falling. In order to confine the irregularities in acreage to the northernmost tier of lots, the excess or deficiency in measurement is thrown north to the quarter-section corner, and the latter consequently is set *not* midway but an even 40 chains from the south end of the line.

In the west range of sections, again, the latitudinal lines are connected to corners along the west township boundary. Each is therefore run first on a random parallel to the south boundary of the section and then corrected back according to its falling. Here again, in order to confine the irregularities in acreage to the westernmost range of lots, the error (which normally is a deficiency equal to the meridional convergence) is thrown west of the quarter-section corner, and the latter is set *not* midway but an even 40 chains from the east end of the line.

MEANDERS.

Where any lines cross rivers, the right-angle width of which is 3 chains and upward, lakes, bayous, and deep ponds of 25 acres area and upward, meander corners are established on each bank, and from these are run meanders (corresponding to traverse lines) along the banks, to close on other meander corners. Similarly, water bodies of 25 acres area and upward, lying within sections, are surrounded by a meander tied to the two nearest section or quarter-section corners. Islands, finally, are located by triangulation from meanders on the shore, an auxiliary meander corner being established on each one of them.

Meanders are run for the sole purpose of providing a definite boundary for the land areas in the lots abutting on water bodies, so that the acreage of such fractional lots may be computed with accuracy. There is consequently no object in publishing meanders on the topographic maps, and they are to be omitted. At the same time, distances to meander corners and notes or plats of meander lines are often of great value in the construction of the maps in the field, and such data should therefore be procured in all important cases.

Care should be taken in drafting the field sheets to discontinue land lines at such river banks and lake shores as have been meandered. They should not be represented as crossing the water body unless the lines were actually run.

BLAZING LINES.

Trees on line have two chops or notches cut on the side facing the line. Other trees standing within 50 links of the line, on either side of it, may be blazed on two sides diagonally or quartering toward the line, the blazès approaching nearer each other the farther the tree stands from the line.

Random lines are not blazed.

MARKING CORNERS.

Classes.—Land-survey corners are divided into the fourteen following classes, each of which has a distinctive set of marks and is marked in accordance with definite rules:

Standard township corners.
Closing township corners.
Corners common to four townships.
Corners common to two townships only.
Corners referring to one township only.
Standard section corners.
Closing section corners.
Corners common to four sections.
Corners common to two sections only.
Corners referring to one section only.
Quarter-section corners.
Standard quarter-section corners.
Meander corners.
Corners on reservation or other boundaries not conforming to regular system.

Each of these fourteen classes of corners may be constructed as the character of the country and the availability of the materials permit, in eight different ways, as follows:

Stone, with pits and mounds of earth.
Stone, with mound of stone.
Stone, with bearing trees.
Post, with pits and mounds of earth.
Post, with bearing trees.
Mound of earth, with deposit and stake pit.
Tree corner, with pits and mound of earth.
Tree corner, with bearing trees.

No less than 112 different combinations may be met in the field. There is, however, no need of describing each combination separately; the marks follow a definite simple system and in a measure are self-explanatory.

Notches and grooves.—Stones and posts on all township and section corners (except those on standard parallels) are set *diagonally* to the lines—that is, with an edge on each line. On the edges are cut *notches*, the number of which indicates the number of miles to the nearest township corner in the direction of the edge. Thus, the first mile corner on a range line between two townships has one notch on the south edge and five notches on the north edge; and the second mile corner, two notches on the south edge and four notches on the north edge. On a latitudinal township boundary the first mile corner west of the township corner has one notch on the east edge and five notches on the west edge; and the second corner west has two notches on the east edge and four notches on the west edge. A corner common to four townships has six notches on each of its four edges.

Section corners within a township are notched on their south and east edges only. The number of notches on them, therefore, indicates the distance in miles to the south and east township exteriors, respectively Thus, the corner between secs. 25, 26, 35, and 36 has one notch on its south edge and one notch on its east edge; the corner between secs. 10, 11, 14, and 15 has four notches on its south edge and two notches on its east edge; the corner between secs. 5, 6, 7, and 8 has five notches on both its south and east edges.

Stones and posts on standard parallels are set *square* with the lines; that is, with a flat face on each line Their faces are *grooved*, the number of grooves on any face indicating the number of miles to the nearest township corner in the direction of the face. Accordingly, standard township corners have six grooves on their north, east, and west faces; closing township corners have six grooves on their south, east, and west faces. Standard section corners are grooved only on their east and west faces with respect to the standard township corners. Closing section corners are similarly marked with respect to the closing township corners.

Tree corners are notched to correspond with the notches or grooves which stones or posts would bear in the same situation.

Additional marks.—Standard corners of all kinds are marked "s c" on the north face; closing corners, "c c" on the south face. If posts or trees are used the township and range numbers also are indicated on the appropriate sides of standard and closing township corners, and the township, range, and section numbers on the appropriate sides of standard and closing section corners.

Posts at ordinary township corners have each township and range marked on the appropriate face; tree corners bear the same marks on large blazes.

Posts at section corners are similarly marked with the numbers of the surrounding sections and, in addition, with the number of the township and range on the northwest and northeast faces, respectively.

Quarter-section corners are marked "¼s" on their north face if on a latitudinal line, on their west face if on a meridional line. If stones are used the s is omitted.

Pits and mounds.—In open country, where the soil is soft enough to permit digging, square pits are dug about each corner, and the earth taken from them is heaped up into a conical mound. At corners common to four townships the mound is placed immediately south of the monument; at corners common to four sections, west of the monument; at standard corners north and at closing corners south of the monument; and at quarter-section corners, north or west of the monument, according as the line is a latitudinal or meridional one.

