Aug. 7, 1951 W. M. STRATFORD 2,562,962

PROSPECTING

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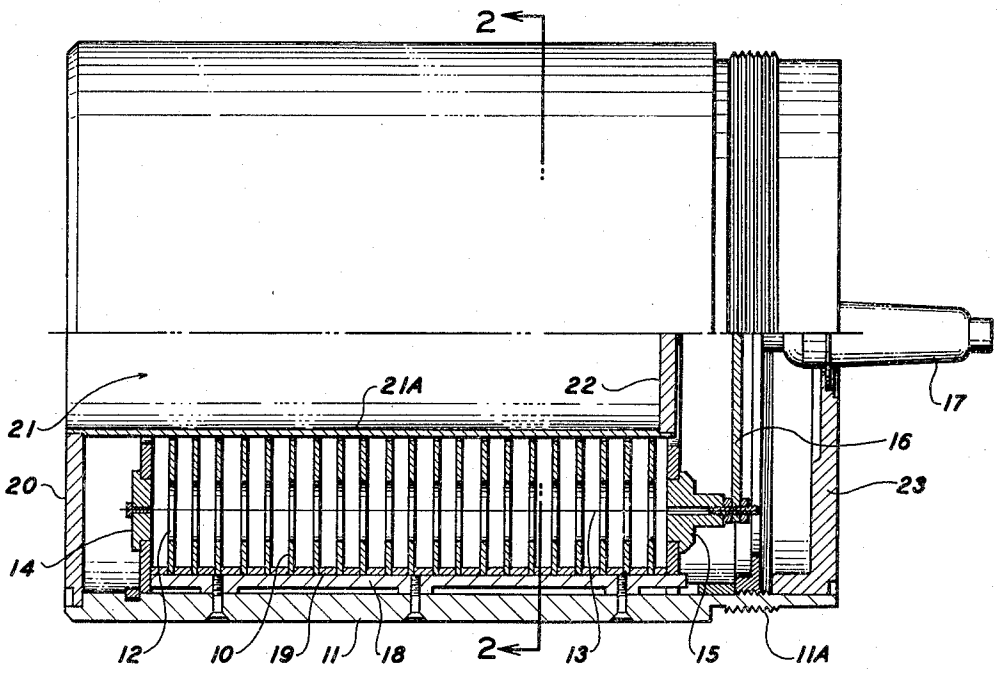


FIG. 1.

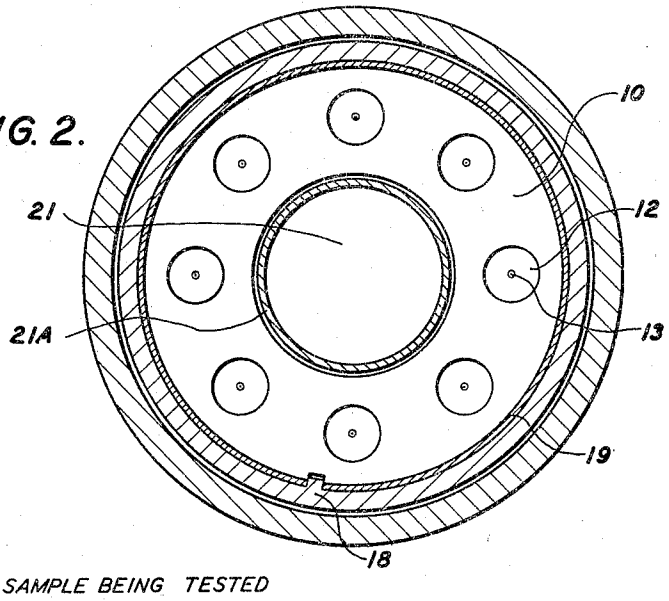
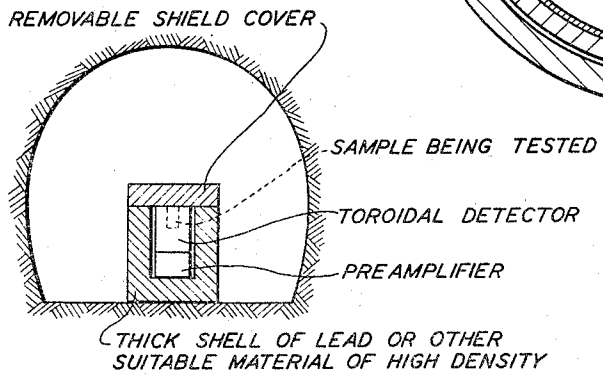


FIG. 2.

FIG. 3.



