MANUAL

...OF...

TERREOHMETRY

By Ethan Scheidler

Manual of Terreohmetry

By Ethan Scheidler, *Terreohmetric Engineer*

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PREFACE

In order to have a correct understanding of this Manual it is necessary that the reader shall be possessed of a fair working knowledge of (1) the department of electricity which treats of resistance, (2) civil engineering, and (3) the geology of ore deposits.*

***Note.**—The necessary knowledge of electricity may be obtained by a careful study of the chapters on measurement of resistance in any standard textbook.

Some practical experience in ordinary surveying is very helpful. If the engineer is without this it will be wise for him to secure the services of an assistant who has such experience.

Any of the standard works on geology may be used in preparation for the practice of this art. Practical experience in prospecting and mining also counts for much.

No matter how much or how little preparatory education and experience engineers may have, there is one rule that applies to all, and must be remembered as essential to success in terreohmetric surveying, namely, all preconceived notions, theories and opinions in regard to the existence, location or character of mineral deposits in the area to be surveyed must be disregarded. Terreohmetry is an accurate method of observing facts, and the mind of the engineer must be free from speculations in order that he shall make the survey correctly. After the work is completed, having the facts established thereby as additional basis to what was before known, he may construct new theories if he pleases in regard to what is still undetermined.

Terreohmetry is a new science the development of which was commenced soon after the invention of the terreohmeter in 1900. The author has conducted numerous experiments under a great variety of conditions to determine the fundamental principles of the science. All was theory to begin with, based only on the analogy of other sciences. The result was that some notions had to be discarded; that facts new to the scientific world have been established and principles deduced therefrom.

Herein the attempt has been made to set forth in practical form the knowledge derived both from such experiments and the work of above forty actual surveys.

Let it be recognized that the science is in its infancy and let every engineer who undertakes to practice the terreohmetric art become a student of it. Wider experience will surely have its fruit in a steady accumulation of valuable information. There are a thousand conditions yet to be tested,—and it has been the author's experience that each new condition means a new problem to be solved. But having the foundation already laid, the rest is comparatively easy.

Any who may desire further instruction or advice on the practice of terreohmetry should correspond with the author. Address South Pasadena, California.

NOTE ON PATENTS

The terreohmeter is covered by patents issued to the inventor, Fred Harvey Brown, and cannot legally be used for surveying except under rights acquired originally from the patentee.

CHAPTER I.

Sec. 1. Definition. Terreohmetry is the science of securing and comparing the electrical resistances of different earth-sections in the same vicinity for the purpose of determining whether bodies of mineral or mineral-bearing ores exist therein, their exact location, and other facts concerning them.

Sec. 2. Theory of Earth Resistance. The resistance of massive bodies has been but little investigated, that of the earth not at all outside the terreohmetric art. In some authorities it is stated that the earth has no resistance; in others, that it cannot be measured. The latter was a fact until the invention of the terreohmeter. The former statement is a mistaken surmise, arising from necessarily insufficient investigation of the problem.

This field of study is exceedingly interesting—all the more because it is new—and bids fair to produce a wealth of useful knowledge.

In measuring the resistance of massive bodies, the fundamental principle of electricity still has first place;—the current seeks the path of least resistance. The resistance of a lineal conductor decreases as the diameter increases. Therefore in traversing a massive conductor like the earth, the current utilizes a portion of large sectional area. If the earth-mass, the resistance of which is measured, be perfectly homogeneous with regard to its conducting power, it is supposed that the current disperses and ramifies through it somewhat in the manner that the brush discharge from a spark coil does through the air, and that the diameter of the sectional area of earth section utilized as a conductor by the current varies as the conductivity of the material may be better or worse.

In other words, the conductivity of a section of earth is dependent upon two factors, namely, the mass of material utilized as a conductor and the relative* conductivity of the same.

The former also is dependent upon the latter in some ratio. The theory is incomplete on this point.

In practice it is found that the presence of low-resistance minerals in an earth section reduces the resistance thereof in a ratio much larger than would be supposed considering only the mass of mineral contained therein. This is true whether the mineral be in fine particles diffused through the mass or in lumps.

Nature does not often furnish the ideal condition of homogeneity with regard to conductivity, consequently a comparative study of the relative resistances of the different earth formations covered by each survey is a wise precaution.

Sec. 3. Resistance of Rocks. Not sufficient data has yet been collected for the compilation of tables showing the actual resistance of dif-

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***Note.**—The term "specific conductivity" would be here used, but it is impossible, as not sufficient reliable data has been collected for the selection of a standard of conductivity for massive earth formations and the creation of a table of results with reference thereto.

ferent kinds of rocks in massive form, but experience so far tends to establish the fact that all the crystalline rocks offer approximately the same resistance. Compared with them the igneous rocks are much poorer conductors and the secondary and recent rocks are considerably better conductors.

The absolute resistance of rocks is not, however, a question of first importance in terreohmetry, as that art requires only the determination of relative resistances and the location of bodies of low-resistance material encased in masses of comparatively high-resistance material. Usually the difference of resistance between the material it is desired to locate and the surrounding rock is so great that any variations likely to be found in either are not sufficient to interfere appreciably with the location of the former. Most earth formations that constitute country rocks are exceedingly poor conductors of electricity as compared with mineral bearing ores.

Sec. 4. Relation of Distance to Resistance. Resistance increases with the length of earth-section measured, but the exact ratio of increase has not been established. Increase of resistance, however, is small as compared with increase of length of earth-section.

CHAPTER II.

Description of Apparatus.