The pits are placed on each line about all corners except section corners; at these last the pits are placed diagonally, one in each section.

Where neither stone nor wood is available for suitable corner monuments a marked stone, charred stake, or quart of charcoal is deposited 1 foot below the surface of the ground and the mound placed above it.

Where the ground is stony and does not permit the digging of pits, a pyramid of stones is built in lieu of a mound.

Bearing trees.—Bearing trees, each with a large blaze facing the corner monument, are used wherever the required number of trees within proper distance is available. They are disposed and marked as follows:

At township corners, one in each surveyed township, marked with township, range, and section number, followed by the letters "B T" (bearing tree). At section corners, one in each section, marked with township, range, and section number. At standard corners of all kinds, two trees, one in each section *north* of the parallel; at closing corners, two trees, one in each section *south* of the parallel. At quarter-section corners, two trees, one in each section.

Witness corners.—When the true point for any corner falls in a place where its destruction by natural or other causes would be certain, a witness corner is established in a secure position on a surveyed line, if possible, and within 20 chains of the corner point thus witnessed.

A witness corner bears the same marks that would be placed on the corner for which it is a witness with the addition of the letters "W C" conspicuously displayed above the markings. Its bearing trees, similarly, are marked "W C."

REQUISITIONS.

STATIONERY.

In ordering stationery it is advisable to request not more than three months' supply at one time. Requisitions should be made on the proper form and should designate articles by numbers if any are known. Below are summarized the amount and kinds of stationery suitable for the several classes of field parties. Attention is called to the schedules of general articles (pp. 212-217), any of which may be supplied any class of party.

Precise-level party.

1 account book, 60-page, 9-918.
12 address, notification of, 1-567.
6 bill of lading, 9-060.
25 employment contracts, 9-009.
6 employees, temporary, report of, to Civil Service Commission, 9-946.
6 employment, field, application for, 9-921.
10 freight or express shipment, label for, 9-050b.
2 instruments, transfer of, 9-139.
2 leave of absence, 1-034.
1 level book, bench-mark descriptions, 9-916.
4 level notebooks, yard rod, 9-940.
25 level party, weekly report, 9-922.
24 mail forwarding card, postmaster, 1-044.
15 mail, second class, label for, 9-160.
15 monthly report 9-908.
20 postal cards, plain, 9-482.
20 precise levels, computation form, 9-932a.
2 property, inventory of, 9-054.
10 proposal for general supplies, livery, etc., 9-005.
2 requisition, instruments, 9-445.
5 requisition, notebooks and blank forms 1-420d.
10 requisition, stationery, 1-396b.
6 envelopes, blue, cloth-lined, 5 by 10 inch.
12 envelopes, addressed for Topography.
6 envelopes, white, extra letter size, 4½ by 10⅜ inches.
25 envelopes, standard letter size, 3⅝ by 8⅞ inches.
6 envelopes, manila, 9 by 12½ inches.
2 ink, fountain pen, wood case.

6 pencils, No. 4.
1 paste, tube.
1 rubber bands, box.
10 tags, linen, express shipment.
5 tags, linen, penalty or plain.
3 tags, instrument repair.
10 vouchers, miscellaneous field expense, 9.019.
6 voucher, pay, 9-013a.
6 voucher, party pay and subsistence, 9-015.
15 voucher, purchase, 9-012.
2 voucher, subvoucher book, 9-017 (2 additional for camping parties).
6 voucher, traveling expense, with detached memorandum, 9-016.

Primary-level party.

1 account book, 60-page, 9-918.
12 address, notification of, 1-567.
6 bill of lading, 9-060.
15 employment contracts, 9-009.
6 employees, temporary, report of, to Civil Service Commission, 9-946.
6 employment, field, application for, 9-921.
10 freight or express shipment, label for, 9-050b.
2 instruments, transfer of, 9-139.
2 leave of absence, 1-034.
1 level book, bench-mark description, 9-916.
3 level notebooks, primary, black cover, 9-903.
3 level notebooks, primary, yellow cover, 9-903.
25 level party, weekly report, 9-922.
24 mail forwarding card, postmaster, 1-044.
15 mail, second class, label for, 9-160.
15 monthly report, 9-908.
20 postal cards, plain, 9-482.
2 property, inventory of, 9-054.
10 proposal for general supplies, livery, etc., 9-005.
2 requisition, instruments, 9-445.
5 requisition, notebooks and blank forms, 1-420d.
10 requisition, stationery, 1-396b.
6 envelopes, blue, cloth-lined, 5 by 10 inches.
12 envelopes, addressed for Topography.
6 envelopes, white, extra letter size, $4\frac{1}{2}$ by $10\frac{3}{8}$ inches.
25 envelopes, standard letter size, $3\frac{7}{8}$ by $8\frac{7}{8}$ inches.
4 envelopes, manila, 9 by $12\frac{1}{2}$ inches.
1 ink, fountain pen, wood case.
1 paste, tube.
10 pencils, No. 4.

1 rubber bands, box.
5 tags, linen, penalty or plain.
10 tags, linen, express shipment.
4 tags, instrument repair.
10 voucher, miscellaneous field expenses, 9-019.
6 voucher, pay, 9-013a.
6 voucher, party pay and subsistence, 9-015.
15 voucher, purchase, 9-012.
1 voucher, subvoucher book, 9-017 (2 additional for camping parties).
6 voucher, traveling expense, with detached memorandum, 9-016.

Secondary-level party.

