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RADIATION SURVEY METHOD

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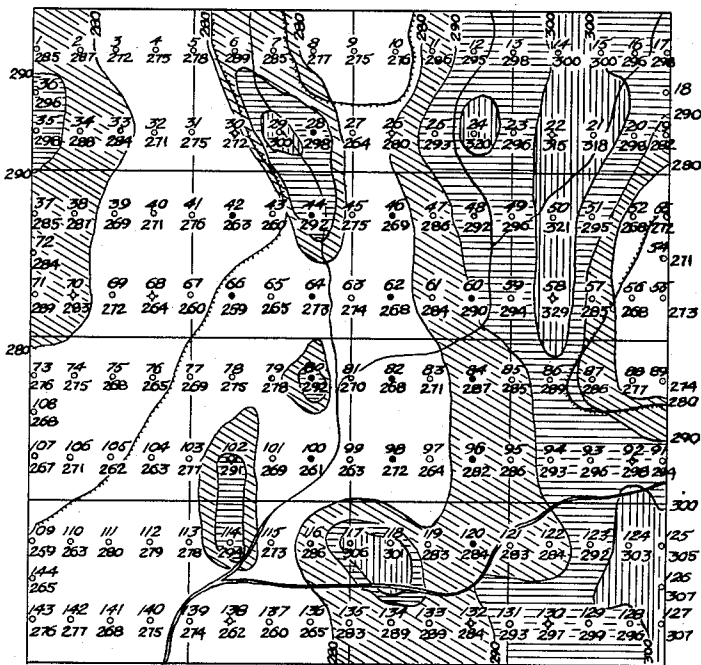


Fig. 1

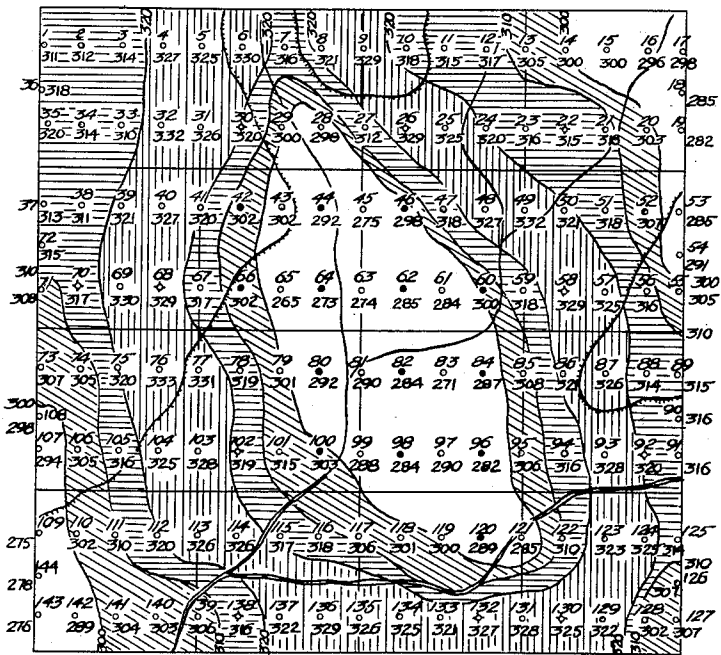


Fig. 2

- PRODUCING WELLS
- ⊕ DRY HOLES

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2,906,882

RADIATION SURVEY METHOD

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2 Claims. (Cl. 250—83)

This invention relates to surface surveying methods used in locating and identifying subsurface deposits of petroleum and refers more particularly to an improved method for direct detection of such deposits.

This application is a continuation-in-part of my pending application Serial No. 500,889, filed April 12, 1955.

Heretofore, various methods for locating petroleum deposits or structural features favorable to the accumulation of such deposits have been proposed and adopted. The known methods can be conveniently divided into two broad categories: The first and more prevalent of the two are the indirect methods wherein the primary purpose is to locate subsurface geological structures suitable for containing the petroleum deposit, for example, stratigraphic traps, anticlines, faults and domes. Falling in the second category are the direct methods, which make use of observations and measurements of phenomena which are directly associated with and the direct result of the actual existence of a petroleum deposit without reference to the subsurface geological structure. Examples of direct surface surveying methods are the so-called geochemical methods involving soil analysis and the more recent gamma ray methods which are based upon the existence of variation of radiation intensity in the vicinity of petroleum or natural gas deposits.

