NATIONAL RADIO INSTITUTE

Complete Course in PRACTICAL RADIO

Radio-Trician
(REG. U. S. PAT. OFF.)

LESSON TEXT No. 43

RADIO PROSPECTING

Originators of Radio Home Study Courses
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Washington, D. C.

"Success in life depends upon understanding one's capabilities. The people who achieve the greatest and most satisfying success in life are those, who pursue vocations to which they are best adapted."

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Complete Course in Practical Radio

NATIONAL RADIO INSTITUTE WASHINGTON, D. C.

RADIO PROSPECTING

For several thousand years, men have been engaged in trying to locate valuable ore in the earth. In the olden days when kings wanted a new supply of valuable minerals for the temples, such as gold and silver, they sent their engineers and soldiers into far distant lands to bring it back. At that time, there was only one way of finding ores and mines. The engineers and soldiers would walk around until they chanced to see some precious mineral protruding out of the ground. Then, they had found a mine.

A great many changes have taken place since that day, but even today, in this century of steam engines, airplanes and Radio, the majority of individual prospectors are locating valuable ores and mines the old way. They merely walk around until they stumble over some piece of valuable ore.

Practically every great mine has been found in this way. Tonopah, the famous silver camp in Nevada, was discovered because a prospector's mule got away and kicked a chunk off a rock. The chunk proved to be silver ore. Cobalt, one of the richest of the Canadian mines, had a railway built right over the ore without anybody recognizing it. The blacksmith of the construction gang used a lump of silver ore for a spare anvil, thinking that it was ordinary rock. It was months afterwards before any one discovered that the railway builders had accidentally found a mine. The gold find at Weepah, Nevada, also was purely accidental. Two boys merely happened to see a badger's hole in the ground and noticed that near the entrance, small sparkling, shiny substances were being brought out by the badger.

So it has been for a great number of years that we have depended solely upon chance and accident in finding valuable ores and mines. However, during the past few years, we have been trying to bring into use some of the scientific instruments and methods which are used to advantage in other fields.

Electrical prospecting is not, contrary to what seems to be the popular belief, a new method. The various attempts to evolve a reliable means of locating ore bodies electrically cover a period of more than thirty years. In 1890, attempts were made to locate sulphides (a compound of sulphur and a metal or other elements) through the medium of conductivity, using a telegraphic receiver connected in series with a battery and wire brush. Contact was made in the earth, and the brush was moved over the surface. When touching sulphide, the brush would complete the circuit, causing a click in the receiver. As it could be used only on mineralized surfaces already exposed, the method was of little or no value.

Several years later, further attempts were made, using the Wheatstone Bridge, an instrument for measuring resistance. Here again, conductivity was the deciding factor, but indirectly, the conductivity between the two points on the earth's surface being calculated by first measuring the resistance. This method was also impracticable, due chiefly to the high resistance of the point of contact on the earth. As a result the resistance measurements were not truly indicative of the conductivity.

Another method which has been given considerable publicity employs the measuring or plotting of equi-potential lines (having equal power or influence). Direct current or a low frequency alternating current is allowed to flow between points, and the lines of equi-potential across the field are plotted by means of a galvanometer or telephone. The presence of an ore body causes these lines to warp or distort. Although this method has been successful to a degree, natural water layers, uneven moisture areas, and other substances in the soil are indications which can be misconstrued as indicating the presence of an ore body. On the other hand, failure of this method to indicate ore would not necessarily indicate barren ground. The oxidized condition existing above sulphide ore bodies forms an almost perfect insulator, an ore body thus insulated may cause indications similar to those caused by granite or other insulating materials. The low resistance of acid dikes to direct current or low frequency alternating current has been a source of annoyance also in trying to determine the presence of ore by this method.

Before going further into this subject we shall explain something about the various geological formations and the way that mineral deposits occur.

In very general terms, there are two kinds of such deposits, flat, layer-like deposits called "strata", and narrow pipe-like deposits called "veins". Coal is a good example of the first kind. A coal bed is just a layer of coal between layers of rock—like one black blanket between several gray or brown ones.

The vein deposits are different. They are cracks or holes in the rock, like cracks in a cement pavement, or like worm-holes in garden soil. Into these fissures in the rock, there have come up from deep down in the earth hot waters carrying in solution, gold, silver, or other minerals. These waters deposited, in the cracks and holes of the rocks, the minerals that they carried. This makes the vein. We find these veins (where they reach the surface of the ground) and explore into the interior of the earth, discovering the kinds of metal that they contain.

A good illustration of all this is an old-fashioned layer cake with a lot of icing in between the layers and none at all on the top. We can think of the icing as representing the minerals in the ground; the cake part represents the rock. A full layer of icing spread out evenly between two layers of cake will represent, for example, a strata or bed of coal. That is just the way the coal occurs, spread in between two layers of ordinary rock or other substance.

Now suppose that here and there in the cake there have been little cracks and holes. The icing will penetrate into these. If the cook has pressed down the layers of the cake as he put them together, the icing would be squeezed into such cracks or holes in the cake. This is a good illustration of a mineral vein. It is a thin piece or pipe of metal running through the unmineralized rock.

Now suppose that the cake, after it was made, had been jarred and cracked in a dozen places and squeezed out of shape. This is exactly what has happened to the rocks of the earth. Not that anything has fallen on the earth and smashed it, but the slow contraction of the globe, as a whole, has crushed and tilted and fractured the surface rock until layers that were once horizontal have been stood on end, until great breaks that the geologists call faults have cut across the whole earth's structure; in other words the original character of the rock and mineral deposits has been thoroughly obscured, even more thoroughly than the character of the cake and icing layers in the cake that has been squeezed out of shape.

So, the problem that confronts the geologists who try to do for the earth what we could have easily done by seeing the layers of the cake in the example above, is a very difficult problem indeed. The ground under his feet is so bent and twisted and broken that it is usually impossible to figure out in any detail what it was like in the beginning. The geologists know, perhaps, that there is mineral in these rocks somewhere. The question is, where? If he bores a hole down at random, he is as likely to miss the mineral deposit as he is to hit it; much more likely, in fact, for the mineral deposits occupy only a small fraction of the total volume of the rock.

The student can readily appreciate how valuable it would be if the geologists had some way of exploring the conditions underground without going to the extent of digging shafts, or boring holes, both of which are extremely expensive operations.

The methods described in this lesson are the result of efforts of various scientists to aid the geologists in locating valuable ore deposits without extensive drilling, and the accidental discovery by the prospector of these valuable mineral deposits.

The Equi-Potential Method

The fundamental principle of this method is, that an electric field is generated in the area to be investigated. By using a telephone receiver, a series of level lines is determined upon the surface, and by observing the disturbances in these level lines, it may be determined whether or not deep lying ores are present. If ore is present, the disturbances indicate the position and approximate extent of the ore.