Sec. 1. List of Apparatus. The necessary apparatus for ordinary work* consists of: the terreohmeter (otherwise called "Brown's Electro-Geodetic Mineral Finder"), with tripod; three dozen one-half inch, hexagon, spring-brass rods, 30 inches long, pointed at one end; three one-half inch round tool-steel rods, 36 inches long, pointed one end; two jacks for pulling the rods (see fig. 4.); three dozen spring clamps for attaching the wire to the rods; one $3\frac{1}{2}$ lb. hammer; one-half dozen spools (about 4000 feet) No. 18 annunciator wire; one-half dozen field reels which must be made especially for this work (see fig. 5.); and sufficient canteens or other receptacles for conveying water to be used in making earth-contacts.

FIG. 1. FIRST PROCESS

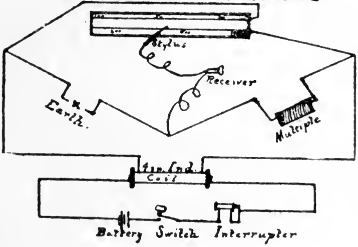
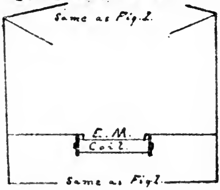


FIG. 2. SECOND PROCESS



***Note.**—The amount of apparatus necessary depends upon the kind of work that is to be done. The list given is that which the author found necessary in surveying large mining properties on the Pacific Coast.

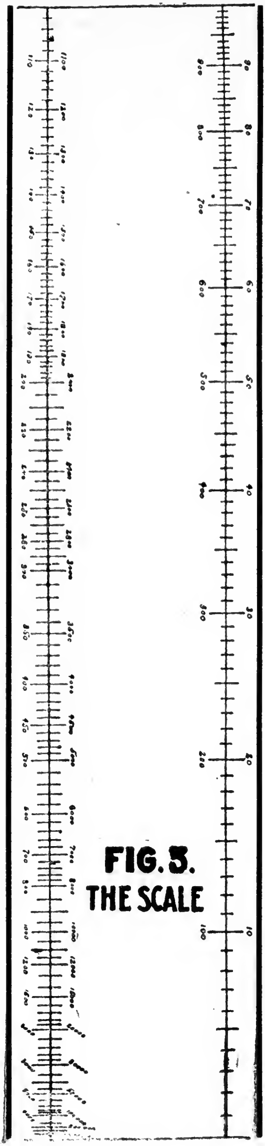


FIG. 3. THE SCALE

Sec. 2. Description of the Terreohmeter. The terreohmeter is an adaptation of the Wheatstone Bridge. (See Fig. 1.) The primary circuit includes battery, switch, interrupter, and the primary of a small induction coil. The secondary circuit traverses the arms of the bridge, one of which consists of a short piece of fine nickel-steel (or other high-resistance) wire laid on a scale calibrated to read from 1 ohm theoretically to infinity, but practically to about 10,000 ohms with ample accuracy. (See Fig. 3, which is one-half actual size.) This scale wire should have a resistance of not less than 7 or 8 ohms. The other arm of the bridge includes the "earth" and a coil of known resistance. In some instruments the latter is 250 ohms; in others there are two coils of 100 and 1000 ohms respectively, either of which may be used as desired by changing a plug. Fig. 3 shows the scale of the latter form of instrument.

The arms are "bridged" by a telephone receiver in circuit with a stylus, connected by flexible cord. The stylus is held in the hand and brought into contact with the scale-wire, while the receiver is held to the ear. A sound is heard in the receiver, which decreases in volume as the stylus is moved along the scale, until a point of silence is reached. Beyond this point the sound is again heard. The figures on the scale at the point of silence indicate the number of ohms resistance of the earth section or other object measured.

The terreohmeter is small that its weight may not be burdensome. The strength of current has no effect on the accuracy of the instrument. As long as there is sufficient current to cause the buzzer to vibrate, measurements may be taken and are the same as though a powerful battery were used.

There are two processes. One form of apparatus (see Fig. 1) uses an alternating current. In the other (see Fig. 2) the induction coil is replaced by an electro-magnetic coil (having primary winding only) and the bridge is traversed not by an alternating current, but by an interrupted extra-direct current. Either form of apparatus may be used with equal facility, but the second is simpler and, under some conditions, has been found to produce a more decided point of silence on the scale.

All connections within the instrument should be soldered. The battery should consist of two or three small dry cells.

The switch must be kept open except when the current is actually employed in measuring resistance; otherwise the battery will soon become exhausted. When using the instrument great care should be exercised to touch the scale-wire very lightly with the stylus. Otherwise the wire will soon become so much abraded that the accuracy of the instrument will be entirely destroyed.

A heavy camera tripod serves very well as a mount for the instrument. To attach same use a square brass plate, with suitably threaded center hole, screwed to the bottom of the instrument box.

When the battery and buzzer are in a box separate from the rest of the apparatus, this second box should be strapped to one of the legs of the tripod. When the battery is contained in the instrument box, the buzzer should be carried in the pocket, suitably wrapped to deaden its sound, and connected in for each reading of measurement by plugs or snap connectors. In this case no switch is needed, for the removal of the buzzer connections breaks the battery circuit.

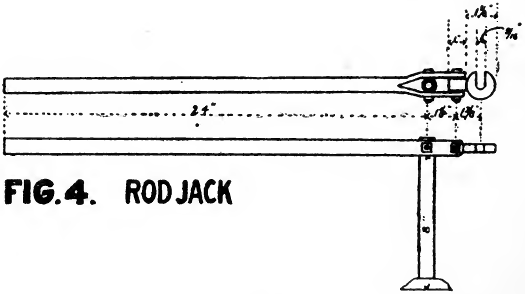


FIG. 4. ROD JACK

Sec. 3. Other Apparatus. The rod-jack is made of 7/8 inch gas pipe. A piece of solid steel rod is welded in at the end of the handle, split and bored to receive 3/8 inch bolts. (See Fig. 4.) The link which engages the rod is of forged steel.