The direct methods, if they can be made accurate, undoubtedly provide a much more desirable tool than the indirect. The inherent and unavoidable disadvantage in the latter is that even though the results of a survey, for example, a seismic survey, may indicate the presence of structure favorable to the accumulation of petroleum, still there exists no means other than drilling to determine its actual presence. Moreover, the indirect methods decrease sharply in value in locating anticlinal structures of low relief, structural closures against faults, and stratigraphic traps whether they be depositional sand lenses, unconformities or lenticular zones of porosity resulting from chemical action. The importance of the shortcomings of the indirect methods is clearly revealed when it is realized that some of the largest and most prolific oil pools, such as the East Texas Field, occur in stratigraphic traps. Moreover, with the decline in new discoveries of major fields, particularly in the United States, more and more attention has been devoted to re-examining those areas in which for one reason or another the indirect methods did not indicate any positive results.

One of the first attempts to apply a new technique to oil exploration resulted in the development of Geo-Chemistry. Chemical analysis of the soil at spaced points in and around known producing fields revealed a pattern showing a greater hydrocarbon content there as compared with the barren ground surrounding the production. It was also discovered that more frequently the density pattern took the form of a ring or halo of high values lying approximately above the margin of the production, and thus, defining the borders of the field. The

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higher concentration of hydrocarbons in the ring or halo was attributed to gas movement upwardly through the earth from the deposit or pool. Succeeding investigations resulted in the discovery that due to the gas movement and to progressive and greater evaporation of moisture from the soil in the areas of excessive gas movement, an excessive quantity of minerals were accumulated by capillary action in the area occupied by the gas halo. As a result the analysis of the soil was revised to develop a pattern of watersoluble inorganic mineral which proved far more simple and was unaffected by changes in temperature and atmospheric pressure. However, several difficulties still remained which often prevented the obtaining of a recognizable pattern; the chief among these being the non-uniformity of the distribution of the hydrocarbons or water-soluble minerals in the soil. Added to this difficulty was another important one, namely, the fact that without any previous indication above ground whether oil or gas might be found, or, if so, where the margins might be, the geochemist had no idea whether his sampling would be either excessive or insufficient in area. As a result, either too much field work is done or another trip to the field becomes necessary in order to round out the survey and make the geochemical pattern all inclusive. A new and more simple method was thus required.

As hereinbefore noted, it has been recognized that water-soluble mineral concentration and liquid hydrocarbon concentration patterns at the surface closely approximate one another. It also has been discovered that the presence of the mineral concentrations results in patterns of relatively high gamma ray radiation against the background of the surrounding surface. This latter discovery resulted in the technique of the gamma ray survey in which readings of gamma ray activity close to the surface are taken at points along parallel transverse lines across the area being investigated. The readings at the individual stations are then plotted either as profiles along a single traverse or on area maps to provide a gamma activity contour. By noting the anomalies in the pattern (the gamma ray highs), it theoretically should be possible to discover the ring or halo effect discovered in the geochemical surveys and in some cases this theory has been successfully borne out.

However, more often than not, the gamma ray readings obtained in field surveying show unpredictable variations in closely adjacent areas which still may lie within the band of mineral concentration. Also it has turned out that the degree of these variations frequently reaches into the class of the anomalies which serve to define the location of the halo or rings surrounding the production. As a result the pattern obtained is clouded to a considerable extent, often to the point that it is extremely difficult, if not impossible, to accurately locate the borders of the field.

A primary object of the present invention is to provide an improved radiation survey technique in which the radiation pattern obtained accurately reflects the anomalies created by the high concentration of radioactive material in the hydrocarbon halo and which suppresses the effect of the variation in radiation activity caused by changes in soil character from point to point.

Another equally important object of the invention is to provide means for determining the relationship between changes in soil character at each gamma ray reading station and the change in the gamma ray values obtained, and to provide a method for applying this relationship to the observed gamma ray activity to thus produce a pattern of relative gamma ray activity which reflects more accurately the variations due to presence or absence of gas movements in the soil.

Still another object of the invention is to provide an improved gamma ray survey technique in which the abnormal high and low readings in gamma ray activity caused by changes in the retentivity characteristics of the soil are corrected and in which the final plot of the readings reflects the variation due primarily to presence or absence of concentrations of radio-active mineral substances in the hydrocarbon band or halo.