1 account book, 60-page, 9-918.
12 address, notification of, 1-567.
2 bill of lading, 9-060.
10 employment contracts, 9-009.
2 employees, temporary, report of, to Civil Service Commission, 9-946.
2 employment, field, application for, 9-921.
4 freight or express shipment, label for, 9-050b.
2 leave of absence, 1-034.
3 level notebook, yellow cover, 9-903.
25 level party, weekly report, 9-922.
12 mail forwarding card, postmaster, 1-044.
10 mail, second class, label for, 9-160.
20 postal cards, plain, 9-482.
6 proposal for general supplies, livery, etc., 9-005.
1 requisition, instruments, 9-445.
5 requisition, notebooks and blank forms, 1-420d.
5 requisition, stationery, 1-396b.
6 topographic party, monthly report, 9-908.
3 envelopes, blue, cloth-lined, 5 by 10 inches.
12 envelopes, addressed for Topography.
12 envelopes, standard letter size, 3⅝ by 8⅞ inches.
2 envelopes, manila, 9 by 12½ inches.
1 ink, fountain pen, wood case.
6 pencils, No. 4.
5 tags, linen, express shipment.
3 tags, instrument repair.
10 voucher, miscellaneous field expenses, 9-019.
3 voucher, pay, 9-013a.
4 voucher, party pay and subsistence, 9-015.
15 voucher, purchase, 9-012.
1 voucher, subvoucher book, 9-017 (2 additional for camping party).
3 voucher, traveling expense, with detached memorandum, 9-016.

Triangulation party.

1 account book, 60-page, 9–918.
10 address, notification of, 1–567.
6 bill of lading, 9–060.
1 computation book, large, 9–889.
15 employment contracts, 9–009.
6 employees, temporary, report of, to Civil Service Commission, 9–946.
4 employment, field, application for, 9–921.
6 freight or express shipment, label for, 9–050b.
2 geodetic coordinates, computation of, 9–902.
1 geodetic distances, computation of, 9–901.
2 instruments, transfer of, 9–139.
2 leave of absence, 1–034.
10 mail forwarding card, postmaster, 1–044.
10 mail, second class, label for, 9–160.
20 postal cards, plain, 9–482.
2 property, inventory of, 9–054.
6 proposal for general supplies, livery, etc., 9–005.
2 requisition, instruments, 9–445.
5 requisition, notebooks and blank forms, 1–420d.
10 requisition, stationery, 1–396b.
12 topographic party, monthly report, 9–908.
6 envelopes, blue, cloth-lined, 5 by 10 inch.
12 envelopes, addressed for Topography.
6 envelopes, white, extra letter size, $4\frac{1}{2}$ by $10\frac{3}{8}$ inches.
25 envelopes, standard letter size, $3\frac{7}{8}$ by $8\frac{7}{8}$ inches.
6 envelopes, manila, 9 by $12\frac{1}{2}$ inches.
1 ink, fountain pen, wood case.
1 paste, tube.
6 pencils, No. 4.
3 pencil tips, metal and rubber.
1 rubber bands, box.
5 tags, linen, penalty or plain.
5 tags, linen, express shipment.
4 tags, instrument repair.
4 triangulation field notebook, 9–912.
10 voucher, miscellaneous field expenses, 9–019.
6 voucher, pay, 9–013a.
6 voucher, party pay and subsistence, 9–015.
15 voucher, purchase, 9–012.
2 voucher, subvoucher book, 9–017 (2 additional for camping party).
6 voucher, traveling expense, with detached memorandum, 9–016.

Primary-traverse party.

1 account book, 60-page, 9-918.
20 address, notification of, 1-567.
12 bill of lading, 9-060.
25 employment contracts, 9-009.
6 employees, temporary, report of, to Civil Service Commission, 9-946.
8 employment, field, application for, 9-921.
10 freight or express shipment, label for, 9-050b.
2 instrument, transfer of, 9-139.
2 leave of absence, 1-034.
24 mail forwarding card, postmaster, 1-044.
15 mail, second class, label for, 9-160.
1,000 paper, manila, 3 by 5 inch sheets.
20 postal cards, plain, 9-482.
12 primary-traverse field notebook, 9-928.
10 primary-traverse distance record notebook, 9-929.
2 property, inventory of, 9-054.
10 proposal for general supplies, livery, etc., 9-005.
2 requisition, instruments, 9-445.
5 requisition, notebooks and blank forms, 1-420d.
10 requisition, stationery, 1-396b.
12 topographic party, monthly report, 9-908.
6 envelopes, blue, cloth-lined, 5 by 10 inches.
12 envelopes, addressed for Topography.
6 envelopes, white, extra letter size, $4\frac{1}{2}$ by $10\frac{3}{8}$ inches.
25 envelopes, standard letter size, $3\frac{7}{8}$ by $8\frac{7}{8}$ inches.
6 envelopes, manila, 9 by $12\frac{1}{2}$ inches.
1 ink, fountain pen, wood case.
1 paste, tube.
10 pencils, No. 4.
4 pencil tips, metal and rubber.
1 rubber bands, box, No. 32.
5 tags, linen, penalty or plain.
10 tags, linen, express shipment.
3 tags, instrument repair.
10 voucher, miscellaneous field expenses, 9-019.
6 voucher, pay, 9-013a.
6 voucher, party pay and subsistence, 9-015.
15 voucher, purchase, 9-012.
3 voucher, subvoucher book, 9-017 (2 additional for camping parties).
6 voucher, traveling expense, with detached memorandum, 9-016.

Topographic party (1 topographer).

