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EXPLORATION FOR OIL BY SOIL ANALYSIS

Filed Dec. 29, 1950

2 Sheets-Sheet 1

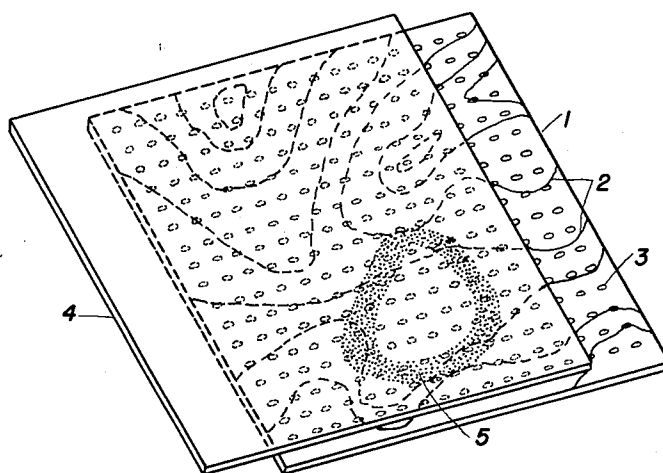


FIG. 1

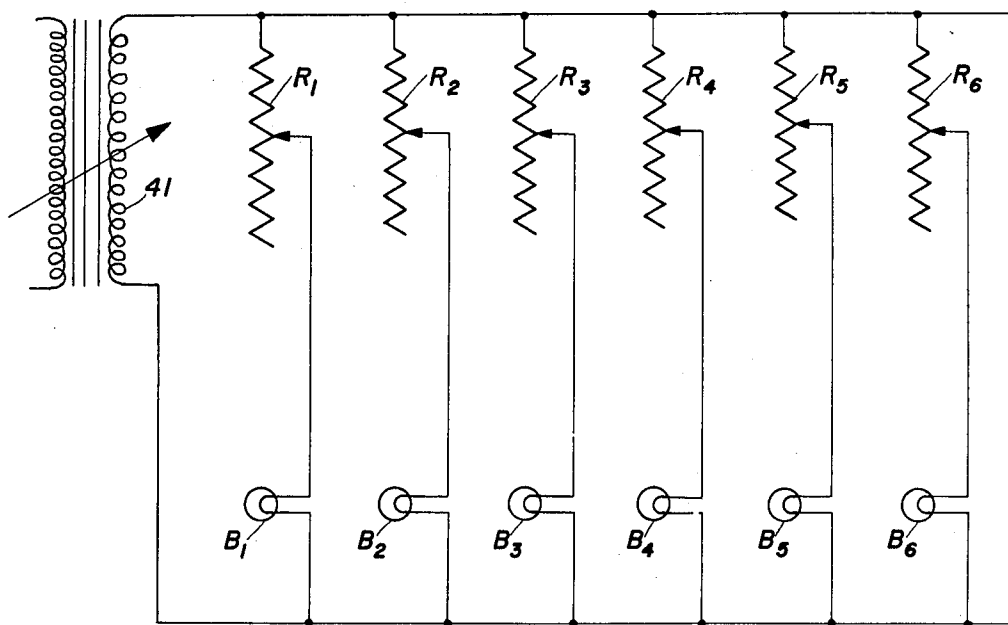


FIG. 4

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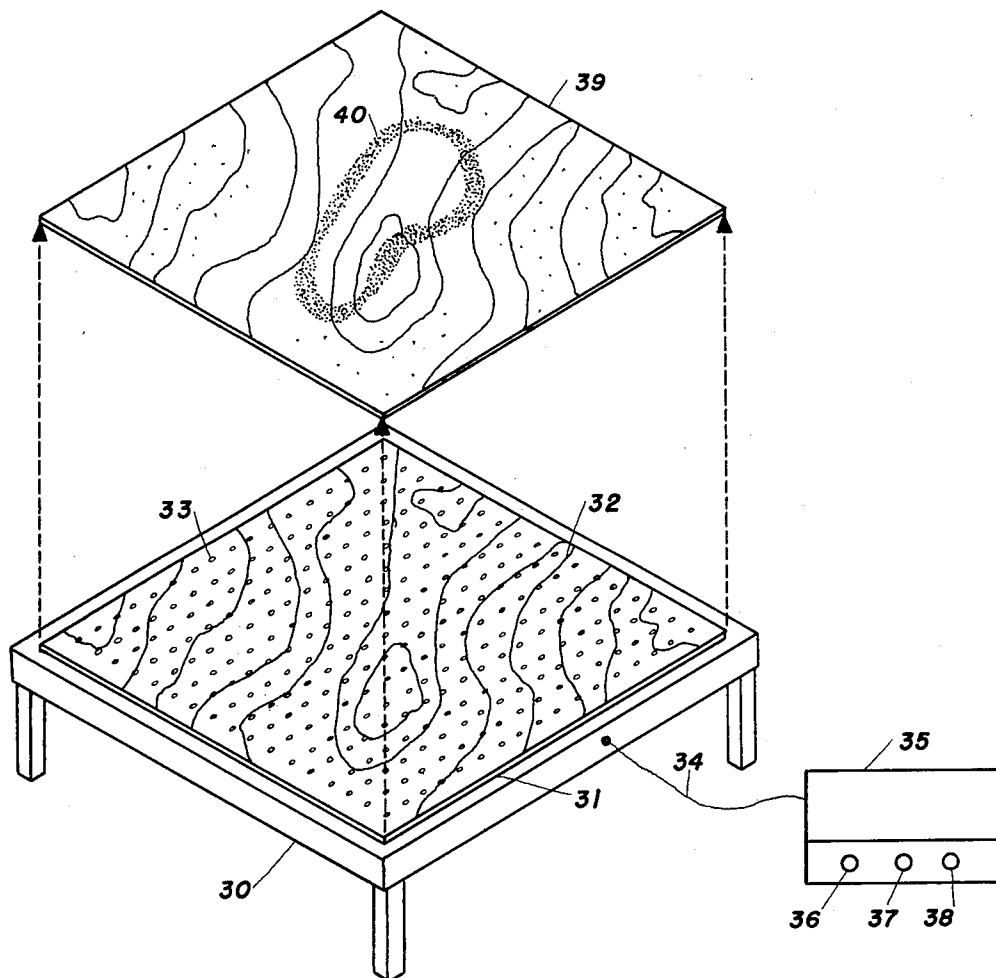


FIG. 3

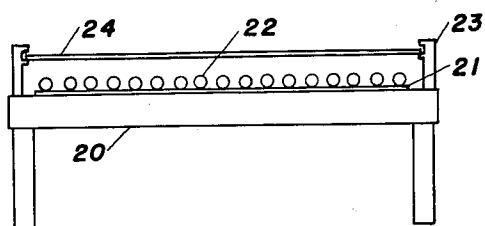


FIG. 2

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EXPLORATION FOR OIL BY SOIL ANALYSIS

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8 Claims. (Cl. 23—230)

The present invention relates to a method of geochemical prospecting for underground petroleum deposits, and more particularly, to a method and apparatus for measuring and interpreting geochemical results.