A further object of the invention is to provide a gamma ray survey technique of the character described in which in one step of the method the retentivity characteristics of the soil from point to point are established through measurement of the electrical conductivity or resistance of the soil. A feature of the invention in this respect resides in the provision of a procedure for eliminating variations or anomalies in resistivity or conductivity measurements which occur primarily from the presence of excessive concentrations of water-soluble mineral constituents which have accumulated in the soil as the result of phenomena other than the capillary accumulation of such constituents resulting from gas movement through the soil.

Another object of the invention is to provide a survey technique which is simple in operation, can be carried out quickly and yet which is extremely accurate in result.

Other and further objects together with the features of novelty appurtenant thereto will appear in the course of the following description.

In the accompanying drawings, which are included to illustrate a manner of practicing the invention and the advantages resulting therefrom,

Fig. 1 represents a map of an oil producing field showing the locations of producing wells and dry holes on which have been plotted the gamma ray contour lines resulting from a conventional gamma ray survey. The contour lines connect points of equal gamma ray activity and are hereinafter referred to as "isogams"; and

Fig. 2 represents a map of the area illustrated in Fig. 1, but shows the isogam pattern obtained by employing the method described and claimed herein.

Referring initially to Fig. 1, this map represents a typical example of the pattern obtained by known gamma ray survey techniques. The surface gamma ray readings at spaced points along parallel traverse lines are shown by the numbers below the small circles, each circle representing the exact location of the station where the reading was taken. The stations are identified in numerical order the station identifying number appearing above the circle.

Equipment for obtaining readings of ground gamma ray activity is well known and in general use. Perhaps the most accurate type and the type I prefer is the portable ionization chamber which fundamentally consists of two electrodes immersed in an inert gas contained under pressure in a steel chamber. The electrodes are connected externally to a circuit containing batteries. When gamma rays (which have sufficient penetrability to pass through the steel walls) enter the chamber and ionize the gas, a current flows in the circuit which is directly proportional to the ionization or intensity of radiation. Ordinarily the current is stepped up through amplified circuits and passed through a meter where the values can be read directly or may be automatically recorded on a chart. It will be understood, of course, that other equipment for measuring gamma ray radiation emanating from the ground may be used and my invention is not limited to the use of any particular type of equipment.

In obtaining a map as exemplified by Fig. 1, the portable gamma ray measuring unit is moved from point to point along the traverse lines, a reading being taken at each succeeding station. As a satisfactory spacing for the stations, I prefer proceeding along parallel traverses 660 feet apart, readings being taken at 330 foot intervals along the traverses. The sides of the field can be closed by taking intermediate 330 foot readings between the traverses at each end, as indicated.

The readings from which the Fig. 1 map was prepared are found in column A of Table 1.

Station	Gamma A	Soil B	98-Soil C 98-B	Correction D 1.228×C	True Value E A+D
1	285	76	22	26	311
2	287	77	21	25	312
3	272	63	35	42	314
4	275	55	53	52	327
5	278	59	39	47	325
6	289	64	34	41	330
7	285	72	26	31	316
8	277	61	37	44	321
9	275	53	45	54	329
10	276	63	35	42	318
11	286	74	24	29	315
12	295	80	18	22	317
13	298	92	6	7	305
14	300	98	0	0	300
15	300	98	0	0	300
16	296	98	0	0	296
17	298	98	0	0	298
18	295	98	0	0	295
19	282	98	0	0	282
20	298	94	4	5	303
21	318	98	0	0	318
22	315	98	0	0	315
23	295	81	17	20	316
24	320	98	0	0	320
25	293	71	27	32	325
26	280	57	41	49	329
27	264	58	40	48	312
28	295	98	0	0	295
29	300	98	0	0	300
30	272	58	40	48	320
31	275	56	42	51	326
32	271	47	51	61	332
33	284	76	22	26	310
34	288	76	22	26	314
35	298	80	18	22	320
36	296	80	18	22	318
37	285	75	23	28	313
38	287	78	20	24	311
39	289	55	43	52	321
40	271	51	47	56	327
41	276	61	37	44	320
42	263	66	32	39	302
43	260	71	27	32	292
44	292	98	0	0	292
45	275	98	0	0	275
46	260	74	24	29	298
47	286	71	27	32	318
48	292	69	29	35	327
49	296	28	30	36	332
50	321	98	0	0	321
51	295	79	19	23	318
52	288	66	32	39	307
53	272	87	11	13	285
54	271	81	17	20	291
55	273	71	27	32	305
56	268	58	40	48	316
57	285	65	33	40	325
58	329	98	0	0	329
59	294	78	20	24	318
60	290	90	8	10	300
61	284	98	0	0	284
62	268	84	14	17	285
63	274	98	0	0	274
64	273	98	0	0	273
65	265	98	0	0	265
66	259	62	36	43	302
67	260	51	47	57	317
68	264	44	54	65	329
69	272	50	48	58	330
70	283	70	28	34	317
71	289	82	16	19	308
72	284	72	26	31	315
73	276	72	26	31	307
74	275	73	25	30	305
75	268	55	43	52	320
76	265	41	57	68	333
77	269	46	52	62	331
78	275	54	37	44	319
79	278	79	19	23	301
80	292	98	0	0	292
81	270	81	17	20	290
82	298	85	13	16	294
83	271	98	0	0	271
84	287	98	0	0	287
85	285	79	19	23	308
86	293	79	19	23	321
87	286	65	33	40	326
88	277	67	31	37	314
89	274	64	34	41	315
90	284	71	27	32	316
91	284	80	18	22	316
92	298	80	18	22	320
93	296	71	27	32	328
94	293	79	19	23	316
95	286	81	17	20	306
96	282	98	0	0	282
97	264	77	21	26	290
98	272	88	10	12	284
99	263	77	21	25	288
100	261	71	27	32	303
101	269	60	38	46	315
102	291	75	23	28	319
103	277	56	42	51	328