1 account book, 60-page, 9–918.
10 address, notification of, 1–567. 7
2 Beaman alidade notes, 9–913a.
12 bill of lading, 9–060.
3 15 employment contracts, 9–009.
6 employees, temporary, report of, to Civil Service Commission, 9–946.
6 employment, field, application for, 9–921.
10 freight or express shipment, label for, 9–050b.
2 instruments, transfer of, 9–139.
2 leave of absence, 1–034.
10 mail forwarding card, postmaster, 1–044.
20 10 mail, second class, label for, 9–160.
20 10 postal cards, plain, 9–482.
4 property, inventory of, 9–054.
24 proposal for general supplies, livery, etc., 9–005.
2 requisition, instruments, 9–445.
5 requisition, notebooks and blank forms, 1–420d.
6 requisition, stationery, 1–396b.
24 2 topographic party, monthly report, 9–908.
6 envelopes, blue, cloth-lined, 5 by 10 inches.
25 envelopes, addressed for Topography.
6 envelopes, white, extra letter size, $4\frac{1}{2}$ by $10\frac{3}{8}$ inches.
25 envelopes, standard letter size, $3\frac{5}{8}$ by $8\frac{7}{8}$ inches.
6 envelopes, manila, 9 by $12\frac{1}{2}$ inches.
1 ink, fountain pen, wood case.
Paper, drawing. (See p. 217.)
1 paste, tube.
3 pencil tips, metal and rubber.
10 pencils, No. 4.
1 pins, pyramid.
1 rubber bands, box, No. 32.
2 Ruby erasers.
4 1 sandpaper pencil pointer.
24 12 tags, linen, express shipment.
6 tags, instrument repair.
4 2 vertical-angle traverse record, 9–913.
1 vertical-angle record, 9–914.
10 voucher, miscellaneous field expenses, 9–019.
3 voucher, pay, 9–013a.
3 voucher, party pay and subsistence, 9–015.
12 voucher, purchase, 9–012.
3 1 voucher, subvoucher book 9–017 (2 additional for camping party).
12 4 voucher, traveling expense, with detached memorandum, 9–016.

The following articles are usually required in camping parties only

Additional outfit for camping parties only.

Auction sale, advertisement, 9-051.
Auction sale, report of, 9-040.
Pasturage public animals, proposal, acceptance, and receipt, 9-008.
Property affidavit, 9-048.
Property, abandoned or lost, certificate for, 1-515.
Property, inspection report of, 9-047.
Proposal for rations and forage, 9-006.
Proposal for supplies, field, 9-947g.
Storage public property, proposal, acceptance, and receipt, 9-007.

The following articles may also be had on requisition if not already supplied:

Additional outfit for all parties.

Topographic Instructions.
Regulations of Geological Survey.
Telegram book, carbon duplicating, 9-431.
Paper, official letter.
Blotting-paper sheets.
Clips, Gem, Mogul, etc.
Fasteners, paper.
Letter file, Favorite.
Paper, carbon copy books, official.
Paper, ruled, 8 by 10½ inches.
Paper, scratch, note size.
Paper, carbon sheets.
Pencils, Kohinoor, 6-H, 7-H, 8-H, 9-H.
Pencils, red, blue.
Sealing wax.
Tacks, thumb.
Temporary receipt—freight and express.
Tracing linen, 10-yard rolls.
Tracing paper, ~~thin~~ sheets.
Water colors, burnt sienna, Prussian blue.
Paper, manila covers, 18 by 24 or 15 by 15 inches.

The following articles should be called for on requisitions separate from those for other stationery:

Articles for which separate requisitions are requirea.

Baldwin solar charts.
Celluloid sheets, 18 by 24 inches, clear, frosted, or opaque.
Solar transit tables.

Stadia tables, new or old style.
Stadia tables, Anderson's.
Wheel tables.
Vertical-angle tables.
Geographic tables and formulas.
Logarithms, 7-place.
Natural sines and cosines.
Nautical almanacs.
Paper, double mounted, 18 by 24 or 24 by 31 inches.
Paper, manila, 3 by 5 inches.
Paper, single mounted, 15 by 15 or 9 by 9 inches.
Polaris tables.
Tracing paper, 20-yard rolls, thick.

The following are miscellaneous articles that may be had on requisition when required:

Miscellaneous stationery.

Account book, 140-page, 9-919.
Primary-traverse computation notebook, 9-931.
Transit record, 9-905.
Traverse book (blank leaves), 9-904.
Envelopes, return-penalty, $3\frac{5}{8}$ by $8\frac{7}{8}$ inches.
Penholders, drawing, writing
Pens, drawing, K. & E., Gillott's, 290, 291, 303.
Pens, writing, stub, falcon, etc.
Ink, indelible, black, red, green.
Water colors, saucers, and brushes.

INSTRUMENTS.

Requisitions for instruments for individual field men of the classes named below should be on form 9-445 only:

Plane-table triangulator.

1 alidade, 25-inch telescopic.
1 compass, 4-inch.
1 glasses, field.
1 level, circular.
1 plane-table board, 24 by 31 inches.
1 scale, projection.
1 tape, metallic, 50-foot.
1 tripod, Johnson.
1 umbrella, wagon.

Tape traverseman.

1 alidade, sight, Burkland.
1 aneroid.
1 compass, 4-inch.
1 compass, pocket.
1 counter, hand.
1 level, circular.
1 level, Locke.
1 plane-table board, 9 by 9 inches, with compass.
1 plane-table board, 15 by 15 inches, with compass.
1 tripod, Bumstead.

Foot traverseman.

1 alidade, sight, Burkland.
1 aneroid.
1 plane-table board, 9 by 9 or 15 by 15 inches, with compass.
Tape or rope.
1 tripod, Bumstead.

Wheel traverseman.

1 alidade, sight, Burkland.
1 aneroid.
1 compass, 4-inch.
1 counter, hand.
1 level, circular.
1 odometer, Veeder or Bell.
1 plane-table board, 15 by 15 inches, with compass.
1 tape, metallic, 25-foot.
1 tripod, Johnson.
1 tripod, Bumstead.