It has long been known that through the geological ages there has been an effusion of hydrocarbons through the relatively impervious underground rock formations due to the pressures and concentration gradients which exist in petroleum accumulations. Mining geologists and petroleum geologists have studied both the geology and geochemistry of earth formations in their efforts to discover methods of prospecting which give a direct indication of the actual presence or absence of petroleum rather than the indirect geophysical methods. There has developed the art of microscopic geochemical prospecting which has led to the discovery of many geochemical anomalies within earth structures. One of these discoveries has been called the "halo theory" which is a geochemical manifestation of the presence of a petroleum accumulation which may result from a near-surface or near-deposit analysis of the formation for the presence of hydrocarbons that have leaked from the formation bearing petroleum. More specifically, surrounding each petroleum accumulation or area of production, there will exist a zone of geochemical influence produced by the slow effusion of hydrocarbons from the area of production upwardly to the earth's surface, and therefore, surrounding the area of production will be a zone of higher concentration of hydrocarbons. The near-surface geochemical analysis will, of course, be influenced by any existing surface and sub-surface anomalies especially effecting deep-seated deposits. The results of many experiments conducted at the surface around known producing areas has definitely established the efficacy of the "halo theory" and the value of its use as a means of geochemical prospecting. For a more complete discussion of the halo theory, reference is made to "Geophysical Prospecting for Oil," by Nettleton, published 1940 by McGraw-Hill Company.

This chemical method of prospecting, to which the present invention relates, is based on the idea that the lighter hydrocarbons associated with petroleum would penetrate the overlying earth formations and spread upward therethrough. Sufficient quantities of these hydrocarbon gases should be present in the surface soil overlying petroleum accumulations to detect by existing analytical methods. The concentration of hydrocarbons found in the surface soil is said to be proportional to the quantity of petroleum from which they have diffused. Such hydrocarbons as ethane and propane are known only to emit from petroleum deposits and not to come from the decomposition of vegetation.

It has been theorized that as the escaping hydrocarbons migrate upwardly to zones of lower pressure, they take on the gaseous phase and this continuous increase in volume causes the evaporation of connate waters and the concentration of minerals therein. There results a replacement of this evaporated ground water by

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near-by normal ground fluids which migrate laterally through capillary action and the like toward the escape paths of the ascending hydrocarbon vapors. This lateral inward flow of ground water tends to reduce the natural diffusion which the ascending hydrocarbons would assume and there results a direct correlation between typical hydrocarbon halos, annular seismic anomalies, and gravity changes with even deep-seated accumulations.

The methods of hydrocarbon analysis used in detecting small quantities within soil samples vary widely. The most successful method is based on the difference in vapor pressure characteristics of the different gases found in the soil samples by cooling the mixture to liquid-air temperatures and then applying sufficient heat to slowly vaporize the constituents which are given off at different temperatures. The relative quantities of each hydrocarbon gas so separated are determined by chemical analysis. Minute quantities of each constituent can be accurately detected by the presently developed chemical analysis methods. Other recently developed methods which are proving successful are based on occluded gases pumped off from a soil sample or extracted therefrom by solvents.

The procedure involved in discovering the presence of these anomalies and the "halo effect" is to collect soil samples at spaced and pre-determined points over an area of the earth's surface to be explored at depths from a few inches to several feet in the ground. The points of sampling and the depths are accurately plotted on a contour map of the area and are usually spaced at intervals of about $\frac{1}{10}$ mile. The samples so taken are then carefully analyzed for their hydrocarbon content and the results are plotted on the map at the corresponding sampling points. Then those points which represent nearly the same concentrations of hydrocarbons are connected by a line and the halo established. Each hydrocarbon constituent analyzed for may be plotted on a separate map and final interpretation is made either by comparison of the maps or by connecting the points of equal hydrocarbon content. Experience has indicated that there is a tendency for those hydrocarbons associated with petroleum to be more concentrated around the periphery of the oil-bearing formation from which they diffuse. When this is brought out by plotting and connecting points on a map, the area of said concentration is known as the "halo" surrounding a possible producing formation. This halo is closely related to the subterranean petroleum reservoir and the accuracy with which it is established depends on the accuracy of the interpretation of the hydrocarbon analyses by the interpreter.

The present invention is directed to a method and apparatus for removing the subjective element from soil analysis interpretations and to eliminate the errors which occur due to the choice made by the individual observer.

Accordingly, the primary object of the invention is the provision of a method and apparatus for interpreting analyses of soil for hydrocarbon content to establish the location of underground petroleum deposits.

A second object of this invention is to provide a method for interpreting soil gas analyses efficiently and accurately.