To produce the necessary electric field in the area being investigated, a fixed primary circuit is employed, consisting of two poles or electrodes and two conductors connected to a source of current. In this method of ore detection, the electrodes are formed of long galvanized steel rope, which for convenience of handling, are divided into lengths of 50 meters. In order to produce good electrical contact with the ground, these ropes are fastened to steel spikes which are driven into the ground at regular distances. Electrodes of this type are called common linear poles or line electrodes. The conductors consist of ordinary insulated copper wires. The source of the current consists of a small hand or power driven generator, which produces a single phase alternating current with a maximum of 220 volts. To find the level lines, a movable secondary circuit, the so-called testing circuit, is employed, consisting of two iron rods with insulated handles, the so-called testing rods, connected with each other by insulated copper wires to which a telephone receiver is coupled. Usually, it is most convenient to use a telephone helmet with doube ear-pieces, which can be coupled in series or in parallel according to circumstances.

In order to set out a series of equi-potential lines, a pair of line electrodes 200 meters in length are usually employed, spiked down parallel to each other, and generally at about 200 meters apart. One end of each of these electrodes is connected by the insulated copper conductors to one of the poles of the generator, which is placed on one side some little distance beyond the ends of the electrodes in a position where it will not interfere with the observation.

If the field in between these two electrodes consists of material of uniform electrical conductivity, the equi-potential line lies parallel with the electrode in the intervening field. If, however, there is any marked irregularity in the electrical conductivity of the field, the equi-potential line will be distorted; and by plotting the equi-potential lines in this area, the distortion can readily be rendered visible.

The method employed is for the observer and an assistant to determine a series of equi-potential points, which are plotted by another assistant using a plane table; by joining these points, the equi-potential line can be drawn on the plan. The principal observer wears the telephone helmet and carries one of the searching rods, the other searching rod being carried by an assistant, who moves it about in obedience to the signals of the observer.

The observer first then drives a peg into the ground and the searching rod well into the ground beside it, then he signals his assistant to move the rod which the latter carries to a series of point lying in a line approximately perpendicular to the direction of the electrode, the distance between the two men varying from 3 to 10 meters. When the assistant has driven his rod into the ground at a point where the telephone is silent, the observer knows that both rods are on an equi-potential line. He then signals his assistant to put in a peg at that point. He next transfers his own searching rod to this peg, the assistant proceeds as before to get another point a few yards further along, until in this way, the whole area has been pegged out with a series of equi-potential points. The number of equi-potential lines thus determined may vary from 5 to 20 according to circumstances.

If the electrodes lie over bare rock, holes may be drilled and spikes clayed in, or a special device employed in order to obtain fair contact between the electrode and the ground. It is always advisable to drive the spike into the ground the same depth so as to obtain at all points the same electrical contact with the earth, this is especially important when the ground is very variable in character. When the ground is frozen, the contact between the electrodes and the earth becomes worse, but not so much so as to be a serious obstacle to the operation; the most serious difficulty is that of obtaining good contact between the searching rods and the ground, as it is very difficult to drive these into the frozen earth. The best plan, is to send a man ahead with a pointed steel rod with which he can make holes in the ground, to receive the ends of the searching rods, but the measurement will in any case proceed more slowly under these conditions.

As soon as the frost comes out of the ground, it is possible to measure at a maximum speed as soon as the surface is thawed to a depth of five centimeters.

Rain does not greatly affect the measurements; in districts where the moisture conditions present considerable variation, it is in fact possible to measure during, or immediately after, a rain.

By following the above procedure, a considerable area can be surveyed. In not too wooded or broken country, one sitting a day can be completed; in open, flat country, two or three settings can be completed in a day; in very wooded or broken ground, the rate of measurement can be reduced. By using electrodes a kilometer in length and a great distance between them a motor-driven generator and several observers, the rate of measurement can be increased considerably, but this is only possible in open and slightly undulating country. In other cases, when great speed is necessary, recourse must be had in the employment of several sets of apparatus. The method described is essentially a method of survey. In many cases, the results thereby obtained are so clear that no further measurements are necessary. In other cases, extra disturbances may arise so that it is necessary to carry out additional measurements. In very difficult cases, an attempt must be made to reproduce the occurrences on a small scale by laboratory experiment and by measurement on the laboratory scale to endeavor to obtain the information that will make it possible to verify the results obtained in the field. With the assistance of the above given supplementary means, which in any case needs a certain amount of experience on the part of the workers, it is understood that all precautions possible should be taken to avoid a misinterpretation of the indications obtained.

The Schlumberger Method

Professor Schlumberger describes the action of the passage of an electric current through minerals as follows: "Any mineral mass which possesses metallic electrical conductivity throughout a sufficient depth, and which lies underground in such a fashion that part of it lies above the water table, produces in the surrounding moist terrain, electrical currents observable by the differences of potential which they produce. This electrical action is probably due to the activity of the dissimilar waters of the oxidization and cementation zone when in contact with a metallic mass."

To detect with accuracy the presence of electrical currents in the earth, it is necessary that they be diverted to a measuring instrument by a contact that will not polarize when touching moist soil. Metal electrodes, even when gold plated are not suitable.

For his purpose, Professor Schlumberger devised an electrode made of a porous earthen cup cemented to the end of a copper tube, the tube and cup being filled with a saturated solution of copper sulphate containing an excess of copper sulphate crystals. The copper tube is slipped into a brass sleeve for convenience in the field, making the whole apparatus stand breast-high. The upper end of the sleeve is arranged to screw into the base of the potentiometer and galvanometer which are used for measuring electric currents. Two of the electrodes are connected by insulated wire about 200 ft. long, wound on two small reels arranged to clamp, one to each electrode. The path of the current is as follows: Ground, electrode, potentiometer and galvanometer, wire, electrode, ground.

The potentiometer and galvanometer are contained in a small aluminum case about 8 inches square and 2 inches deep. The galvanometer is sensitive to one milli-volt. It measures not only the strength, but also indicates the direction of the flow of the current.

The electrode bearing the potentiometer and galvanometer is carried by the operator and the other by an assistant. When prospecting, the following procedure is used:

A suitable distance between electrodes is chosen, say 25 or 50 ft. where two contacts are made, and the direction of the flow of the current is noted. The assistant's electrode is placed at the contact of the lowest potential, or contact towards which the current is flowing. The operator then feels in the direction of flow of current, makes contact, and again takes a reading. This is continued until a reversal of current direction is noted, whereupon the two then proceed to follow a line at right angles to the first, still going in the direction of lowest potential. This is repeated until the point of lowest potential in that region is found; that is, the point towards which the current seems to be flowing from all sides. The operator is now above the apex of the vein, and the next step is to discover the strike and shape of the ore body in question. This is done by tracing equi-potential curves above the center thus discovered, which is called the negative center.