Stadia traverseman.

1 alidade, telescopic.
1 alidade, sight, Burkland.
1 compass, 4-inch.
1 level, circular.
1 level, plumbing, stadia.
1 plane-table board, 15 by 15 inches.
1 plane-table board, 18 by 24 inches.
1 rod, stadia.
1 tape, 50-foot, metallic.
1 tripod, Johnson.

Topographer.

1 alidade, telescopic.
1 alidade, sight, Burkland.
1 aneroid.
1 compass, 4-inch.
1 counter, hand.
1 set dies, figures, and letters VA.
1 glasses, field.
1 level, circular.
1 level, Locke.
1 plane-table board, 9 by 9 inches, with compass.
1 plane-table board, 15 by 15 inches, with compass.
1 plane-table board, 18 by 24 inches.
1 plane-table board, 24 by 31 inches.
1 protractor, celluloid.
1 rod, stadia.
2 rods, stadia, paper patterns.
1 scale projection.
1 tape, 50-foot, ~~metallic~~.
1 tripod, Johnson.
1 tripod, Bumstead.
1 umbrella, wagon.

Precise levelman.

Dies, figures, 1 set.
Dies, letters.
1 level, Locke.
1 level, prism.
2 pins, turning.
2 rods, precise.
1 tape, steel, 25-foot.

Primary levelman.

Dies, figures, 1 set.
Dies, letters.
1 level, plumbing.
1 level, Y, 20-inch.
2 pins, turning.
1 rod, New York.
1 tape, 25-foot, steel.

Secondary levelman.

1 glass, field.
1 level, 15-inch.
1 rod, Philadelphia.
1 tape, metallic, 50-foot.

Triangulator.

1 aneroid.
2 compasses, prismatic.
2 glasses, field.
1 lamp, electric, hand.
1 plumb bob.
1 protractor, celluloid.
1 tape, steel, 6-foot.
1 tape, steel, 25-foot, meters on back.
1 theodolite.
1 umbrella, wagon.

Primary traverseman.

3 counters, hand.
Dies, figures, 1 set.
Dies, letters.
1 glass, field.
2 lamps, electric, hand.
11 pins, tally.
2 plumb bobs.
2 rods, range.
1 rod, stadia.
1 tape, 100-foot, steel.
2 tapes, 300-foot, steel.
1 tape-repair outfit.
1 transit, 30-second.

FOUNTAIN PENS.

One fountain pen only will be issued to each employee who holds a Secretary's appointment, on written request approved by the division chief. The recorder, as well as the chief of each precise-level party, must be supplied with a fountain pen.

MISCELLANEOUS ARTICLES.

The following articles may be procured on form 9–445:

Bags, book, large or small.
Batteries, for flash lamps, round or flat.
Bench marks, copper nails with washers.[1]
Bench-mark posts.[1]
Bench-mark tablets.[1]
Canteens, 2-quart.
Celluloid sheets, opaque or transparent, 15 by 15 or 18 by 24 inches.
Cement, cans.[2]
Drills, $1\frac{1}{8}$-inch bit.
Flags (for camping parties only).
Hammers.
Hatchets.
Keel, red or blue.
Level bubbles (specify size wanted).
Paint cans, with brushes.
Paper, double-mounted, 18 by 24 or 24 by 31 inches.
Paper, single-mounted, 9 by 9, 15 by 15, or 18 by 24 inches.
Paper, tracing, 20-yard rolls or less.
Posthole diggers.
Scales, flat boxwood, 1:240,000, 1:125,000, 1:96,000, 1:62,500, 1:48,000, 1:31,680, 1:24,000, 1:21,120, 1:20,000, 1:10,000; inches, tenths, and fiftieths; inches, tenths, and eightieths; also 1:48,000 for chains. (Either of these may be made into Burkland sight alidades on request.)

---

[1] Estimate number required for each locality and order accordingly. For cooperative work give the State name.

[2] Estimate number required for each locality and order accordingly.

THE GREEK ALPHABET.

Greek letters are generally used in mathematical formulas to represent quantities, although similar roman letters are often substituted for them. ϕ is generally used to indicate latitude and λ longitude, Δ being prefixed to indicate a difference between two values. δ is often used to indicate the astronomic declination. α represents an azimuth or vertical angle.

Greek alphabet.

Caps.	Lower-case.	Greek name.	English sound.	Caps.	Lower-case.	Greek name.	English sound.
A	α	Alpha.	A.	N	ν	Nu.	N.
B	β ϐ	Beta.	B.	Ξ	ξ	Xi.	X.
Γ	γ	Gamma.	G.	O	o	Omicron.	O short.
Δ	δ	Delta.	D.	Π	π ϖ	Pi.	P.
E	ϵ	Epsilon.	E short.	P	ρ	Rho.	R.
Z	ζ	Zeta.	Z.	Σ	σ ς	Sigma.	S.
H	η	Eta.	E long.	T	τ	Tau.	T.
Θ	θ ϑ	Theta.	Th.	Υ	υ	Upsilon.	U.
I	ι	Iota.	I.	Φ	ϕ φ	Phi.	F.
K	κ	Kappa.	K.	X	χ	Chi.	Ch.
Λ	λ	Lambda.	L.	Ψ	ψ	Psi.	Ps.
M	μ	Mu.	M.	Ω	ω	Omega.	O long.

CONVENTIONAL SIGNS.

The conventional signs shown on the following pages have been adopted by the United States Geographic Board for use by all map-making departments of the Government. As many of the signs are not used at present by the Geological Survey, none should be used on manuscript sheets unless they also appear on the sheet of conventional signs printed by the Survey.