Station	Gamma A	Soil B	98-Soil C 98-B	Correction D 1.228×C	True Value E A+D
104	263	56	52	62	325
105	262	53	45	54	316
106	271	70	28	34	305
107	267	76	22	27	294
108	268	73	25	30	298
109	259	85	13	16	275
110	263	66	32	39	302
111	280	74	24	30	310
112	279	65	34	41	320
113	278	58	40	48	326
114	294	71	27	32	326
115	273	61	37	44	317
116	286	71	27	32	318
117	306	98	0	0	306
118	301	98	0	0	301
119	283	84	14	17	300
120	289	98	0	0	289
121	283	96	2	2	285
122	284	76	22	26	310
123	292	72	26	31	323
124	303	80	18	22	325
125	305	91	7	9	314
126	307	98	0	0	307
127	307	98	0	0	307
128	296	93	5	6	302
129	299	79	19	23	322
130	297	75	23	28	325
131	293	69	29	35	328
132	284	62	36	43	327
133	289	71	27	32	321
134	288	66	32	37	325
135	283	62	36	43	326
136	265	45	53	64	329
137	260	46	52	62	322
138	262	53	45	54	316
139	274	71	27	32	306
140	275	75	23	28	303
141	268	68	30	36	304
142	277	88	10	12	289
143	276	98	0	0	276
144	265	87	11	13	278

Once plotted on the map, isogam lines are drawn to define the readable pattern of activity. It will be observed from Fig. 1 that the areas in which readings below 280 gamma units are found are represented by the portions of the map free from cross hatching. The areas between isogam lines representing an increase of from 280 to 290 are distinguished by diagonal cross hatching. Between isogams of 290 and 300 the area is distinguished by horizontal cross hatching and above 300 by vertical cross hatching.

As is believed at once evident, the pattern obtained in Fig. 1 shows no correlation with the actual production characteristics of the region mapped. As has been hereinbefore noted, the pattern indicating possible producing zones of oil is a band or series of high values surrounding the location of the oil deposit and appearing substantially vertically above the outer limits of the deposit.

Fig. 1, however, shows no conclusive or readable pattern of this character. No "halo" or parallel band effect is present, and such a pattern would not justify a recommendation of the area as a favorable prospect. However, as shown by the symbols on the map, there is definitely a large producing field running through the central portion of the area.

I have discovered that the primary reason for the failure of the known gamma ray techniques to adequately reflect the anomalies which indicate the presence or absence of oil deposits is the rather extreme variation in localized areas in soil characteristics with particular reference to the ability of the soil to retain the water-soluble mineral concentrations resulting from gas movements. It is generally agreed that surface gamma ray readings ordinarily measure the radiation only from the radio-active minerals located to a depth of from ten to twelve inches below the surface. The intensity of radiation from concentrations below that depth is suppressed by the shielding effect of the surface layer. The ability of the surface layer to retain the mineral concentrations resulting from subsurface hydrocarbon activity thus has a direct effect on the gamma activity at any point. In loose sandy soils it often happens that even though the mineral concentrations were once present in the surface layer, the

continual leaching caused by rainfall, flooding and the like carries some or all of the minerals downwardly into lower strata to a point well below the limits at which their radiation can be measured by surface equipment.