An equi-potential curve is the line which joins all points which are the same potential difference from the center. That is, the distance from the center to the curve in question, which is always a closed curve, and will vary inversely as the resistance of the rock through which the current passes. The drop of potential is greater in a given distance for a resistance material than it is for a conducting material. Therefore in a resistance material, a given drop of potential will take place in less distance than it will in a conducting material.

It will be observed that the equi-potential curves in question will be elongated along the strike of the vein. They are in reality, the out-crop of equi-potential surfaces enclosing the vein beneath the surface. The equi-potential curves outline more or less regularly the horizontal projection of the ore body in question, and will be nearer the outside of the ore body than when lying in or traversing it. These equi-potential curves are traced by placing the assistant's electrode in any convenient point near the center; the operator then feels about with his own electrode for that point which is at the same potential as the aide's; that is, the needle of the meter or galvanometer indicates no flow of current. The assistant then puts his electrode at that point. The operator then repeats the process and this is continued until the curve is closed, which should be within a five or ten foot area.

Further study may be made by determining the profiles of the electrical potential across the strike of the ore body. To do this, the aide places his electrode at a point 100 feet or more distant from the veins being studied, and the operator makes contact with the ground nearer the vein, the distance between him and the aide depending upon the probable size of the mass. Such distance may vary from 5 to 100 feet. He then measures the difference in potential between the two points, whereupon the aide moves closer, makes contact there, and the operator proceeds towards the ore body in a line at right angles to the strike, and then repeats the process. This is repeated until the ore body has been traversed. Since ore body is the source of the electric current, this activity is manifested by the shape and peak in the graph of the potentials where the profile crosses the vein. That is, the equi-potential curve may be likened to contour lines of the electrical field, and the profiles to the cross section thereon. A test is thus provided, as the profiles should indicate the same potentials as the point where they cross the same equi-potential curve.

Professor Schlumberger has also discovered that anthracite coal is not only a conductor, but apparently, also a generator, of electricity. From the results obtained by the use of this system, it would seem that metallic disseminations in a siliceous gangue (vein bearing silicia or quartz) cannot be prospected by this method, but the same minerals when deposited in a schist (layer-like formation) can easily be discovered.

The results of the experiments described warrant the conclusion that it is entirely possible for electrical prospecting to be applied in searching for silver cobalt veins of this type, where they are not covered by more than three or four feet of over-burden, and deeper if they are wider than the ones of only a few inches in thickness. Considerable expense in sluicing (to uncover by water under pressure) might thus be avoided.

The Chilson Method

The idea of electrically locating ore bodies was first conceived by Mr. D. G. Chilson, a mining engineer, in 1904. The discovery of large ore bodies where frequently the surface geology did not indicate the presence of ore furnished the incentive for his early experiments. These early experiments were made to determine the conductivity of various elements—earth, water, and other substances, and it was found that sulphides furnished the best conductors.

In 1909, Mr. Chilson turned to Radio, experimenting with some of the short waves, using the method now in use for directional telegraphic communication. During the following years, he spent considerable time in determining the audibility of signals from Radio stations, through readings taken in so-called "dead" spots in Alaska. Comparative conductivity tests on sulphides and soils proved the electrical continuity of sulphide ore bodies, contrary to the general contention of geologists that ore bodies and depth are not connected. By introducing currents of different electrical frequencies into sulphide ore bodies, it was found that by using a critical frequency, sulphide ore bodies could be followed regardless of other conductors such as earth, water, or other materials. The result obtained at that time proved accurate and established the practicability of the process. During the following five years, tests were made in California and in Arizona with good results. From 1920 to 1922, further experiments were carried on at the University of Arizona, and refinements and improvements were made which brought the process to its present state of perfection.

Briefly, the fundamental principle upon which the Chilson process operates is as follows: Contact is made upon sulphide ore having electrical continuity, with electrical energy of the proper frequency impressed upon same in such manner that all connecting ores will act in unison with the transmitter and as a part of the transmitter. A receiver, operating in proximity to the ores thus affected, will indicate their location, through the medium of the magnetic field caused by the ores acting as a part of the transmitter. It has proved possible with this method to locate sulphide ore bodies under favorable conditions to a depth of 2,000 ft. or more.

The frequency of the electrical impulse is the deciding factor in making this possible. Where the impulses vary from 300,000,000 impulses per second to 100,000 impulses per second, the waves created are very difficult to classify, because they are affected in the same manner as light, being reflected from metals, water, and hills. Impulses varying from 100,000 to 40,000 per second are affected only slightly, and while having the advantage of following metal conductors, they do not pass through the earth and water as readily as lower frequencies. These two groups are known as "Radio frequency." The range between 40,000 and 20,000 impulses have similar advantages and disadvantages. Between 20,000 and zero, or in other words, nearing a continuous flow of current, the disadvantage of the current flow taking place through wet material, rocks, and soil, makes the use of this group of frequencies impracticable. The range of frequencies between 40,000 and 20,000

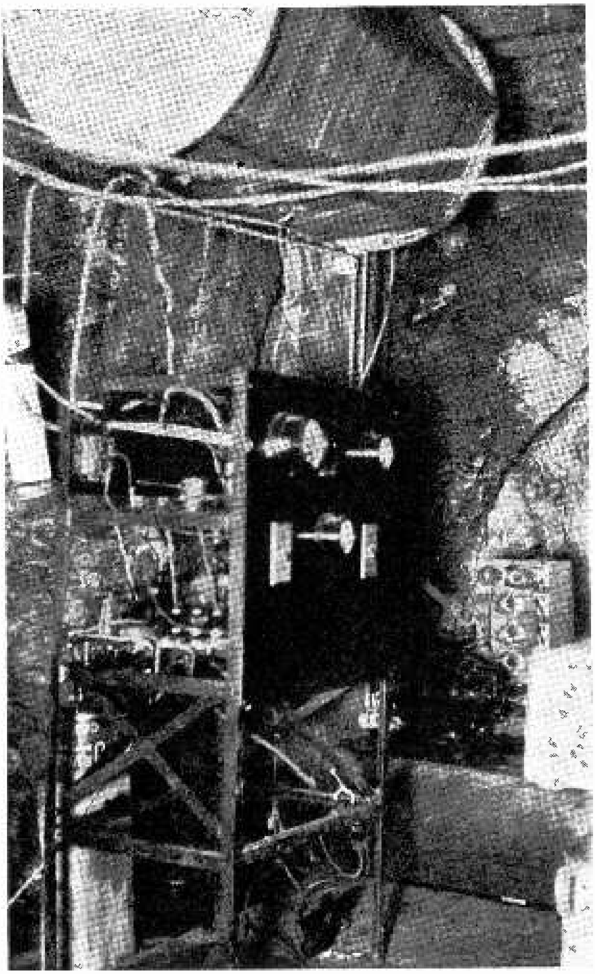

Fig. 1.—The Transmitter Installed Underground.

is the one generally used in this work. However, a higher frequency within the Radio band can be used to good advantage as a means to check the results obtained with the lower frequency.