The arrangement of marginal lettering adopted for Geological Survey maps is shown on page B

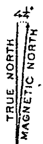
B

ILLINOIS
HERRIN QUADRANGLE

5′ R.2 E. 89°00′ 38°00′
T.6 S.
55′ T.7 S.
50′ T.8 S.
T.9 S. 37°45′
R.1 E. 5′ R.2 E. 89°00′

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

89°15′ R.1 W. 10′ R.1 E.
38°00′
T.6 S.
55′
T.7 S.
50′
T.8 S.
T.9 S.
37°45′
89°15′ R.1 W. 10′ ENGRAVED OCT. 1909 BY U.S.G.S.



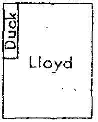
APPROXIMATE MEAN DECLINATION 1908.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by W.J. Lloyd and J.A. Duck.
Control by L.E. Tucker, Henry Bucher.
Surveyed in 1908.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.



WORKS AND STRUCTURES

- *Canal or Ditch*
- *Aqueduct or Waterpipe*
- *Aqueduct Tunnel*
- *Canal Lock* **(point up stream)**
- *Wagon Roads*
  - ***Metaled***
  - ***Good***
  - ***Poor or Private***
  - ***On small-scale maps***
- *Trail or Path*
- *Railroads*
  - ***Railroad of any kind (or Single Track)***
  - ***Double Track***
  - ***Juxtaposition of***
  - ***Electric***
  - ***In Wagon Road or Street*** — ***Steam*** / ***Electric***
- *Tunnel*
- *Railroad Station of any kind*
- *Telegraph Line*
  - ***Symbol (modified below)***
  - ***Along road***
  - ***Along road (small-scale maps)***
  - ***Along trail***
- *Electric Power Transmission Line*

D

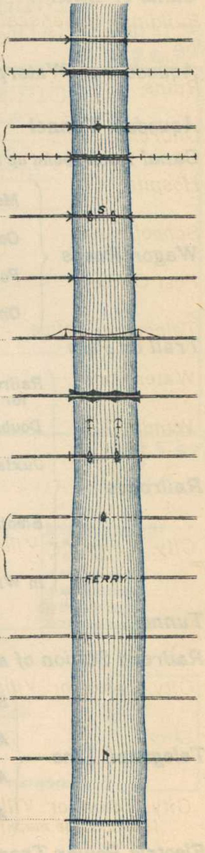
WORKS AND STRUCTURES

Bridges
- *General Symbol*
- *Drawbridges (on large-scale charts leave channel open)*
- *Truss (W, Wood; S, Steel)*
- *Foot*
- *Suspension*
- *Arch*
- *Pontoon*

Ferries

Fords
- *General Symbol (or Wagon and Artillery)*
- *Infantry and Cavalry*
- *Cavalry*

Dam



WORKS AND STRUCTURES

Buildings in general .... 

Ruins ....

Church .... ı or +

Hospital .... • HOS

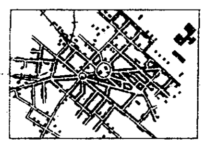
Schoolhouse .... ı or • S H

Post Office .... • PO

Telegraph Office .... ı or • TO

Waterworks .... • W W

Windmill .... or

City, Town, or Village .... 

City, Town, or Village (generalized) .... 

City, Town, or Village (*small-scale maps*)

- *Capital* ....
- *County Seat* ....
- *Other Towns* .... ○

WORKS AND STRUCTURES

Cemetery .... CEM or †

Mine or Quarry of any kind (or open cut) .... ⚒

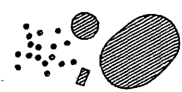
Prospect x

Shaft .... ▪

Mine Tunnel { Opening .... ⅄
Showing direction ....

Oil Wells .... °°°°

Oil Tanks (abbreviation OT) ....



Coke Ovens ....

Fences .... {
Fence of any kind (or board fence) ....
Stone ....
Worm ....
Wire .... Barbed x—x—x—x—x—x Smooth o—o—o—o—o
Hedge ....

BOUNDARIES, MARKS, AND MONUMENTS

National, State, or Province Line

County Line

Civil Township, District, Precinct, or Barrio

Reservation Line

Land-Grant Line

City, Village, or Borough

Cemetery, Small Park, etc.

Township, Section, and Quarter Section Lines (any one for township line alone, any two for township and section lines

Township and Section Corners Recovered

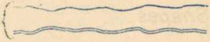
Boundary Monument

Triangulation Station

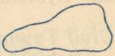
Bench mark — B M × 1232

U. S. Mineral Monument

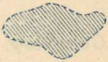
DRAINAGE

Streams in general


Intermittent Streams


Lake or Pond in general
(with or without tint, waterlining, etc.)


Salt Pond (broken shoreline if intermittent)

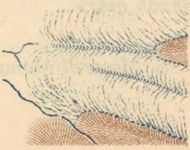

Intermittent Lake or Pond


Spring


Falls and Rapids


Glaciers

- *Contours (or as below)*


- *Form Lines showing flow*


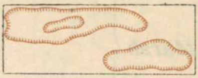
RELIEF

(Shown by contours. form lines. or shading as desired)

Hill Shapes .... *Form lines. hachures. stipple, or other shading*

Contour System ....

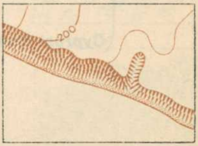
Depression Contours, if otherwise ambiguous. hachured thus ....



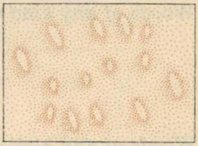
Bluffs

Rocky (or use contours) ....

Other than rocky (or use contours) ....