5 On the other hand, in tight clay loams surface moisture has little or no effect and the anomalies in gamma ray measurements accurately reflect the degree to which radioactive minerals have been concentrated. In almost every field the character of the soil varies from point to point between these extremes, and this variation has a marked effect on the results of the gamma ray surveys.

The map appearing as Fig. 2 is a plot of the same area shown in Fig. 1 but prepared in accordance with the method embodying my invention. That this map is in complete accord with the location of the production area is believed evident. The fifteen producing wells are surrounded by a closed ring or halo of high values which clearly delineate the area in which production can be expected. It will be noted that the abandoned wells lie outside the halo and further drilling in this area would appear to be pointless.

To obtain the Fig. 2 map, the following procedure is carried out. Gamma ray readings are taken at each station as explained in connection with Fig. 1. However, in addition to the gamma ray reading there is taken at each station according to my method a sample of the soil. Preferably it is taken at a six-inch depth with any one of the several conventional devices employed for such purposes, for example, a sampling pick or soil auger. 25 The samples are placed in individual bags or other suitable containers, each bag marked with the identifying data for the particular station. The samples are accumulated as the survey proceeds and are preserved for later use, as hereinafter described.

Following the completion of the field survey which includes the obtaining of the gamma readings and the soil samples at each station, the next step is the obtaining of a measurement of retentivity characteristics of the soil at the stations. For this, the samples collected during the survey are employed.

A number of procedures for measuring the retentivity characteristics of the samples may be used. In one preferred method the retentivity is obtained by measuring the conductivity of the sample after it has been exposed to and allowed to adsorb moisture. Highly porous soils such as loose sands lose by leaching action whatever minerals that may collect. Therefore they do not adsorb and retain moisture readily and will have a high resistance (or low conductivity) while tight and heavier soils are not so easily leached and thus will adsorb and retain more moisture and will consequently have a lower resistance (or higher conductivity).

In another method, a weighed quantity of soil is placed in the bottom of a centrifuge tube and is covered with water. Following centrifuging the unabsorbed water is poured off and the soil is again weighed. The difference in weight of course provides a value which can be compared with values obtained from other samples to determine their relative water absorbing and retaining properties. In a third method, a measured volume of water is placed in the centrifuge with a weighed quantity of soil, and the discharge water is caught in the process of spinning the sample. The figure obtained by subtracting the measured volume of discharged moisture from the original volume of water placed with the centrifuge soil sample provides a direct measure of the retentivity of the soil.

In obtaining the Fig. 2 map, the electrical conductivity method was relied upon. Each soil sample is first dried at below 212° F., preferably at 180° F. to remove all free moisture and then is ground sufficiently fine to break up clods and lumps but without destroying its natural texture. The sample is then thoroughly dried again and placed in a humidifier maintained at a constant temperature and humidity. By way of example, suitable values

for this are 80° F. and a relative humidity of 80%. Each sample is kept in a humidifier for the same period of time (say six hours), after which it is removed and immediately tested.

Any suitable testing equipment adapted to be used in measuring electrical conductivity of fine granular materials may be employed. I prefer a test cell comprising a simple tube of conductive material having in its interior a centrally disposed coaxial rod, also formed of material which is a good conductor. The rod and tube are insulated from one another and the opposite leads from any suitable source of electrical energy of known potential are connected respectively therewith. The sample is placed within the annular space between the two electrodes (the tube and rod) and its conductivity is measured by connecting a voltmeter in series between the source of potential and the tube.

The figures in column B of Table I represent the voltage readings for the samples when tested according to an electrical method. It will be noted that the values obtained vary over a wide range. These readings point up very clearly the changing character of the soil from station to station across the field, particularly in connection with the ability of the soil to retain the mineral solution concentrations deposited by gas movement. The analysis or testing of the soil provides the basic data necessary for correcting the gamma ray survey to counteract so far as possible the influence of the soil conditions on the radiation measurements.