For the spring clamps mentioned in Sec. 1, Bulldog paper clamps that can be purchased at any large stationery store, have been used and found to serve very well though they are much wider than necessary. The essential part of this device is a strong spring to hold the wire firmly in contact with the rod.

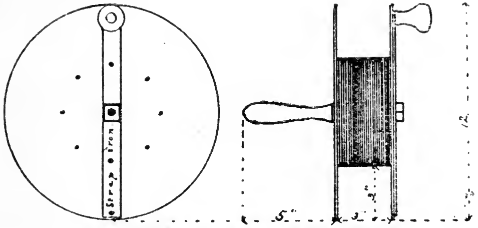


FIG. 5. FIELD REEL

The field reels (see Fig. 5), are made principally of wood. The side pieces are constructed in the same manner as chair bottoms. Brass axles are fitted neatly into bearings of the same metal.

Other devices for making contact with the earth have been used, such as, brass cylinders, brass strips made in the form of a gridiron, brass plates, steel rods. The brass rods described have, however, been found by far the most practicable form of electrode to use in actual work.

The steel rods are used to make holes in which brass rods are placed and their use saves the latter from destruction by excessive hammering.

Sec. 4. Making Repairs. Accidents frequently happen to the apparatus. The following hints, if noted, will save time in repairing same.

When the battery cells become polarized they may be renewed by making an opening in the top with a nail or knife blade and pouring in as much water as the cell will absorb in five or ten minutes. Test the cells separately with the buzzer. A "live" cell will not send a current through a "dead" one.

If the point of silence occurs unexpectedly at the zero end of the scale, the chances are the two ground connections are crossed so that the earth is short circuited. If the point of silence appears at the opposite end of the scale, one of the ground connections is broken.

When no sound can be heard in the receiver, though the buzzer is known to be vibrating, something is wrong with the receiver, the stylus, or with one of their connecting cords.

Always keep the battery and buzzer connections turned up tight. Always see that the insulation is removed from a wire where it is placed in contact with a rod and that the surface of the rod is clean at that point.

CHAPTER III.

Measurement of Earth Resistance.

Sec. 1. General Principles. It is of primary necessity that each measurement of resistance (or "observation," as it is sometimes called) shall be taken with as near an approximation to absolute accuracy as the conditions render practicable.

If a stream of water is to pass freely from a flume into a field the gateway must be of such size and shape that it offers no obstruction to the water. This is fairly analogous to the process of constructing a circuit for an electric current, partly of wire and partly of a section of earth. The rods are the gate by which it must pass into the earth and must be of such number and so placed in contact with earth particles that there is the least obstruction possible to the free passage of the current.

Some conditions (a moist, compact, clay soil, for instance) render this such an easy matter that one rod inserted to a depth of 18 inches gives practically a perfect contact.*

When the surface soil is composed of loose-lying gravel or roughly broken rock mixed with more or less fine material, the difficulty is increased and great care and watchfulness on the part of the engineer are necessary in order that the work may be perfectly reliable. This is true especially where a variety of conditions are met with in the area surveyed. If good contacts are made where it is easy to make them, and at other points on the same survey the contacts have a variety of values as the conditions are more or

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***Note.**—A perfect contact is one which offers no resistance. Perfect contacts must be made at both ends of an earth section in order to secure an absolutely accurate measurement of earth resistance.

less difficult, the work will be worthless as far as deductions regarding the location of mineral are concerned.

An "indicated" measurement of earth resistance always consists of a sum of three resistances, namely, the resistance of the two earth contacts and that of the earth section.

An "absolutely accurate" measurement is one which is made to show the resistance of the earth section alone. An indicated measurement should not be more than five per cent greater than the same if taken with absolute accuracy.

This should be carefully studied as it is a very important point. The above is a description of the greatest and most common error committed by those who have attempted to practice this art. The engineer should therefore be sure that he understands thoroughly the following section.

Sec. 2. Method of Securing Correct Measurements. The rule which must be followed is: MAKE EVERY CONTACT PRACTICALLY PERFECT. This must be done, no matter how difficult the task, or the work will not be worth recording.*

The following is the method by which measure-

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*Note.—It will not do to use for earth-contacts one, or two, or even three, electrodes driven to the same depth at every contact point on a survey, and assume that by this means conditions are equalized and the results therefore rendered reliable. This is an error which must be carefully avoided. On a survey made in this manner some contacts are perfect; others have a value equal to the resistance of the earth section measured; others have a value ten or twenty times that of the earth section measured. The record of work done in this manner is manifestly worth little.

ments of sufficient accuracy may be secured anywhere: at one end of the earth section to be measured insert a steel rod to any depth to which it can be driven with the use of moderate force, taking care to leave sufficient length of rod projecting so that the jack can be used to draw it out. If it is held so firmly that there is danger of breaking the rod or jack, use two jacks, set on opposite sides of the rod. Rods should never be driven with such force as to be bent either in driving or drawing. Unless the ground is already very wet, fill the hole with water. Insert a brass rod to the bottom of the hole—no more, no less. With one of the spring clamps attach an end of wire to the electrode, which now becomes an earth-contact.*

Unreel wire to the other end of the earth section. In the same manner as before place an electrode in position. Now set up the instrument and attach the line-wire (that which connects with the distant contact) to one of the binding screws intended for the earth connections. It is not necessary to cut the wire in order to do this; simply scrape off the insulating material for

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***Note.**—A brass "rod" becomes an "electrode" when it is properly placed in the earth and connected so as to form a portion of an electric circuit of which a wire and an earth section are also portions.