The quality that an electric current possesses of oscillating within definite limits determined by the frequency of the current and conductivity of the body submerged within any substance, makes possible the location of any exact area of predetermined conductivity value. This action is similar to the action which takes place in a Radio antenna, which is highly insulated, so that high frequency oscillatory current may be used with minimum leakage. Inferior insulation might be used with lower frequencies and with some loss in efficiency. This could be likened unto the ground ore contact of the transmitter used in this work.

The apparatus used in this work consists of two units, a transmitter designed to radiate the proper current at the desired frequency, and a receiver to record the audibility of the signal. The transmitter is generally installed underground and contacts are made upon the sulphide. The receiver is specially designed, employing several stages of amplification. The receiver cabinet is suspended from a tripod, and the receiving coil is secured to the tripod in a swivel frame, so that it may be either swung in an arc, or horizontally. In taking readings, the receiver is set up so that the coil is in a vertical position. It is then swung in an arc until maximum signal audibility is reached—this gives the strike of the ore. Without changing the angle of the coil, it is dipped horizontally until maximum audibility is again reached. This gives the dip angle. After several set-ups taken in line, these dip angles are projected and the apex of the resultant triangle is the center of the magnetic field caused by the ore body acting as a part of the transmitter. When directly over an ore body, the dip angle is, of course, zero.

It is possible to cover as large an area as 30 or 40 square miles without moving the transmitter. This depends, of course, upon the characteristics of the particular field being surveyed. In mineralized ground, it is possible to make as many as 80 or more set-ups a day.

The Hertzian Wave System

Thus far, the systems described have been those using surface methods depending upon the conductivity or resistance of the ground and the out-cropping of the mineral. The Hertzian Wave System indicates the possibility of using Hertzian waves to penetrate the surface and indicate the presence of ore.

The Hertzian system of locating mines by Radio is based on the well-known phenomena of the penetrating resistance offered by good conductors to electric lines of force. As illustrated in Fig. 3, a Hertzian oscillator produces no phenomena of resonance because of the interposed grating shown in this figure. This grating is grounded as shown.

Let us assume that it is desirable to locate ore deposits in the side of a hill where out-crops of mineral have been found and also to determine how important these deposits are. It is necessary first to make some preliminary drifts to

Fig. 2.—View of the Field Receiver, Showing the Operator Taking a Dip Reading.

determine the extent of the out-crop and shafts to determine its depth. Both of these operations may be avoided by using the apparatus for directional waves. In Fig. 4, the transmitter is located at the point T, and the detecting device or receiver is located at the point R. It is found that along the dash line T R, as indicated, no impediment exists to cut off the waves; but if the detector is moved from R to R_1, the telephone of the receiver is silent because the waves emitted from T meet the mineralized mass, which acts as a shield. If the receiver is placed in the next position, R_2, so that the line T R_2 passes below the mass, the telephones will produce a sound. The process is carried on by shifting the transmitter from T to T_1 while the detector remains at R_2; again, the waves are intercepted and the telephone becomes silent. The experiment is repeated, carrying the transmitter to T_2, and again, the telephone is silent.

By placing the transmitter and receiver successively in all directions, and, with the aid of plans and calculation, the existence and position of the mineral mass may be established. Of course this work should be preceded and accompanied by a complete study of the geological formation of the hill, and in this case, the Hertzian method will give a preliminary indication of the existence and location of the mineral mass. The study should be continued and completed by the means described above. For

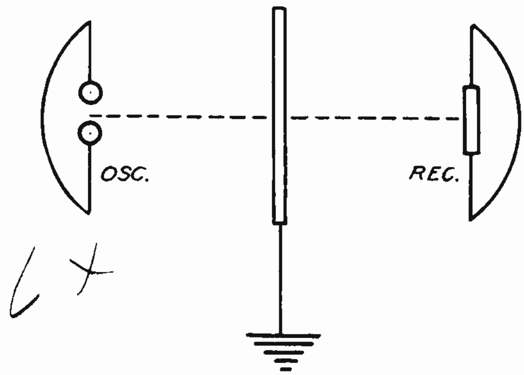

Fig. 3

instance, between the out-crop and the side of the hill to which the lower extremity of the vein seems nearest, the electrical resistance method may be applied. Then, between R and R_2, assuming that there is a covering of earth over the deposit, the silent zone system can be applied. When a well-organized series of experiments have been completed, sufficient data is available to make possible an intelligent attack on the problem of exploiting the deposits.

Let us now take up a case, that of examination from the interior of a working mine, and from the exterior, to determine the presence of a mineral zone whose existence is suspected. Figure 5 illustrates this case, which is that of a zinc mine containing calamine mixed with lead carbonate and hydroxide.

First, the transmitter is placed at the point T, and the receiver is placed in a drift at the bottom of the mine at the point R—the clear sound produced in the telephone shows that the line T R is clear of all mineral deposits. Leaving the receiver at the point R, the transmitter is carried down the hill to the point T_1; the transmitter remains in operation while it is being moved down from T to T_1, and the operator listening below, finds a rapid diminution of the sound. As the point T_1 is reached, the telephones become silent. This shows the presence, which we may assume has been suspected by other indications, of a new mineral zone; keeping the receiver at the point R, the transmitter is carried down the hill still further toward T_2. At a certain moment, the

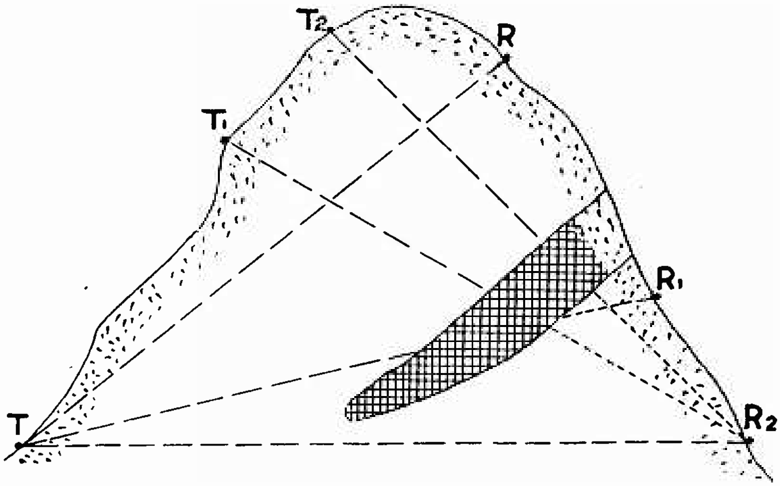

Fig. 4

sound which was lost is again heard, gradually becoming louder. Finally it is heard with full intensity, which indicates that on a given line, R T_2, the rock again is completely sterile.