A third object of the invention is to provide an apparatus which will efficiently outline and set out the halo effect of hydrocarbon effusion from an unknown petroleum reservoir.

The apparatus and method described herein is designed to eliminate the subjective element in geochemical interpretation and to place before the observer an accurate indication of the relationship between the variation of hydrocarbon content in the soil and the stratigraphic contour of the area under geological survey.

The invention is best explained by reference to the

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drawings. Figure 1 is an isometric view of a cartograph and screen for use in practicing the invention. Figure 2 is an end elevational view of one possible specific form of apparatus of the type generally shown in Figure 1. Figure 3 is an isometric view of another embodiment of the invention illustrating the use of magnets to impart their magnetic field upon magnetic metal particles which orient themselves and accumulate in concentrations proportional to and in accordance with the field intensity. Figure 4 is a diagram of one possible electrical control circuit for the apparatus.

In Figure 1, the cartograph is any map, chart or other representation of an area to be investigated. Cartograph 1 has distinguishing lines 2 for the purpose of identifying the area and ultimately disclosing the location of the halo effect thereon. Projecting through the cartograph are indicators 3 which are positionable in any chosen pattern over the surface of the cartograph 1. The indicators 3 comprise means for transmitting detectable forms of energy such as light or magnetism and are adapted to emit such energy in varying intensity depending on the amount of regular input which is adjustable so as to be proportional to the values of the hydrocarbon analyses at the corresponding point on the cartograph. Each indicator 3 may be adjustable in its position on the cartograph so that it may be placed in a position conforming to the point at which a soil analysis was made. The distance between points of soil analysis may be varied depending upon the size of the area being explored and the geological history of the area. Generally, the distance between points of soil analysis will be about $\frac{1}{4}$ mile during the actual sample-taking. The cartograph of the area is scaled to a workable size and may be as small as 10 feet by 10 feet or as large as is convenient for handling.

Transposed upon, and immediately adjacent to cartograph 1 and indicators 3 is screen 4 having the same dimensions as cartograph 1. Screen 4 is made of material which is resistant to the form of energy given off by indicia 3. Also screen 4 should be of uniform texture and be uniformly transparent to or sensitive to the energy produced by indicators 3. Where the form of energy to be recorded is light the screen 4 may be composed of translucent paper, ground glass, parchment, oiled or waxed paper. Screen 4 may be ordinary paper, as tracing paper, where the form of energy to be recorded or measured is magnetism.

With screen 4 in position adjacent to cartograph 1 and with each indicator 3 transmitting energy of an intensity corresponding to the hydrocarbon content of the soil at the corresponding point on the cartograph 1, there will be produced upon screen 4 a summation of the energy intensities. At those points upon the cartograph where the hydrocarbon analysis is higher than other points due to the infusion of hydrocarbon gases through the earth formations from a subterranean deposit, there will be produced an area or circle of greater response 5 which may be visible to the naked eye or which can be photographed, traced or otherwise recorded. The over-all amount of energy passing through all of the indicators 3 may be adjusted so that the energy transmitted will be just sufficient for those of highest intensity to be recorded through the screen 4. The indicators of lowest energy content will then be practically undetectable through the screen 4. This will sharpen the halo image. The last described technique can be accomplished by variable control of the over-all energy intensity of the indicators 3 after the circuit to each has been supplied with an amount of energy proportional to the hydrocarbon content of the soil at the point of sampling. Where electrical energy is used to activate the indicators, one possible circuit for controlling the energy intensities may be represented by Figure 4, wherein 41 is a variable transformer, 110 v. A. C., R₁, R₂, R₃, R₄, R₅, and R₆ are variable resistors and B₁, B₂, B₃, B₄, B₅, and B₆ are the indicators.