An "earth-contact" is constituted of one electrode or a group of electrodes connected together so as to form one gateway for the passage of the current. There must of necessity be two earth-contacts in every complete circuit which includes an earth section.

the distance of an inch and slip this bare portion of wire under the screw. With a short piece of wire connect the last rod set with the other binding screw.

Now take the reading and record the resistance. Next, place another electrode in position a foot or so from the last one. Connect the two last electrodes together and take another reading as before, except that now the last two electrodes together form one earth-contact. Note the difference between the readings.

If the second reading is a material reduction of the first, continue by inserting a third rod in close proximity to the two already in use and connect it to them. Each rod is inserted to any depth that can be attained with the use of reasonable force, without reference to the depth to which other rods are driven. Take the reading again and note the reduction. Continue thus increasing the number of electrodes used to make the earth-contact, taking the reading with the addition of each electrode, until the reduction noted on the addition of an electrode is less than one per cent of the final reading. By this process a contact having a sufficient degree of perfection is obtained at this point. But the first earth-contact still remains to be corrected.

Disconnect the line wire from the instrument and attach it to the entire earth-contact just completed, in place of the short connection, which is removed. Return with the instrument to the first earth-contact. Disconnect the line wire from the electrode and attach it to the instrument, using an appropriate binding post. Again use a short connecting wire from the instrument to the electrodes. Repeat the last reading taken at the other end of the line. Repeat the operation of adding electrodes to the contact, testing it after the addition of each one until a reduction of less than one per cent of the final reading is again obtained. This last reading, then, is sufficiently accurate to be recorded as the indicated resistance between the points of contact.

In practical work the conditions usually vary so that from two to five electrodes are required to make contacts. The following is a typical table of results from such work as that described above:

From	1	electrode at 1st contact to	1	electrode at 2nd contact	2000 ohms		
"	1	do	2	do	1700 "	reduction	300
"	1	do	3	do	1600 "	"	100
"	1	do	4	do	1570 "	"	30
"	1	do	5	do	1565 "	"	5
"	2	do	5	do	1200 "	"	365
"	3	do	5	do	1100 "	"	100
"	4	do	5	do	1080 "	"	20
"	5	do	5	do	1075 "	"	5

It will be noted that the last reduction, 5 ohms, is less than one per cent of the final reading, 1075 ohms. A further addition of any number of electrodes at both ends of the line will not produce a reduction of the reading five per cent.

Sec. 3. Difficult Conditions. Ground that is so rocky and barren of soil that correct contacts cannot be obtained with, say, five or six rods, should be avoided if possible. If the nature of the survey requires that contacts be made in such ground, it is sometimes necessary to drill holes for the electrodes. Ordinary miners' drills should be used and the holes filled with wet clay or stiff mud made of the finest material obtainable, tamped lightly. The rods should be driven carefully, one in each hole thus prepared.

Sec. 4. Underground contacts in soft seams can usually be made with two or three electrodes. Where drill-holes in hard rock must be used, as many as ten or a dozen electrodes are often necessary to make a contact. In such cases special care must be used to see that an ample number of electrodes is employed. It is better to use the time in securing few measurements and have them perfectly reliable than to accumulate a larger amount of data of a doubtful nature.

Sec. 5. The Minimum Number of Electrodes. Surface conditions are often met with, which render it an easy matter to make contacts. Dependence should *never* be placed on *one* electrode, however, as conditions often vary unexpectedly. It is impossible to *know* what a rod penetrates beyond the first inch or two of surface. If the material happens to be such that a one-electrode contact has a high resistance, the second electrode will reveal the fact. It is therefore necessary to follow the rule of always using at least two electrodes at each contact.

CHAPTER IV.

Technical Description of a Terreohmetric Survey.

Sec. 1. Establishing Stations. The first act in a survey is the establishment of one or more "stations." These are earth-contacts which are used as centers from which many measurements are taken. The contact resistance of stations is eliminated by the test described in Chapter III, using for the purpose, in the case of the first station, a line wire connecting with an earth-contact called a "test-station," consisting of one or two electrodes placed at a distance of not less than 100 feet. This method may, of course, be used with any station, but it is usually the case that in establishing stations subsequent to the first, some line wire by which the necessary tests may be made, is convenient to hand. The electrodes forming a station must not be disturbed in any way while in use.

"Line-wire" or merely "line" is an expression arbitrarily used to indicate a wire which connects with a station at a distance, and distinguishes it from the short wire, or "connection," which extends from the instrument to the earth-contact that is close at hand. When several lines are being used, connecting to various stations in different parts of the field, they are numbered to correspond with the arbitrary numbers assigned to the stations to which they are connected.

Sec. 2. Position of the Instrument. Always set up the instrument at the working end of the line. Never set up the instrument at a station and attempt to measure a set of resistances produced by changing the distant end of the line to successive points of contact. He who reads the instrument and records the measurements must be near enough to those who drive the rods to observe closely the conditions they are meeting and direct their work.

Sec. 3. Area of Earth-Contacts and their Dis-

tance Apart. As a general rule the electrodes used for each earth-contact may be distributed over an area the diameter of which is not greater than two per cent of the length of earth-section measured. Thus, when measuring the resistance of an earth section one hundred feet in length, the electrodes, which, connected together produce the earth-contact at each end, may be distributed over an area of ground surface not greater than two feet in diameter. When the earth section is a thousand feet in length, the rods may be distributed over an area twenty feet in diameter, if desired, without affecting the accuracy of the work.

Contact points on arcs or lines (see Figs. 6 and 7) should seldom be placed at greater distance than 25 or 30 feet apart, usually much less. For economy of time, this distance should, of course, be as great as may safely be used. No rule can be given that will apply to all conditions. The preliminary measurements on each survey can often be planned so that their results determine this question—at least in a general way—for the conditions there found.