In a preferred embodiment of my method, the necessary correction of the original radiation measurements is accomplished through the use of a correction factor reflecting the ratio of the range between maximum and minimum gamma ray readings (taken from Table I) to the range of soil retentivity measurements. In the instant example, the ratio is obtained by dividing the difference between the maximum and minimum gamma readings (329 minus 259) by the range of voltage readings (98 minus 41) which gives a factor of 1.228.

The gamma correction to be applied to the original reading is obtained by converting the variations in retentivity of the soil to gamma units through the use of the correction factor. As stated earlier, the ability of a dry soil sample to absorb moisture from the air is a direct indication of its ability to retain the water soluble minerals which may have been deposited therein by gas movement. Soils which adsorb the least moisture are most likely to lose the water-soluble minerals by the leaching action of rain or flood waters, while those that are fine, tight and relatively highly absorbent exhibit much better retention qualities. In the electrical testing method the most retentive soils are represented by the highest voltage readings in Table I while the least retentive and highly porous soils have the lowest values. Therefore, in order to convert the readings into values which tend to indicate the degree of correction in the original gamma reading which must be made, the highest value is accepted as the standard for the area and all values are subtracted therefrom; the differences in each case are listed in column C of Table I. To convert these differences to gamma ray corrections, the figures in column C are multiplied in each case by the correction factor. The resultant (column D) is then added to the original reading (column A) and the sum of the two is the corrected radiation value.

The final step in my method consists of the plotting of the corrected readings (column E) on the area map and the interpolation of the map of the isogam lines in order to delineate the pattern of gamma ray activity. In the specific example herein disclosed, the final corrected readings are taken from column E of Table I and were spotted on the map next to the stations to which they correspond. Isogam lines are then drawn to connect the points of equal radiation intensity with the result observed in Fig. 2. The band of highs encompassing within

it the producing wells reflects the outline of the subsurface deposit, and it will be seen that this band correlates very closely with the results indicated by the producing wells and abandoned dry holes.

Essentially the same procedure is carried out when the retentivity characteristics are determined by the use of the non-electrical procedures hereinbefore set forth. In the first of these, that is, when weighed samples of dried and ground soil are placed in a centrifuge tube, covered with water, and after centrifuging and after the free water has been poured off, weighed again, the gains in weight represent the retentivity characteristics of the particular samples. The correction factor is obtained by dividing the difference between the greatest and smallest gain into the radiation range, and the correction value is reached by multiplying each gain value by the correction factor. As in the electrical method, the correction is added to the radiation reading to arrive at the figure to be charted on the map for the particular station. In the volumetric method, the measured water thrown off during centrifuging is used as a basis. However, to properly correlate the measurements with the degree of retentivity, the amount thrown off from each sample is subtracted from the volume originally placed in the centrifuge. Highly retentive soils will retain more water and thus the difference will be greater than in the case of soils with low retentivity. Again, the range of retentivity measurements is divided into the radiation range to correlate the two as a correction factor, and the factor is utilized in the same fashion as in other methods.

Turning now to a modified form of the invention in which the electrical conductivity or resistance of the samples provides the basis for determining retentivity characteristics, I have found that in some isolated fields there occur instances of extreme concentration of water-soluble minerals which can serve to cloud the true radiation picture even after correction as contemplated in the preferred embodiment. In low spots there may be a soil of highly alkaline or saline characteristics which, due to the excessive concentration of the mineral constituents, will not under normal atmospheric conditions leach out to the same degree as the more uniform soil surrounding the area. In this case if conductivity measurements in accordance with the preferred embodiment are employed, samples taken from the areas of excessive concentration will produce abnormally high conductivity (low resistance) measurements which do not accurately reflect the relative retentivity characteristics of the soil in the area of concentration as compared with the surrounding soil in which the concentrations are not present. This is due to the excessive quantity of electrolytic material in the soil at the areas of concentration. Where this condition is suspected, either from visually observable phenomena or from a spot chemical analysis, then the following steps may be employed.

The radiation measurements of the field are taken precisely as described in the preceding embodiment and at the same time a soil sample is obtained at each station. The samples are, of course, tagged to identify them with a particular station.