Sand Dunes ....

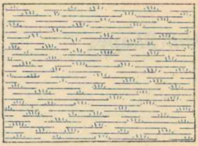


Levee ....

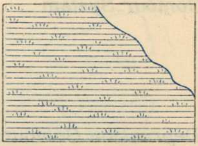
LAND CLASSIFICATION

Marsh

Marsh in general (*or Fresh Marsh*)

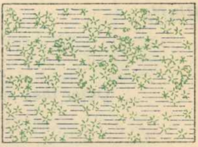


Salt

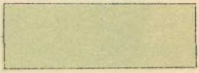


Wooded

Cypress Swamp



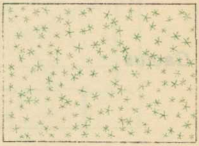
Woods of any kind (*or as shown below*)



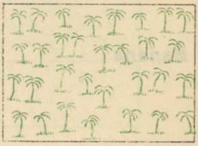
Woods of any kind (*or Broad-Leaved Trees*)

LAND CLASSIFICATION

Pine (or Narrow-Leaved Trees

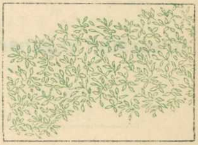


Palm

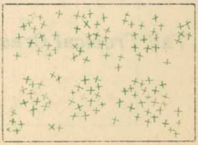


Palmetto

Mangrove



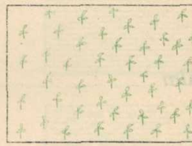
Bamboo



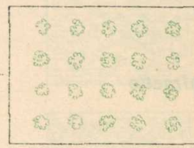
LAND CLASSIFICATION

Cactus ....

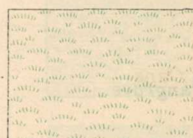
Banana ....



Orchard ....



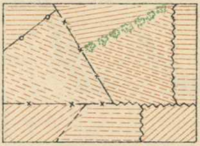
Grassland in general ....



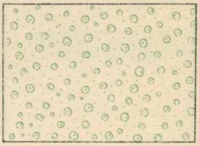
Tall Tropical Grass ....

LAND CLASSIFICATION

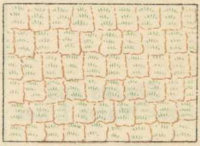
Cultivated Fields in general



Cotton

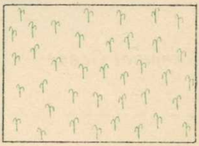


Rice



Sugar Cane

Corn



N

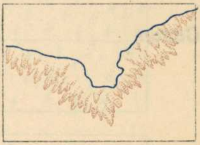
HYDROGRAPHY. DANGERS. OBSTRUCTIONS

Shorelines
- *Surveyed*
- *Unsurveyed*

Shores and Low-Water Lines

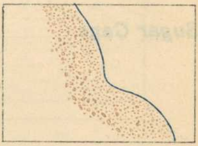
Tidal Flats of any kind (or as shown below)

Rocky Ledges

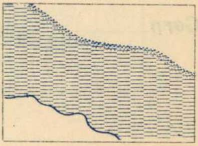


Sand

Gravel and Rocks



Mud



HYDROGRAPHY, DANGERS, OBSTRUCTIONS

Coral Reefs 

Kelp 

Eel Grass 

Rock under water + +

Rock awash (*at any stage of the tide*) * *

Rock whose position is doubtful + *PD*

Rock whose existence is doubtful + *ED*

Overfalls and Tide Rips 

Limiting Danger Line

Whirlpools and Eddies 

Wreck of any kind (*or Submerged Derelict*)

Wreck or Derelict not submerged

Gable (*with or without lettering*) — — — — — — — — —

P

HYDROGRAPHY, DANGERS, OBSTRUCTIONS

Current, not tidal, velocity 2 knots .... 2 kn

Tidal Currents	*Flood, 1½ knots*	1½ kn	
	Ebb, 1 knot	1 kn	
	Flood, 2d hour		or
	Ebb, 3d hour		or

No bottom at 50 Fathoms 50 50

Abbreviations relating to Bottoms

M. mud, *S.* sand, *G.* gravel, *Sh.* shells, *P.* pebbles, *Sp.* specks, *Cl.* clay, *St.* stones, *Co.* coral, *Oz.* ooze, *bk.* black, *wh.* white, *rd.* red, *yl.* yellow, *gy.* gray, *bu.* blue, *dk.* dark, *lt.* light, *gn.* green, *br.* brown, *hrd.* hard, *sft.* soft, *fne.* fine, *crs.* coarse, *rky.* rocky, *stk.* sticky, *brk.* broken, *lrg.* large, *sml.* small, *stf.* stiff, *cal.* calcareous, *dec.* decayed, *rot.* rotten, *spk.* speckled, *fly.* flinty, *gty.* gritty, *grd.* ground, *str.* streaky, *vol.* volcanic.

HYDROGRAPHY, DANGERS, OBSTRUCTIONS

Depth Curves

1 Fathom or 6 Foot Line

2 Fathom or 12 Foot Line

3 Fathom or 18 Foot Line

4 Fathom Line

4½ Fathom Line

5 Fathom Line

6 Fathom Line

10 Fathom Line

20 Fathom Line

30 Fathom Line

40 Fathom Line

50 Fathom Line

100 Fathom Line

200 Fathom Line

300 Fathom Line

500 Fathom Line

1000 Fathom Line

2000 Fathom Line

3000 Fathom Line

R

AIDS TO NAVIGATION, ETC.

Life-saving Station .... L.S.S. (T)
[(T) *indicates telegraphic connection*]

Light of any kind (*or Lighthouse*) ....