Sec. 4. Protection of Stations. When several stations are in use on a survey, a full set of measurements between them should be taken and recorded: that is, 1 to 2, 1 to 3, 1 to 4, 2 to 3, 2 to 4, 3 to 4, etc. These measurements should be frequently repeated during the progress of the survey to make sure that the lines and stations have not been disturbed. Underground stations and any that may be in remote spots on the surface may thus be known to be in perfect condition though not seen for days by any of the surveying party. If a variation is discovered the damage must be repaired before the station can be again used.

The line-wire attached to a station must be fastened to some secure object near the electrodes, so that in case of sudden strain coming upon the line it will not be jerked loose from the rods.

Sec. 5. Handling Wire. Wire is unreeled by grasping the reel-handle (see Fig 5) in one hand and holding the reel so that it will turn easily on its axle as the one holding it walks away. The thumb of the hand in which the reel is held can be used as a brake if there is a tendency for the reel to turn too rapidly. In laying wire follow the most practicable route of travel. It is not necessary that the wire should lie in a straight line over the earth section to be measured and it is not economical to lay it by any other route than that which consumes the least time. The resistance of even a mile of wire is so small that it need not be considered in a survey.

Wire is reeled up by grasping the reel-handle with one hand and turning the reel with the other, while the one holding it follows the line by which the wire was laid, maintaining sufficient tension to bind the wire firmly on the reel. Never wind up the wire without turning the reel as this twists the wire and causes trouble with kinks when it is used again.

A wire placed in a shaft should be fastened securely at each level to prevent the whole line from going to the bottom in a tangle in case of accidental breaking.

Care must be exercised where several lines lie near or across each other to keep them from touching at uninsulated points.

For the sake of convenience and economy of time, wires must often be cut and spliced. Use the "telegraph splice," made as follows: remove the insulation from each wire for a distance of three inches from the end and scrape the metal bright with *back* of the knife blade. Bring the ends together pointing in opposite directions. Twist them together at a point about three-quarters of an inch from where the insulation begins. Wrap the free end of each wire tightly around the straight portion of the other. A small pair of pliers is needed to produce a neat and satisfactory splice. Never allow carelessness in the performance of this detail, as every splice must not only be capable of sustaining quite a severe strain, but—what is more important—it must fulfill the requirement of a perfect electrical contact.

When the plan of a survey is formed, wires may often be laid which can be used frequently, and by leaving them on the field throughout the survey, even though their entire length be not in use continuously, much time consuming reeling up and unreeling can be avoided.

Sec. 6. The Switchboard. When several lines are in use a small switchboard should be attached to the front of the instrument. It consists simply of a narrow strip of wood, in which are fastened ten binding screws, about

1½ inches apart, having no connection one with another. The connection to the earth-contact is fastened in the first binding screw. The others, or as many as may be required, are used for the line wires, which are unreeled up to the instrument as it is moved from point to point.

Two of the spring clamps, each connected to one of the X binding posts on the instrument by a piece of flexible wire about two feet long, are used to change the connections quickly on the switchboard. If desired, the switchboard may be made a permanent feature of the instrument and connections placed so that the ordinary two X binding posts may be dispensed with.

Sec. 7. The Plat and Report. The engineer must make a plat of every survey. It is an important part of his report. More than that, it is an indispensable aid to himself in conducting the survey. Usually, the problem to be solved can be defined only in a general way at first; but, as the work progresses and the results are added to the plat at frequent intervals, the engineer gains the knowledge that the completed portion of the survey imparts, the problem becomes better defined as its solution progresses, and the plan matures as its execution proceeds.

It is thus impossible, except in the case of very simple problems, to make a complete plan of a survey before its commencement. The work often reveals so much that was before wholly unknown and perhaps unsuspected, that unforeseen features of the problem constantly develop, often necessitating a serious modification if not a complete change of the first plan. Keeping the measurements entered up to date on the plat enables the engineer to follow each development of the work and plan every detail with that intelligent understanding which is necessary to the performance of the survey in an economical manner, and with the most useful results.

When a plat of the property can be secured and the lines are marked with sufficient distinctness on the ground, the points of the survey may be tied in by reference to such lines. If no such marks exist on the ground, an arbitrary base line must be established (and permanently marked) by reference to which the survey points can easily be tied in and platted. The plat must show the development work, if any has been done, the geological formations, topography, and all work of the survey.

Lastly—and this is the object of the survey—the engineer must indicate on the plat the location and extent of all ore-deposits in the survey field, whether exposed in part or not at all. A distinctive color should be used to display ore-bodies on the map, so that no mistaken idea can, by any chance, be conveyed.

The written portion of the report should give a clear description of the conditions found and an explanation of the deductions of the survey as indicated on the map. A clear statement should be made showing just what facts are determined and what are left undetermined.

Sec. 8. Field Notes. In the field-book a graphic record of the work is kept. Sketches in plan and section are used to show the location of all survey points and are much to be preferred to any system of notes.

All readings of the instrument must be recorded, even those taken on the test of each earth-contact. The field book must show every detail of the work, no matter of how small importance it may appear to be, recorded in such form that any other engineer could, from the notes, repeat the work exactly as done, any time thereafter.

CHAPTER V.

Application of the Terreohmetric Art.

Sec. 1. General Principles. The first step in a terreohmetric survey is to make a study of the conditions, get an understanding of the problem to be solved, then form a general plan of operation.

All available information should be collected relating to the character, extent and mode of occurrence of ore bodies on the field or in the neighborhood. While it is to be remembered that ore bodies never occur twice exactly alike, yet it is one of the first principles by which the ordinary mining expert exerts his judgment, that wherever, as far as is shown by development work, a similarity of conditions exists in different places, especially if they be in the same neighborhood, a complete similarity with reference to undeveloped features may be supposed to exist.