When ready for the determination of the water soluble retentivity characteristics of the soil at the various stations, the samples are first thoroughly dried and then screened or sieved to segregate pebbles therefrom. Following this, a fixed quantity of each sample is weighed out and placed individually in a suitable mixer along with a fixed volume of a water whose electrolyte content is known. In most areas city tap water will serve the purpose, care being taken to periodically check the electrolyte content to see that the water is maintained at a standardized value. After a thorough mixing of the soil sample and water, in which the water leaches the water-soluble minerals from the sample, and after the solids have been permitted to settle, the electrolyte content of the resulting solution is measured and compared with the

known value for the water. If the electrolyte content of the solution is substantially above that for the water prior to mixing, then the solution is decanted, more raw water is added, and the process repeated. The leaching of the soil samples should be continued until the electrolyte content of the solution is substantially equal to that of the raw water.

In measuring the electrolyte content of the raw water and the solution, any convenient method or apparatus may be employed. I prefer the use of a conductivity measuring instrument of the conventional type such as the conductivity bridge and dip cell employed in the type RC instrument manufactured and sold by Industrial Instruments, Inc., of Jersey City, New Jersey. This instrument is of the Wheatstone bridge type employing electrodes which are immersed in the liquid to be measured. The conductivity is measured in terms of resistance of the electrolyte and the range is approximately from .2 ohm to 25 megohms.

When the electrolyte content of the leach solution for each sample has been reduced to substantially a standardized value for all samples (which in this example is the electrolyte content of the raw water) the solution is decanted or otherwise removed and the sample thoroughly dried. As in the earlier embodiments the sample should be dried at a temperature below 212° F., preferably 180° F. or under, to prevent the breakdown of crystals formed by water crystallization. If the dried sample is in cake form, it should be ground to the extent necessary to reproduce as closely as possible the original texture and grain size.

After the soil samples have been individually leached to a standardized condition and dried as set forth above, their comparative retentivity characteristics are determined in exactly the same fashion as described earlier herein in connection with the preferred embodiment of my invention by which the Fig. 2 map was prepared. That is, each sample is placed in a humidifier maintained at a constant temperature and humidity and kept there for the same period of time. When removed from the humidifier each sample is immediately tested for conductance as earlier described and the values obtained are utilized exactly as described in connection with the preparation of Table I to obtain a corrected radiation value for each station. The corrected values, as in the illustrative example, are charted on a map of the area to reveal the corrected radiation pattern.

From the foregoing it is believed clear that the modified form of the electrical conductivity method of determining water soluble retentivity characteristics differs from the preferred form in that the soil samples are leached before conductivity measurements are taken to remove excessive minerals which have been concentrated in the area by conditions not arising from the gas movements through the soil, but from other either natural or artificial phenomena. The modified form of the method as herein described is particularly valuable in obtaining a correct pattern in areas where surface alkali concentrations are apparent or where they have been established or are known to be present from other tests and investigations.

From the foregoing, it will be seen that I have provided a method of radiation surveying in which the retentivity characteristics of the soil from point to point are correlated with the radiation measurements to pro-

duce a pattern of activity reflecting the true character of the field. My invention is thus one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the method.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

Since many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. A method of exploring for and locating subsurface hydrocarbon deposits comprising the steps of measuring and recording the surface radiation and intensity of the radioactive constituents of the earth at a plurality of stations in a selected area to obtain for each of said stations a radiation value, obtaining a representative sample of the soil at each of said stations, leaching said samples individually with a water of known mineral content until the leached solution of each sample is at substantially the same level of electrolyte content, drying said samples, exposing said samples to water vapor for a fixed period, passing an electric current through each of said samples to determine the relative water soluble mineral retentivity characteristics of said samples and recording same, applying to the original radiation values a correction based on the variation from station to station in said retentivity characteristics thereby to obtain a corrected radiation value at each station, and charting the corrected values to visually reveal the corrected radiation pattern.

2. A method of exploring for and locating subsurface hydrocarbon deposits comprising the steps of measuring and recording the surface radiation intensity of the radioactive constituents of the earth at a plurality of stations in a selected area to obtain for each of said stations a radiation value, obtaining a representative sample of the soil at each of said stations, mixing a fixed volume of water of known electrolyte content with a fixed volume of each sample, measuring the electrolyte content of the solution, decanting the solution and repeating said mixing step until the solution for all samples measures substantially the same electrolyte content, drying said samples, exposing said samples to air of standardized humidity for a fixed period of time and at a fixed temperature, passing an electric current through each of said samples to determine the relative water-soluble mineral retentivity characteristics of said samples and recording same, applying to the original radiation values a correction based on the variation from station to station in said retentivity characteristics thereby to obtain a corrected radiation value at each station, and charting the corrected values to visually reveal the corrected radiation pattern.

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