After adjustment of the over-all intensity so that the

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halo has been sharpened, the observer may place a thin sheet of tracing paper over the area which discloses the halo and then trace on the paper the location of the best halo or halos. Thereafter, the assemblage of indicators may be rotated or moved laterally without knowledge of the observer and repeated tracings will be taken. These various tracings may then be compared one upon the other to obtain the best halo and its location on the cartograph may be accurately placed by comparison with the distinguishing lines 2. The interpretation of one observer may be checked by having several observers make similar interpretations. Where light is the type of energy to be recorded the entire operation is conducted in a room which is totally dark and observations are made after allowing from 15 to 30 minutes to transpire for the eyes to become accustomed to darkness. Under these conditions, any existing background illumination which has not been eliminated by the over-all voltage influencing the indicators will disappear.

Figure 2 is an end view of one possible form of apparatus comprising a table 20 upon which is placed contour map 21 representing one form of cartograph. Through contour map 21, project one form of indicator, the light bulbs 22. Clamps 23 are provided along the edge of the table 20 to hold translucent screen 24 rigidly and in juxtaposition with the light bulbs 22 and contour map 21. The distance between the light bulbs 22 and the translucent screen 24 may be adjusted so that there is a minimum of distortion due to the heat effect of the light bulbs. Ventilation may be provided between the translucent screen 24 and the light bulbs 22 to substantially eliminate this distortion. Clamps 23 with an inter-imposed sheet of glass (not shown) will hold translucent screen 24 sufficiently rigid to enable the tracing of the best halos.

The electric light bulbs 22 are any ordinary type of electric light bulb which will give an illumination of constant intensity for a given amount of electricity. Preferably frosted bulbs are used which require only a fraction of a watt during maximum intensity. Bulbs may be used having higher voltage, as for example, 1 to 10 watts. The size of the bulbs with respect to the size of the map is adjusted so that the illumination transmitted therefrom is controllable to produce the halo effect desired. The current for controlling the intensity of illuminating light bulbs 22 may again be represented by Figure 4 wherein 41 is a variable transformer, 110 volt A. C., R₁, R₂, R₃, R₄, R₅, and R₆ are the variable resistors and B₁, B₂, B₃, B₄, B₅, and B₆ are the electric light bulbs.

Figure 3 shows a table 30 upon which is placed contour map 31 having contour lines 32 similar to distinguishing lines 2 shown in Figure 1. Small electromagnets 33, which serve as indicators, are placed at points of hydrocarbon soil analysis directly underneath the contour map. Each electromagnet is connected through control cable 34 to individual rheostats within control panel 35.

The electrical circuit within control panel 35 is also represented by Figure 4 wherein 41 is a variable transformer, 110 volt A. C., R₁, R₂, R₃, R₄, R₅ and R₆ are the variable resistors or rheostats mentioned and B₁, B₂, B₃, B₄, B₅, and B₆ may be the electromagnets controlled thereby.

The rheostats are individually adjusted to an arbitrary value proportional to the concentration of hydrocarbon gas found at that point in the geochemical survey, thereby establishing within each electromagnet 33 of table 30 a magnetic field of corresponding intensity. Control panel 35 is fitted with voltmeter 36, ammeter 37, and voltage control switch 38, for purposes of setting up the minimum over-all field intensity necessary to bring out the halo effect.

Duplicate contour map 39 is shown in raised position above contour map 31 for purposes of illustration. In

actual operation, the duplicate contour map 39 will be in juxtaposition with contour map 31 so that the multitude of magnetic fields set up by these small electromagnets 33 will penetrate duplicate contour map 39.

After each electromagnetic indicator 33 is receiving an amount of current proportional to the soil analysis of the point on the contour map 31, which it represents, by proper adjustment of the various rheostats on control panel 36, the operator will adjust voltage control switch 38 so that the minimum field intensity will penetrate through the duplicate contour map 39. This minimum field of influence is then detected by sprinkling metal or metal alloy particles 40 thereon, which are attracted by the magnetic field. Upon vibration or tapping of contour map 39, metal particles 40 will orient themselves in accordance with the magnetic field encountered. At individual points upon the surface of contour map 39, the metal particles will attain a concentration which is proportional to the magnetic field intensity at that point. Any changes in concentration due to changes in magnetic field intensity will be immediately visible to the naked eye or may be photographed. Vibration or tapping is used to hasten the orientation of the iron filings. For this purpose, an electric vibrator may be used or the orientation may be hastened by intermittent application of current through control panel 35. If the soil analysis has been made over an area on the earth's surface which is above a petroleum reservoir, which is effusing hydrocarbons from under a cap rock or similar geological structure, there will be produced a halo effect.