This rule might assume a more absolute nature if all the conditions—not only of present state, but of geological origin and the influences that have wrought perhaps many intermediate changes—could be fully known. But even the present state of conditions must often be judged by necessarily incomplete tests, and the rest is determined—if at all—still less definitely; consequently, the expert is often puzzled and gives faulty advice, having little to base his judgment upon. But his method is nevertheless truly scientific.

The terreohmetric engineer should look the field over, applying the knowledge of the ordinary mining expert as far as he is able; then, as a further application of the same *method*, use terreohmetry to accumulate a mass of data that throws a flood of additional light on the problem.

Where bodies of mineral or ore-bearing ledges are sufficiently exposed, either naturally or by development work, so that their real condition is revealed, preliminary measurements are taken through such known conditions, in order to establish a standard, as it were, by which unknown conditions in the same vicinity may be judged when measured. Such test measurements must be short enough to preclude the possibility of some as yet unknown ore-body being reached by the current and utilized as a partial conductor. (See Sec. 5.)

Wherever possible a known condition should be used as a starting point for a survey. This is not essential but is often a valuable aid and should not be neglected if practicable.

Sec. 2. Arcs, or the Method of Locating Ores Occurring in more or less Horizontal

Beds or Irregular Deposits. The simplest plan of survey is that in which arcs alone are employed. (See Fig. 6.) This plan has been used in the Missouri lead and zinc fields, and is especially applicable to such conditions as there found; namely, the occurrence of ore bodies in irregular masses at no great depth from the surface.

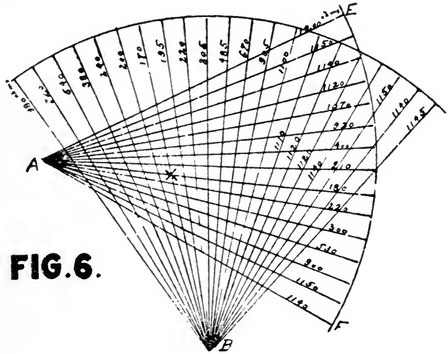

FIG. 6.

A station, as A, is established upon or near the area to be surveyed. From point A as a center, with radius of, say 350 feet, an arc of a circumference, as EF, is described. Upon this line at points 20 feet apart, contacts are successively made and readings taken to station A. A comparison of these readings shows a line or area of low resistance. This operation is repeated with another arc from station B, by which it is shown that under point X an ore body exists.

Successive stations are used until the entire area it is desired to survey has been covered. The arcs should be made to overlap sufficiently to make sure of locating a mineral body anywhere in the field.

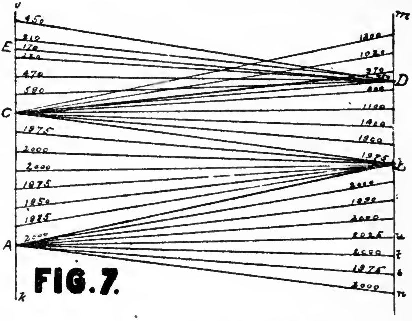

FIG. 7.

Sec. 3. Parallels, or the Method of Locating Ledges. To trace up float or locate any blind ledge, proceed as follows: (See Fig. 7.) Lay out two parallel lines, as jk and mn, at a distance of, say, 300 feet apart, (See Sec. 5.) and at right angles to the direction it is supposed the ledge strikes.

Establish Station A on line j k. Take measurements from points, as n, s, t, u, etc., on line m n (which points are from 12 to 16 feet apart) to station A. No variation* being found within

***Note.**—The term variation has an important use in terreohmetry. It applies to the comparison existing between the measurements of a set, as, those from station A to points on arc EF in fig. 6, or from station A to points on line n B in fig. 7, or from station A to points on line m n in fig. 8; or generally, any proper comparison between measurements. See sec. 16.

a distance of, say, 100 feet from n, station B is established and measurements are taken thereto from points on line j k, as indicated on the figure. Again, no variation being found, station C is established and the operation repeated. This time a strong variation is shown with point of lowest resistance at D, where a station is established and a fourth set of readings shows a line of low resistance passing through D and E.

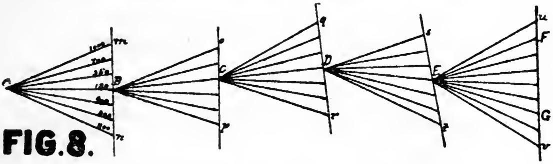

FIG. 8.

Sec. 4. Tracing Extended Deposits. Any ledge, the location of which is already partly known by development work, or by the process of location just described, may be traced and definitely located throughout its entire length by the process illustrated in figure 8.

Station A is established in or over the known portion. A series of straight lines, as m n, o p, q r, etc., are used, in each of which a point of lowest resistance is found. These points (B, C, D, etc.) are used successively as stations, as indicated in the illustration. On line u v, two points of low resistance are found showing that the ledge splits.

The distance between the lines m n, o p, etc., may be less than 50 feet, or it may be as much as 400 or 500 feet, or over, depending on the conditions of depth to the ore and whether or not it is desirable to make any determinations with regard to the character of the ledge itself, as is further explained in sections 5 and 6.

The lines m n, o p, etc., should be laid out, as near as may be at right angles to the strike of the ledge, and should be straight lines, not curves, for the reason, as illustrated in fig. 9,

FIG. 9.
A PLAN

that the current does not traverse the shortest distance between the points of contact as A and m, but travels by the line of least resistance. In other words, from any point of contact not in the ledge, as m, the current traverses country rock to the ledge by the shortest route, thence along the ledge to the other point of contact, as A.