At this point, the operators trace a profile of the ground explored, and then apply other tests. The transmitter is carried to the point T_4 at the end of a drift, and the receiver is placed first at R_1 and then at R_2, then the transmitter at T_1 and T_2. This gives four new lines. T_4 R_1 shows the end of the deposit; T_4 R_2 controls and confirms the preceding test; T_4 T_2 indicates the presence of the deposit higher up; T_1 T_4 indicates the sterility of the rock in this direction. Thus, the operators are able to complete the profile, acquiring an approximate section of the mineralized mass as discovered.

The work is continued afterwards on other sections of the deposit, so as to sketch with the greatest possible accuracy, the point of contact with barren rock surrounding it and its precise boundary. The data thus obtained is controlled and completed by experiments using the other systems. An interesting test is obtained by stretching a long wire on the left side of the hill, making good earth contacts at point T and T_1, measuring the resistance of the intervening soil. In the first case, the circuit being closed through sterile earth and the resistance was high. In the latter case the circuit closed through a portion of the ore bearing out-crop, the resistance was much lower. Such tests should be made over other portions of the hill to detect the presence of deposits which might be otherwise undiscovered. This data is useful when taken in connection with the Hertzian tests and serves to better establish the presence of ore bearing deposits.

Figure 6 shows another application of the Hertzian method. A shaft was dug below a mass of manganese ore, and reached a point where the mass thinned out and disappeared. The question then was to know whether there was a break in the deposit, or whether this was a definite end of the deposit, so as not to keep on pushing drifts without finding any more mineral.

The first investigation was carried on in the open by direct observation, and the result was negative over a large piece of territory to the right of the excavation. It was feared that due to the depth of the new body being searched, and the low power of the transmitter used, the results of the examination would not be positive, and it was decided to try the Hertzian method. The receiver was placed at R_1 at the extreme end of the third drift, and the transmitter was placed at T_2, near the entrance of the excavation. The operator placed at R_1, could determine exactly the lay of the deposit. No signals were heard as indicated by T_2 R_1. He then gave orders to the operator in charge of the transmitter to carry it to T_1, and found that on the new line, there was no mineral mass present as indicated by the line T_1 R_1.

The test was repeated, placing the transmitter at T, and with the same results as when the transmitter was placed at T_1. The receiver was then placed at R, and the discharge tested towards R. No signals were heard between T and R. The operator then took the receiver into the shaft below to its extreme end, R_2, and found that emissions from T were received, while those from T_1 were not. The experiments were then repeated, taking the transmitter a good distance to the right of T, and changing positions in the direction to the lines T_2, T_1, and T. It was found that the passage of the waves was not interfered with, therefore, there was no trace of mineral in the subterranean section explored.

In Fig. 7 is shown tests directed to discover a mass of ore, the probability of whose existence followed from the vicinity of other metal-bearing deposits in an active mine whose

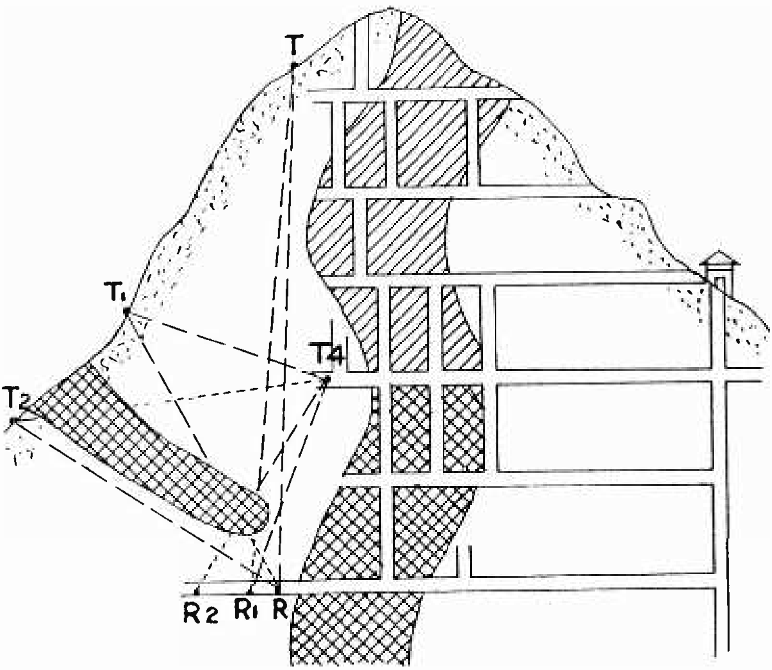

Fig. 5

plan is shown. The Hertzian transmitter was placed at T, and the first experiment consisted of placing the receiver at R_2, in order to be sure that the quality of the mineral of the known deposit was such as to make a screen along the way. Having determined this, the operator at R_2 moved along slowly, following the drift towards R_3, at which position, he began to catch the waves and thus established the line of contact of the bed being explored. Continuing to go on toward T, the operator employed a positive knowledge that all the region between the drift and the deposit was barren.

The operator then went to R_1 and followed along the drift between the same deposit, which was without mineral. Finally, the operator covered the whole gallery, which was dug in sterile ground in the direction of R_1, and having thus gotten to its end, found the sound had ceased, which proved that there was a new deposit in the line explored.

The apparatus used in the Hertzian system consists of a transmitter and a receiver. The transmitter is comprised of a direct current generator giving 320 volts potential. It may be a small dynamo apparatus on a wheeled platform, or a battery of small storage cells. Figure 8 shows this transmitter to be the usual Hartley type. The main characteristic of the apparatus is the absence of an aerial and any ground connec-

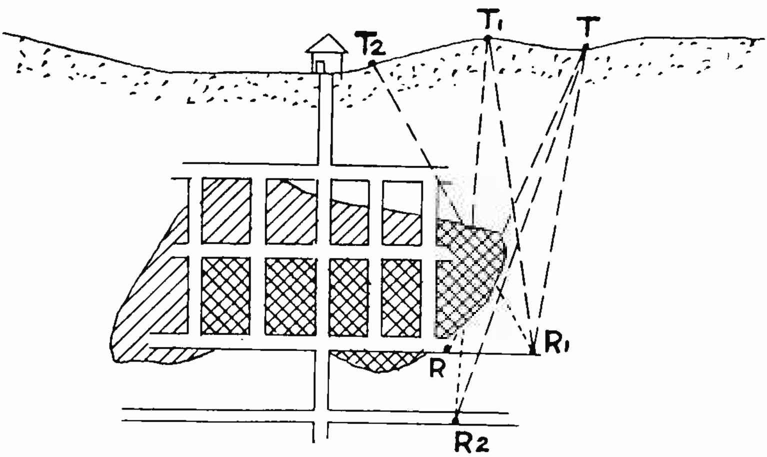

Fig. 6

tion, facilitating the disposition of the apparatus, giving it great mobility and making the exploration very easy. The radiating system consists of an inductance about 8 inches in diameter, wound around the box containing the vacuum tubes, which is mounted on a tripod so as to be turned about as desired. The direction of radiation of the waves can be produced in any desired direction. The whole transmitting set may be mounted on a small truck so as to make it easily transported either on the surface or in the drift, so that the work is made very easy.