One advantage, which is apparent from the embodiment shown in Figure 3, is that the current may be stopped momentarily and the metal particles evenly distributed over contour map 39. Then, upon reapplication of current through the electromagnets 33, followed by vibration of contour map 39, there will result a rapid reorientation of the metal particles. In this manner, repeated determinations can easily and rapidly be made from which the best halo may be outlined.

From the above discussions of the invention, it is apparent that where electrical illumination or magnetic fields are utilized to establish the halo effect, the accuracy of the determination is dependent upon a physical phenomena rather than the subjective element of an observer trying to plot or join those points of soil analysis having the same or similar hydrocarbon concentrations as is used in the prior art. The accuracy of the present method is, of course, dependent upon the accuracy of the soil analysis technique and the sensitiveness of the means used to impart energy into the indicators, namely, the electromagnets or the electric light bulbs. However, the sensitivity of presently-known energy transmitting instruments as for example electrical instruments, magnets and light bulbs is such that the subjective element is removed by the present method.

It is apparent that changes in the procedure and apparatus from that mentioned above can be adopted without departing materially from the scope of the present invention. The metal particles used to detect the magnetic field of influence may be any material which has a magnetic susceptibility comparable to that of iron or is at least paramagnetic in character. Examples of suitable materials are iron filings, iron-nickel alloys, as alloys of iron and nickel having between 45% and 80% nickel, or nickel and cobalt alloys.

Although specific embodiments of the present invention have been described, they are to be taken as only illustrative and the only limitations which exist are those appearing in the following claims.

What is claimed is:

1. A method for prospecting for subterranean petroleum deposits comprising the steps of collecting a plurality of soil samples at spaced points over an area of the earth's surface to be explored, analyzing said soil samples for their hydrocarbon content, releasing detectable forms

of energy at a plurality of unshielded points on a cartograph of said area corresponding to said points of sampling, adjusting the magnitude of said energy at each point of release to correspond and be proportional to the value of said hydrocarbon content of the corresponding point of sampling, transmitting the accumulative summation of said energy upon means for detecting the relative density thereof, reducing the total energy input to said unshielded points on said cartograph until the points of highest intensity on said detecting means are substantially extinct, thereupon gradually increasing the total energy input to said points to produce an area of highest detectable accumulative energy emission and recording such area to thereby locate in relation to said cartograph the halo effect produced by said hydrocarbons from said petroleum deposits.

2. The method for prospecting for subterranean petroleum deposits comprising the steps of collecting a plurality of oil samples at spaced points over an area of the earth's surface to be explored, analyzing said soil samples for their hydrocarbon content, releasing illumination at a plurality of unshielded points on a cartograph of said area corresponding to said points of sampling, adjusting the magnitude of illumination at each point of release to correspond and be proportional to the value of said hydrocarbon content of the corresponding point of sampling, transmitting the accumulative summation of said illumination upon means for detecting the relative intensity thereof, reducing the total amount of illumination from said unshielded points in equivalent value until the points of highest intensity on said detecting means are substantially extinct, thereupon gradually increasing the total illumination input to said points to produce an area of highest detectable accumulative illumination and recording such area to thereby locate in relation to said cartograph the halo effect produced by said hydrocarbons from said petroleum deposits.

3. The method in accordance with claim 2 in which said recording step is carried out by photographing the highest detectable accumulative illumination.