As the distance of the contact from the ledge, as m B, is successively shortened or lengthened by moving the contact in either direction along line m n, as from m to o or from o to m, the length of earth section traversed by the current is successively decreased or increased by the distance m o, and the resistance is also decreased or increased, but in a greater ratio than that of distance, for the reason that points o, m, etc., are successively removed from the center of the zone of more or less mineralized material which surrounds every mineral body in the earth, and therefore, at each successive receding move, a portion of less mineralized, higher resistance material is included.

When the contact point is so far removed from the ledge that a section of practically non-mineral earth is included, no matter how short such section may be, the resistance reaches a high point at once. (See Chap. I, Sec. 4.)

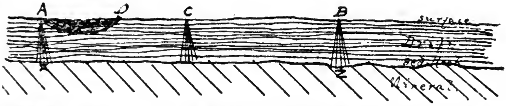

FIG. 10. A LONGITUDINAL SECTION

Sec. 5. Determining Depth. The location of mineral bodies with relation to their depth from the surface is determined by the method illustrated in fig. 10. The condition therein represented is a ledge, covered by drift, which it is assumed has been traced in the manner described in the previous section, and its location in plan marked on the surface.

Earth-contacts at points A and B were used in that operation and the record of the work shows that, on the set of measurements of which point B was finally selected as the lowest (as those taken on line m n in fig. 8) there was a considerable variation. That is, the resistance from A to B was small compared with that from A to m and other points on line m n.

This variation is due to the fact that the current, in traversing the earth between points A and B (see Fig. 10), finds its path of least resistance through the high-resistance drift, perpendicularly from both contacts to the low resistance mineral body, as indicated by the shaded portions of the figure, thence laterally through the mineral between x and z; but when earth-contact B is removed along line m n (see Fig. 11) to a point, as m, some distance from the

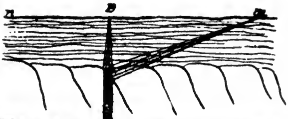

FIG. 11. CROSS SECTION

ledge, the current is obliged to traverse an added portion of high resistance material, for the distance from m to z is much greater than from B to z, and probably includes material of much higher resistance, as m is further removed from the more or less mineralized zone. (See Sec. 4.)

The first move in the operation of determining the depth is to shorten the earth section by removing the earth-contact from B to C. (See Fig. 10.) A set of measurements is taken from A to points on a line projected through C at right angles to the strike of the ledge, to determine what degree of variation exists. It is found to be considerable.

The distance is again shortened by abandoning contact C and making a contact at D. The effect now is changed. The current in passing between A and D finds its path of least resistance near the surface as indicated by the shading in the figure, and does not reach the mineral body. Consequently, when contact is made at successive points on a line through D at right angles to the ledge, the set of measurements from A to such successive points shows *no variation*. The depth is now known to be approximately one-half the distance A D.

Thus the depth is determined by successively shortening the length of earth section employed until the variation is lost. The depth is equal, then, approximately to one-half the last distance employed.

Care must be used in applying this principle to make allowance for modifying conditions. For instance, if a strongly mineralized zone overlies the mineral, the position of the upper portion of this zone will be determined, not that of the mineral itself.

Where the condition is that illustrated in figure 6, the successive shortenings must be at both ends of the earth section simultaneously, so as to keep the middle of the earth section employed approximately over the center of the mineral body.

From a consideration of this principle it will be seen that the depth to which the field is prospected by the survey depends upon the length of earth sections measured, and the latter should be at least twice the depth it is desired to reach.

It must be remembered that this principle of depth determination applies as well to lateral conditions as to vertical; or, in other words, that by this means it may be known to what extent the current deviates from a straight line laterally as well as vertically.

Always commence by measuring long distances, thus learning the general features of the field. Afterwards fill in the details with measurements of appropriate length, together with the use of such stations as may seem proper in the light of preliminary determinations.

Sec. 6. Comparison of Different Portions of Deposit. To secure a comparison of different sections of the same ledge proceed as follows: (See Fig. 8.) Tabulate so as to easily compare measurements A B, B C, C D, D E, E F, etc.; also A C, B D, C E, D F, etc.; also A D, B E, C F, etc; also A E, B F, etc. The variation in each of these sets, or tables, shows a corresponding variation either in the depth of drift overlying the ledge, or in the mass (or width) of material having the same resistance, or in the mineral content of the ledge, or there may be any combination of these causes. Often the depth of overlying drift can be easily determined, when proper allowance may be made, thus eliminating this unknown factor from the problem. Tests by development work may then easily be made to determine the exact cause of variation.

By this means the location of the apex and direction of trend of an ore chute in a comparatively barren ledge may be determined. Various other applications of this principle may be made. Care must be used to observe the conditions accurately so that correct deductions shall be made.

Sec. 7. Size of Deposit. A slide or isolated pocket may easily be distinguished from a continuous ledge in place by the fact that, while a large variation is shown by a set of short measurements which include it, the mass and extent of the mineral are only sufficient to produce a slight variation on longer measurements.

Sec. 8. Faults are detected by the process of tracing described in section 4. Where a ledge has been "lost" by reason of a fault, the lost portion may be located either as a separate ledge by the system described in section 3, or a station may be placed in the mineral body at a point near the fault and sets of measurements taken from this station to lines of points on the surface as in tracing a ledge.

Sec. 9. Complicated Problems are created by the presence in the field of a number of practically separate mineral bodies which may overlie one another or occur in such position that one only is apparently shown by the survey when there are really two; by the presence of different kinds of mineral bodies either associated together or occurring in close proximity; or by the occurrence of parallel or connected ledges. The fact that such problems are more or less complicated means simply that a greater degree of care and patience must be exercised with them than where simpler conditions prevail.