The circuit diagram of the receiving apparatus is shown in Fig. 9. In this too, the inductance is wound around a box, which is carried by the operator, or it may be placed on a tripod, while the plate and filament batteries are held by the assistant.

The Hertzian system is far in advance of the first experiments which used a magnetic means, and those of Schlumberger with polarized electrodes. The main draw-back of all of the previous systems, was that each required too long a time to make the tests and determine the nature of the earth surveyed.

The Re-Radiation Process

The rapid development of Radio, and more especially of the apparatus used in Radio, such as the vacuum tube, during the past ten years, has led to the disclosure of a comparatively new phenomenon known as "re-radiation." This phenomenon borrowed from the Radio world and applied to

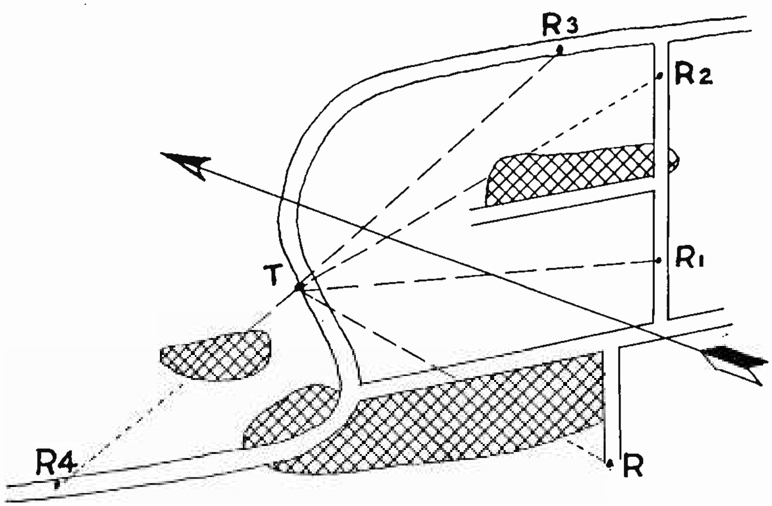

Fig. 7

the art of mining gives every assurance of opening up vast territories of mineralized ground, especially in areas hitherto not open to prospectors.

Re-radiation may be described as the occurrence of a secondary electromagnetic field about a conductor, which is located within a primary electromagnetic field of high frequency, and the unusual and outstanding characteristic of this phenomenon is the extent to which these secondary fields may be caused to reach out into space to comparatively great distances, from the secondary conductor about which they exist. Recognition of this phenomenon, together with an understanding of the many factors which control it, having enabled engineers to develop a means of locating unknown conductive bodies and more particularly, ore bodies which are electro-conductive.

While a complete understanding of the principles involved in the application of re-radiation to locate unknown conductors, requires a thorough understanding of high frequency electrical phenomena, the basic principles are easily grasped by those having an elementary understanding of electricity and Radio principles. These elementary principles will be outlined in the following paragraphs.

Referring to Fig. 10, there is represented in profile view, a vertical conductor, AB, and a vertical conductor, CD. The reader must imagine that alternating current of high fre-

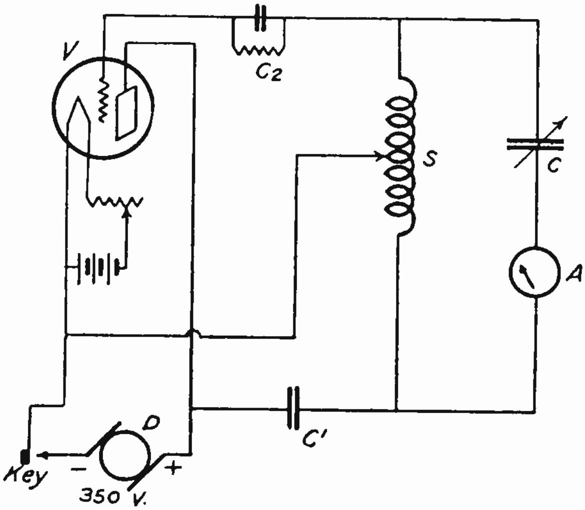

Fig. 8

quency is flowing in the conductor, AB, which, for convenience, will be called the primary conductor. As a result, there exists about this primary conductor, a high frequency electromagnetic field, called a primary field, the magnetic lines of force of which may be represented as circular lines similar to the lines H (center H), spreading out and contracting about the primary conductor, AB, as an axis. The lines of magnetic force H (center), have the ability to travel through space even if this space be filled with non-conductive material, and they further have the ability to cause an electric current to flow in any conductive material through which they might travel.

Therefore, when the lines of magnetic force, H (center), cross the conductor, CD, they cause a current to flow therein. This current is called a secondary current, and it is, of course, accompanied by its own electromagnetic field, for it is a well-known and commonly accepted fact that wherever there is a current flow, there will be an electromagnetic field surrounding the conductor and accompanying the flow of current therein. This latter electromagnetic field is called a secondary field, represented by the circular line H (to the right) of Fig. 10. There will be occasion to refer to it repeatedly throughout this discussion, for this system and process is built upon creating such a secondary field, causing it to extend to considerable distances, and then by means of this field, locating the secondary

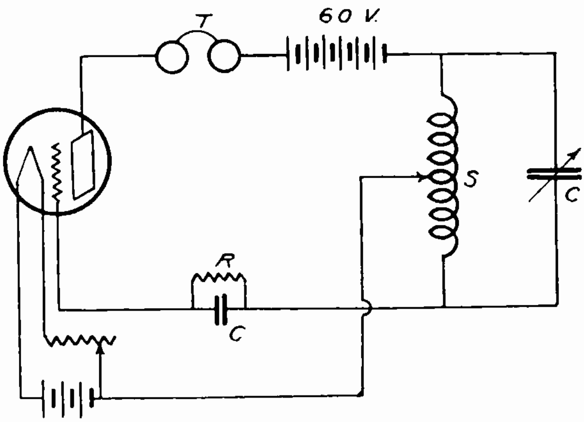

Fig. 9

conductor about which it exists. In Fig. 11, there is shown, drawn to a small scale, a plan view of the conditions pictured in Fig. 10.

