

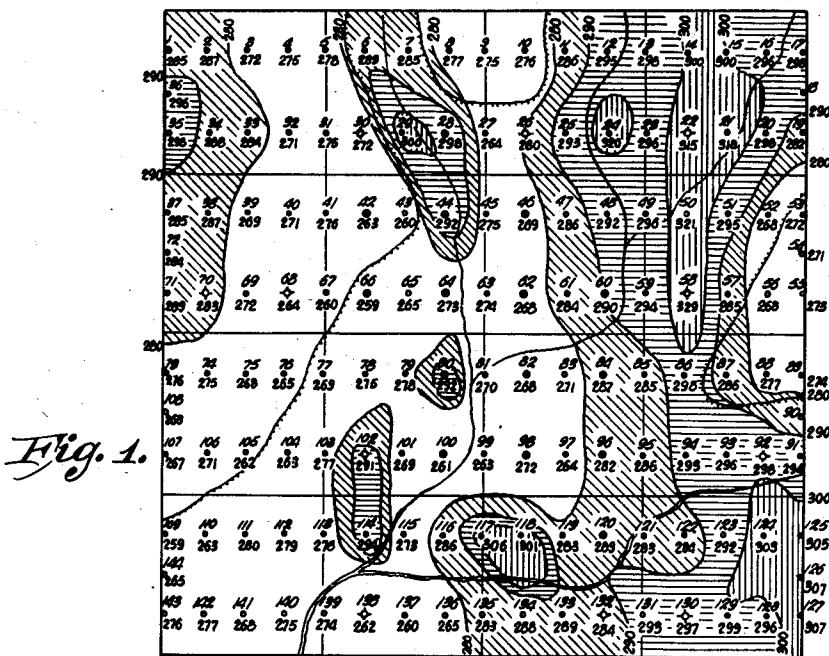
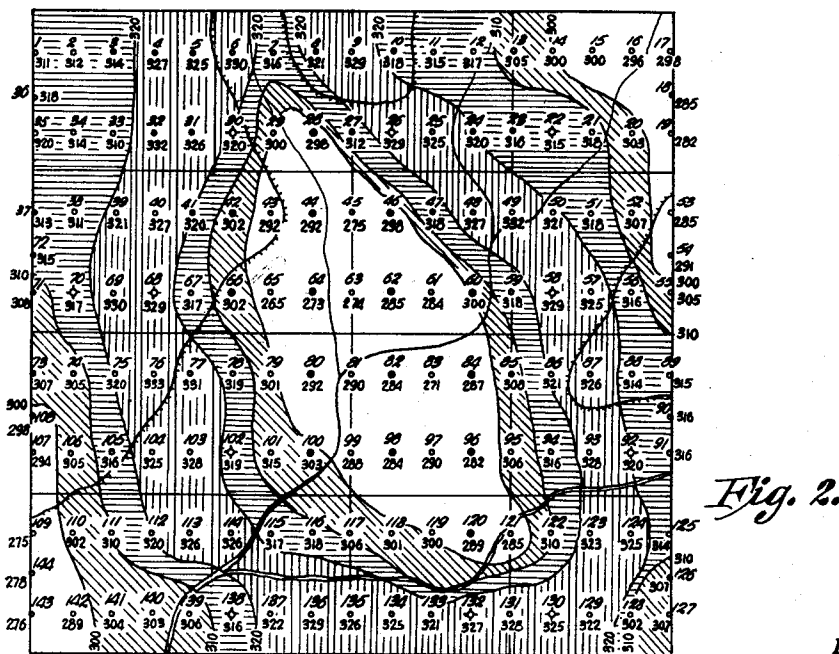
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J. W. MERRITT

2,947,870

RADIATION SURVEY METHOD

Filed April 12, 1955



- — PRODUCING WELLS
- ⊕ — DRY HOLES

INVENTOR.
John W. Merritt
BY *Thos. E. Scophield*
ATTORNEY.

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2,947,870

RADIATION SURVEY METHOD

John W. Merritt, 208-209 Midco Bldg., Tulsa, Okla.

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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.

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 resulted in 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 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 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

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revised to develop a pattern of water-soluble inorganic minerals which proved far more simple and was unaffected by changes in temperature and atmosphere 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 traverse lines across the area being investigated. The readings of 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 successively 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 radio active 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 radioactive mineral substances in the hydrocarbon band or halo.

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 I.

Table I

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	56	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

Table I—Continued

Station	Gamma A	Soil B	98-Soil C 98-B	Correction D 1.228×C	True Value E A+D
22.....	315	98	0	0	315
23.....	296	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.....	298	98	0	0	298
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	25	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.....	269	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.....	269	74	24	29	298
47.....	286	71	27	32	318
48.....	292	69	29	35	327
49.....	295	28	30	36	332
50.....	321	98	0	0	321
51.....	295	79	19	23	307
52.....	268	66	32	39	308
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	329
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	40	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.....	268	85	13	16	284
83.....	271	98	0	0	271
84.....	287	98	0	0	287
85.....	285	79	19	23	368
86.....	298	79	19	23	321
87.....	283	65	33	40	326
88.....	277	67	31	37	314
89.....	274	64	34	41	315
90.....	234	71	27	32	316
91.....	294	80	18	22	316
92.....	298	80	18	22	320
93.....	296	71	27	32	323
94.....	293	79	19	23	316
95.....	286	81	17	20	305
96.....	282	98	0	0	282
97.....	264	77	21	26	290
98.....	272	88	10	12	284
99.....	263	77	21	25	283
100.....	261	71	27	32	303
101.....	289	60	38	46	315
102.....	291	75	23	28	319
103.....	277	56	42	51	328
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

Table I—Continued

Station	Gamma A	Soil B	98-Soil C 98-B	Correction D 1.228×C	True Value E A+D
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 radioactive 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 ray 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 causing by rainfall, flooding and the like carries some or all of the minerals downwardly into lower stratas to a point well below the limits at which their radiation can be measured by surface equipment. 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. The samples are placed in individual bags or other suitable containers, each bag being 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 station. For this, the samples collected during the survey are employed.

A number of procedures are 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 absorb moisture. Highly porous soils such as loose sands lose by leaching action whatever minerals that they 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 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 the 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 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 loose 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 on 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 the other methods.

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 produce 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 sub-combinations 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 sub-surface 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, sampling the soil for its retentivity characteristics at each station, correlating the retentivity characteristics and radiation values and establishing a corrected radiation value for each station, and charting the corrected values to reveal the corrected pattern.

2. A method of exploring for and locating sub-surface 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 such stations a radiation value, obtaining a representative sample of the soil at each of said stations, determining and recording the relative water-soluble mineral retentivity characteristics of said samples, 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.

3. A method as in claim 2 wherein said determination of said retentivity characteristics is accomplished by measuring the relative ability of said samples to absorb and retain moisture.

4. A method as in claim 2 wherein said determination of said retentivity characteristics is accomplished by passing an electric current through each of said samples and measuring the relative conductivity thereof.

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