It should be noted that a single station placed in an extensive, but continuous, mineral body usually serves all the purpose that could be served by a number of stations placed in different parts thereof, for the resistance through long or short sections of continuous mineral bodies is usually very small.

Sec. 10. Placer. The pay streak in placer ground may be located and traced by the same systems as those used for ledges, (see Secs. 3 and 4) where the conditions are such that the current can be made to reach the metalliferous gravel or sand without danger of being diverted, in whole or in part, to some other low-resistance material lying or extending above, below, at one side of, or across the pay streak. To avoid the possibility of such diversion, the measurements should generally be made through the shortest earth sections that can be used consistent with the depth necessary to be reached. (See Sec. 5.)

The possible presence of mineral in placer form in the bed of every gulch and canyon as well as elsewhere must not be forgotten, as it often has a considerable influence upon measurements that are intended for quite another purpose than the determination of its presence. A few test measurements will reveal its presence or absence in any given locality. The fact thus determined can then be taken into consideration if necessary when making deductions from a comparison of measurements through earth so affected with measurements through earth not so affected.

Where, in the course of a survey, a set of measurements is taken *across* a strip of placer ground, it may be assumed—unless there is reason to believe otherwise, when proper tests must be made to secure a determination of fact—that the same effect is had upon each measurement, so that no correction need be made. This principle holds good where the ore dump of a mine or the tail race from a mill are included so as to become possible factors. It has been noted in practice that these latter have little effect upon earth measurements if neither contact is made near to them. It is not wise to establish a station in or very near to a tail race or large ore dump.

Sec. 11. Massive Minerals. Such minerals as Silver, lead, copper, zinc, etc., that usually occur in large masses, present the simplest problems to the engineer. In whatever form they appear, but especially in the sulphide, they offer very small resistance.

Sec. 12.. Gold stands high in the scale of specific conductivity and is usually so intimately associated with other metals that the total metalliferous mass diffused through the gangue rock is sufficient to render the problem of its location easily solved. Even where it is found almost wholly free from association with other minerals, if encased in a high-resistance country rock, it may still be easily located. (See Chap. I, Sec. 2.)

Sec. 13. Buried Treasure, if composed of metal or encased in a metal box, buried in earth without wrappings which will act as insulators, may easily be located, provided the earth be quite damp or that it has been soaked by rain or otherwise at any time after the treasure was buried. If a bag or wrappings of any kind were originally used, or if metal were encased in a wooden box, the metallic object may still be located if sufficient time has elapsed for the bag or box to become so rotted and penetrated with earth moisture that the metal is practically in contact with the earth.

It is usually best to use the plan of operation described in section 2. The length of radius should be, say, 15 to 25 feet, but never less than twice the supposed depth from the surface, of the object sought. If the object be small in mass and buried quite deep, say 10 feet or more, it is a good plan to use rods six to eight feet long for making contacts, especially if the ground be soft. When such long rods are used the radius may be shortened accordingly. A short radius is preferable to a long one in such work, as its use produces a larger variation when the earth section is measured which includes the small metal object, and so renders the location of such object more certain and easy.

As an example of actual work of this kind, in one instance a silver dollar was known to be buried a few inches deep. Measurements through two feet of earth were taken with rods inserted one foot deep and showed resistance of from 30 to 35 ohms. When the right spot was reached so that the coin was included, the resistance measured only 15 ohms.

Sec. 14. Problems Impossible To Solve. Water, oil, coal, sulphur, precious stones, and all such substances that are not better conductors of electricity than the rocks with which nature envelopes them, cannot be located by terreohmetry.

Sec. 15. Country Rocks of Low Resistance. Clay and talc in their various forms consist largely of aluminum, which stands high in the scale of conductivity. Consequently these substances, when massive, offer lower resistance than other adjacent country rocks, and their presence sometimes interferes with the location of minerals. When they are present, tests of their resistance should be made and the conditions of their occurrence carefully noted, so that the facts with relation to them may be known and taken into consideration at all times on the survey.

Sec. 16. How to Make Deductions. Measurements of resistance may be compared and the variation noted (1) when from the same station and of the same length, (2) when of the same length though from different stations, (3) when of different lengths and from the same or different stations. In the first and second cases, the variation shows at once the comparative conductivity of the earth sections and by this their mineral content may be judged. Careful discrimination must be used to note the true meaning of variations, especially in the third case. Very often valuable deductions can be made from such comparisons, but the work should *always* be platted and carefully studied in view of the geological and topographical conditions in order to see the meaning of the results with correctness and certainty.

The different degrees of variation have not always the same meaning. If the variation is in the ratio of 1 to 10 over a ledge in one place and in the ratio of 1 to 4 in another place, it may mean that the ledge bears less mineral in the second place or that it is buried to a greater depth beneath drift; while a variation in the ratio of 1 to 10 again in a third place does not necessarily mean that the same condition exists as at the first point. For the result noted may be caused by the occurrence of a larger mass of lower grade ore, or the presence of a different mineral, or a change in the country rock. These points must be kept in mind and tests made to determine just what are the causes of the results secured, even if such tests must be made with the pick and shovel.

The general plan of the survey should be made with the idea of producing results that have a definite, decided meaning. It is no use to do work if the meaning of its results cannot be definitely determined. However such determinations often must be made by development and the work is none the less valuable on that account.

As one who is seeking for hidden treasure is sometimes disappointed by digging up tin cans or old iron, so the miner occasionally finds a deposit of iron sulphurets when he looks for something more valuable.

Too much should not be expected from a survey, but it nearly always furnishes at least some information of great value—often very much. The exercise of intelligence and care are necessary at every step. It is impossible to give more explicit directions for conducting a survey, because conditions are never alike in two places; but the fundamental principles have been explained and these may be applied either singly or in various combinations as the conditions of each problem seem to require in the estimation of the engineer.