All of the above phenomena are well-known to those versed in the art of high frequency electricity, but it has been generally thought that unless the secondary conductor, CD, (Fig. 10) was very close to the primary conductor, AB, and unless the secondary conductor be tuned to the frequency of the current flowing in the primary conductor, AB, just as a Radio set is tuned to the frequency of the broadcast station which one desires to hear, the secondary current flowing in CD, and its accompanying secondary field would be so small, that it would be useless to attempt to apply this phenomenon to any practical purpose.

However it has been found by those responsible for the development of this process that, the secondary field about the conductor, CD, can be made of sufficient intensity to actuate indicating devices at considerable distances away from the conductor, even if the secondary conductor be at some distance from the primary conductor, and furthermore, even if the secondary conductor is not tuned to the frequency of the primary field, under certain limiting conditions. The facts connected with causing the secondary field to extend to considerable distances and measurable intensities constitutes the phenomenon upon which this process is based.

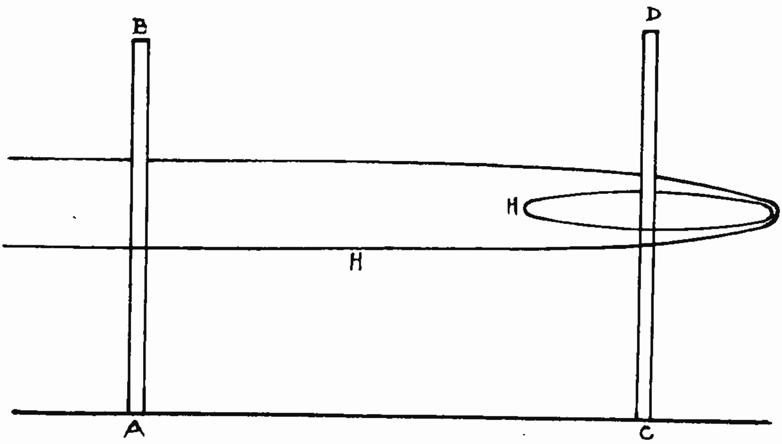

Fig. 10

The mere creation of an intense secondary field is in itself of no value unless a means be developed to utilize this secondary field to indicate its axis, which lies, of course, within the secondary conductor. (If the axis may be located, then the secondary conductor is located.) Here, a principle borrowed from the Radio world, and well-known in its particular application, was applied to this more complex problem of locating a secondary field within a primary field. The principle is that connected with the art of Radio direction finding where a direction finding coil is employed to indicate the direction towards the Radio transmitting station.

In Figure 12, there is represented in plan view, the axis of a primary conductor standing vertically at A, about which there exists a primary electromagnetic field, the magnetic lines of force of which may be represented as the general shape and position of the circular line, H. If a direction finding coil is placed anywhere within the effective area of this field and rotated about its vertical axis, it will indicate by its position of maximum signal intensity, a direction towards the axis of the primary field such as shown at G. If two or more such directions be obtained and plotted to an intersection, the location of the axis of the primary field will be determined. This is the principle connected with the use of a coil for direction finding, when in the presence of a single electromagnetic

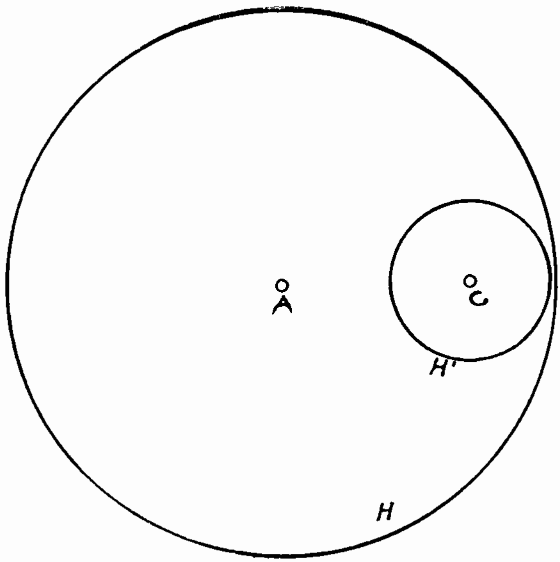

Fig. 11

field. It is well-known and generally employed in the Radio world.

In this method and process of locating ore and mines, the basic principle of the direction finding coil is employed in locating the axis of a secondary field, but the action of the coil becomes more complicated because if the coil is placed within the effective area of the secondary field, it will, of course, be within the effective area of the primary field and as a consequence, the direction finding coil will be acted upon simultaneously by two fields of identical frequency, whose axes do not coincide. This is an unusual application of the direction finding coil and it requires considerable study and work to determine just what sort of direction the coil would give under such a condition, and what the determining factors are for obtaining directions by means of which the secondary axis may be located. This is an interesting problem in itself but leads into highly technical subjects which need individual study and are too complicated to be included in this text.

The elementary principles governing the action of the coil when in the presence of two or more electromagnetic fields

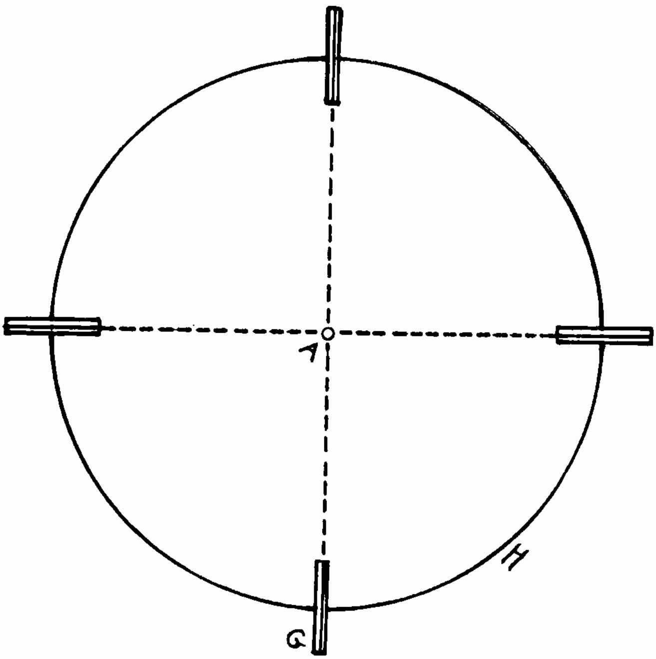

Fig. 12

of identical frequency are, however, easy to grasp. Referring again to Figure 12, if in any location such as G, the direction finding coil is rotated about a horizontal axis, the loudest signal will be obtained when the coil reaches a vertical position. In other words, the direction finding coil, when thus rotated about its horizontal axis, will normally indicate a vertical direction. Now referring to Figure 13, there is represented a profile view of the cross section of a secondary conductor, B, in a primary field, HH. The primary field, HH, has caused a current to flow in the secondary conductor, B, and as a result, there occurs the secondary field H^1. Suppose now that the coil is operated at various points along the line CD by revolving it about the horizontal axis. At points outside of the area of the secondary field H^1, the coil would indicate a vertical direction as at E, F, K, and L. At G, M, V, I and J, the coil would be acted upon by both the primary field, H, and the secondary field, H^1. At any one of these locations, as, for instance, at G, the primary field would tend to cause the coil to indicate a vertical direction along the line G, G^1, while the secondary field would tend to cause the coil to indicate a direction along the line GB, pointing to the axis of the secondary conductor. As a consequence, the coil would give a resultant direction such as is shown by the heavy line