4. The method for prospecting for subterranean petroleum deposits comprising the steps of collecting a plurality of oil samples at spaced points over an area of the earth's surface to be explored, analyzing said soil samples for their hydrocarbon content, establishing a plurality of unshielded variable electromagnetic fields at points on a cartograph of said area corresponding to said points of sampling, adjusting the magnitude of said electromagnetic fields at each point to correspond and be proportional to the value of said hydrocarbon content of the corresponding point of sampling, suspending discrete paramagnetic particles in free-moving relationship within said magnetic fields so produced, agitating said paramagnetic particles while lowering the strength of said magnetic fields in proportionate amounts until the strongest magnetic fields corresponding to the highest hydrocarbon content barely orient and attract said paramagnetic particles, increasing the strength of said magnetic fields proportionately until the greatest detectable accumulative group of oriented paramagnetic particles is established, and recording the location of said detectable group to thereby locate in relation to said cartograph the halo effect produced by said hydrocarbons from said petroleum deposits.

5. An apparatus for prospecting for subterranean petroleum deposits comprising in combination a cartograph of the area explored, a plurality of spaced individual unshielded indicators movably mounted on one side of said cartograph, means for fixing said indicators at places on the cartograph which correspond to points of surface oil analyses for hydrocarbons over said area, a source of energy connected to each of said indicators, means for adjusting the amount of energy imparted to each of said indicators to values which are proportional to the respective soil analysis values for the corresponding sampling point of the area, means for varying simultaneously the

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total amount of energy imparted to all of said indicators so that the accumulated energy emission from all indicators may be brought to extinction, and means for detecting and recording the relative intensity of the area of greatest detectable accumulative energy emission from those indicators receiving the most energy, to thereby locate in relation to said cartograph the halo effect produced by said hydrocarbons from said petroleum deposits.

6. An apparatus for prospecting for subterranean petroleum deposits comprising in combination a plane surface cartograph of the area explored, a plurality of spaced individual unshielded light sources movably mounted on one side of the plane surface of said cartograph, means for fixing said light sources at places on the cartograph which correspond to points of surface soil analysis for hydrocarbons over said area, a variable transformer connected to a source of electrical current, said light sources being connected in parallel to said variable transformer so that the total amount of electrical current supplied to said light sources may be varied simultaneously to reduce the accumulated light emission therefrom to extinction, a variable resistor connected in series with each light source to adjust the amount of current supplied to each light source to values which correspond to the respective values of the soil analysis at corresponding points, and means for detecting and recording the relative intensity of the area of greatest detectable accumulative light emission from those light sources receiving the most current to thereby locate in relation to said cartograph the halo effect produced by said hydrocarbons from said petroleum deposits.

7. An apparatus for prospecting for subterranean petroleum deposits comprising in combination a plane surface cartograph of the area explored, a plurality of spaced individual unshielded electromagnets movably mounted on one side of the plane surface of said cartograph, means

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for fixing said electromagnets at places on the cartograph which correspond to points of surface soil analysis for hydrocarbons over said area, a variable transformer connected to a source of electrical current, said electromagnets being connected in parallel to said variable transformer so that the total amount of electrical current supplied to said electromagnets may be varied simultaneously to reduce the accumulative magnetic field therefrom to extinction, a variable resistor connected in series with each electromagnet to adjust the magnitude of the magnetic field produced by each magnet to correspond to the respective values of the soil analyses at corresponding points, and means for detecting and recording the area of greatest detectable accumulative magnetism from said magnets to thereby locate in relation to said cartograph the halo effect produced by said hydrocarbons from said petroleum deposits.

8. An apparatus in accordance with claim 7 in which the means for detecting and recording the greatest detectable accumulative magnetism produced by said magnets comprises a sheet of non-magnetic material having a surface area substantially the same as that of said cartograph, said non-magnetic sheet being held horizontally in juxtaposition with said cartograph and adapted to suspend discrete paramagnetic particles within the influence of the plurality of magnetic fields set up by said electromagnets, and means for agitating said non-magnetic sheet.

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