Lighthouse, on small scale chart ....

Light Vessel of any kind ....

Light Vessels showing number of masts ....

Light with Wireless ....

Light Vessel with Wireless ....

Light with Submarine Bell ....

Light Vessel with Submarine Bell ....

Light with Submarine Bell and Wireless ....

Light Vessel with Submarine Bell and Wireless ....

Beacons
- *Lighted* ....
- *Not lighted* .... Bn

Sectors, shown by dotted lines

Abbreviations relating to Lights

F. *fixed*, Flg. *flashing*, Fl. *flash*. Fls. *flashes*, Sec. *sector*, Rev. *revolving*, E. *electric*, W. *white*, R. *red*, V. *varied by*, Grp. *group*, Occ. *occulting*. Int. *intermittent*, Alt. *alternating*. m. *miles*. min. *minutes*. sec. *seconds*.

AIDS TO NAVIGATION, ETC.

Buoys

- *Buoy of any kind (or Red Buoy)*
- *Black*
- *Striped horizontally*
- *Striped vertically*
- *Checkered*
- *Perch and Square*
- *Perch and Ball*
- *Whistling (or use first four symbols with word "whistling")*
- *Bell (or use first four symbols with word "bell")*
- *Lighted*

Spindle or Stake *(add word "spindle" if space allows)*

Abbreviations relating to Buoys

C. can, N. nun, S. spar, H. S. horizontal stripes, B. black, R. red, W. white, V. S. vertical stripes, G. green, Y. yellow, Ch. checkered.

Anchorage

- *Of any kind (or for large vessels)*
- *For small vessels*

Mooring Buoy

Range or Track Line

T

SPECIAL MILITARY SYMBOLS

Regimental Headquarters	23 I
Brigade Headquarters	2B 4D★3C
Division Headquarters	5D★3C
Corps Headquarters	8 A C
Infantry in line	
Infantry in column	
Cavalry in line	
Cavalry in column	
Mounted Infantry	
Artillery	
Sentry	
Vidette	
Picket, Cavalry and Infantry	
Support, Cavalry and Infantry	
Wagon Train	
Adjutant General	
Quartermaster	
Commissary	

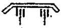
SPECIAL MILITARY SYMBOLS

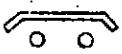
Medical Corps 

Ordnance 

Signal Corps 

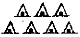
Engineer Corps 

Gun Battery 

Mortar Battery 

Fort } *True plan to be shown if known* { 

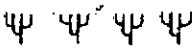
Redoubt 

Camp 

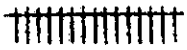
Battle 

Trench 

When color is used execute the following in red

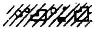
Abattis 

Wire Entanglement 

Palisades 

Contact mines 

Controlled mines 

Demolitions 

CIVIL DIVISIONS

States, Counties, Townships, Capitals and Principal Cities (all capital letters)

ABCDEFGHIJ
KLMNOPQRST
UVWXYZ

Towns and Villages (with Cap. initials)

abcdefghijklmnopqrstuvwxyz

HYDROGRAPHY

Lakes, Rivers and Bays (all capital letters)

ABCDEFGHIJ
KLMNOPQRST
UVWXYZ

Creeks, Brooks, Springs, small Lakes, Ponds, Marshes and Glaciers (with Cap. initials)

abcdefghijklmnopqrstuvwxyz

LETTERING

HYPSOGRAPHY

Mountains, Plateaus, Lines of Cliffs and Canyons (all capital letters)

ABCDEFGHIJKLMNOPQRSTU
VWXYZ

Peaks, small Valleys, Canyons, Islands and Points.
(with Cap. initials).

abcdefghijklmnopqrstuvwxyz

PUBLIC WORKS

Railroads, Tunnels, Bridges, Ferries, Wagon-roads, Trails, Fords and Dams (capitals only).

ABCDEFGHIJKLMNOPQRSTUVWXYZ

CONTOUR NUMBERS

1234567890 *1234567890*

MARGINAL LETTERING

ABCDEFGHIJKLMNOPQRSTU
VWXYZ

(with Cap. initials)

abcdefghijklmnopqrstuvwxyz

1234567890

LETTERING

Names of natural land features, vertical lettering
Names of natural water features, slanting lettering

Thickness of letter $\frac{1}{4}$ of height
Slope of letter 3 parts of base to 8 of height

AUTHORIZED ABBREVIATIONS

A.	Arroyo	L.S.S.	Life Saving Station
abut.	Abutment	L.H.	Lighthouse
A.	Arch	Long.	Longitude
b.	Brick	Mt.	Mountain
B.S.	Blacksmith Shop	Mts.	Mountains
bot.	Bottom	N.	North
Br.	Branch	n.f.	Not fordable
br.	Bridge	p.	Pier
C.	Cape	pk.	Plank
cem.	Cemetery	P.O.	Post Office
con	Concrete	Pt.	Point
cov.	Covered	q.p.	Queen-post
Cr.	Creek	R.	River
cul.	Culvert	R.H.	Roundhouse
D.S.	Drug Store	R.R.	Railroad
E.	East	S.	South
Est.	Estuary	s.	Steel
f.	Fordable	S.H.	School House
Ft.	Fort	S.M.	Saw Mill
G.S.	General Store	Sta.	Station
gir.	Girder	st.	Stone
G.M.	Grist Mill	str.	Stream
i.	Iron	T.G.	Toll Gate
I.	Island	Tres.	Trestle
Jc.	Junction	tr.	Truss
k.p.	King-post	W.T.	Water Tank
L.	Lake	W.W.	Waterworks
Lat.	Latitude	W.	West
Ldg.	Landing	w.	Wood

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B.

D.

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