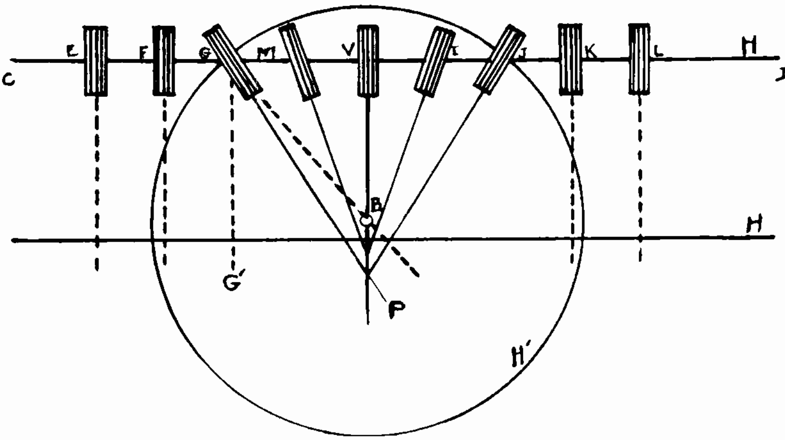

Fig. 13

GP. Similarly, at M, V, I, and J, other resultant directions would be obtained, all of which if plotted to scale as shown by the heavy lines would furnish a very good picture of the location of the axis of the secondary conductor, B.

These principles of re-radiation and of coil action when correctly applied furnish the basis of this method of locating ore bodies. The only requirements are that the ore body being sought must be conductive to high frequency electrical current, and that it must be of resonable length, the minimum length being dependent somewhat upon the depth. By using this method, it will be possible to determine the location of conductive ore bodies, both as to length and depth.

Electro-conductive ore bodies include practically all of the sulphide ores and some ores found in a native state. Ores occurring in a disseminated state are amenable to the process as well as those occurring in a massive condition. It is not possible to determine the character of the ore body located, no distinction being possible between iron, copper, lead or other sulphides. Nor will this process determine the width or the thickness of the ore body located. On the other hand, it will determine the location of all electro-conductive ore bodies down to depths of approximately 500 ft. in the area

10 X

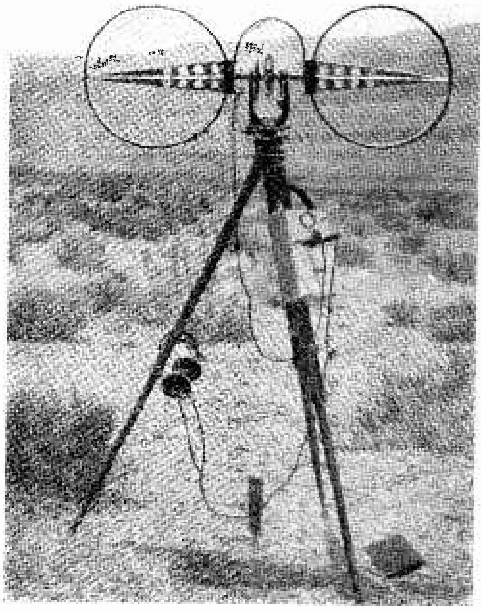

Fig. 14—Re-radiation Process Receiving Apparatus.

to which it is applied, regardless of the over-burden which may be present. It is not necessary that there be actual contact to a known ore body in the vicinity. The application of this process to territories covered with over-burden such as lava cap, or float, or where no ore out-crops occur, offers immense possibility in disclosing unknown mineralized areas.

Figure 14 shows a view of the receiving apparatus used in the Re-radiation process. The two loops are mounted so that they may be rotated easily. The transmitting apparatus is shown in Fig. 15.

With the use of this process, there should accompany as a follow-up, the application of core or diamond drilling, in order that an inexpensive determination of the character of the ore body, its value, width, and thickness may be determined.

It is apparent, that the ways and methods now available are far from perfect, and that this field of experimentation offers great opportunities to the man who is technically trained in Radio. Radio electrical surveying is in no sense destined

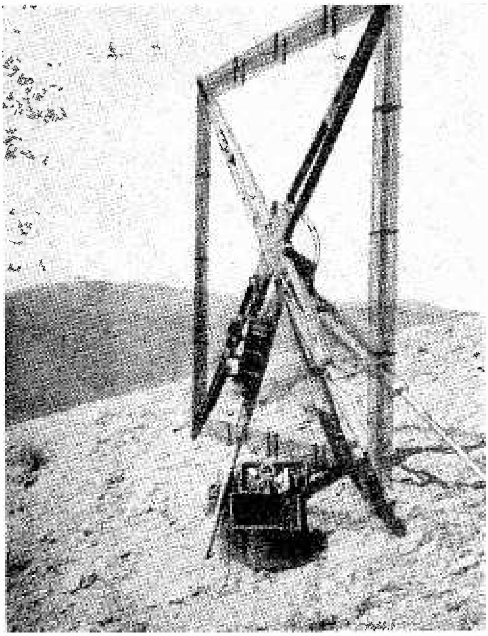

Fig. 15.—Re-radiation Process Transmitting Apparatus.

to render the professional mining engineer and geologist of minor importance in the mining world. On the contrary, the mining engineer and the man specially trained in Radio prospecting will work hand in hand in the future. Thus, by cooperating with each other, by interchanging of ideas, developing new methods and apparatus, it will be possible in the future to accurately locate valuable ores by scientific means solely, obviating the haphazard and chance methods employed in the past.

TEST QUESTIONS

Number Your Answers 43 and Add Your **Student Number**

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way we will be able to work together much more closely, you'll get more out of your course, and better lesson service.

J. A. D.

1. Name the two general kinds of mineral deposits.

2. Name the methods of locating ore deposits mentioned in this lesson.

3. Describe the electrodes used in the Equi-potential method.

4. What is the purpose of the galvanometer used in the Schlumberger method?

5. What range of frequencies is generally used in the Chilson method of prospecting?

6. Draw a diagram and name the type of transmitter used in the Hertzian Wave System.

7. Draw a diagram of the receiver used in the Hertzian System.

8. What is re-radiation?

9. What causes a current to flow in the conductor CD, Fig. 10?

10. What is the greatest approximate depth that electro-conductive ores may be found by the re-radiation method?

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