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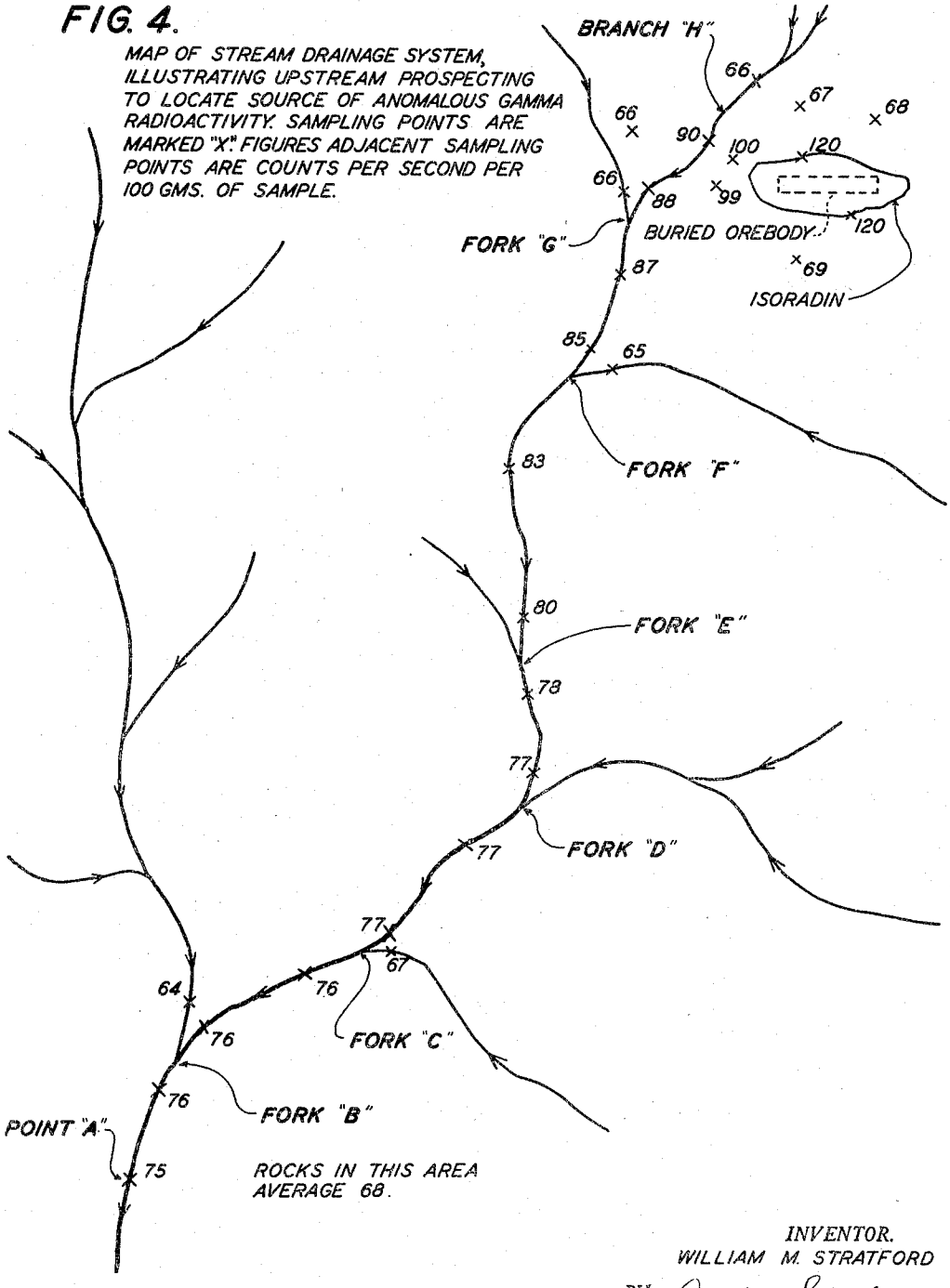
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FIG. 4.

MAP OF STREAM DRAINAGE SYSTEM, ILLUSTRATING UPSTREAM PROSPECTING TO LOCATE SOURCE OF ANOMALOUS GAMMA RADIOACTIVITY. SAMPLING POINTS ARE MARKED "X." FIGURES ADJACENT SAMPLING POINTS ARE COUNTS PER SECOND PER 100 GMS. OF SAMPLE.



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2,562,962

PROSPECTING

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Original application March 9, 1948, Serial No. 13,845. Divided and this application February 7, 1951, Serial No. 209,835

1 Claim. (Cl. 250—83.6)

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This invention is concerned with prospecting for mineral deposits, particularly those of metallic ores, and provides improvements which facilitate the location of such deposits. This application is a division of co-pending application Serial No. 13,845, filed jointly March 9, 1948, by Charles F. Teichmann, Gerhard Herzog and myself.

Mineral prospecting is as old as man's use of metals, but despite its antiquity and the successful application of geophysical methods in a few instances during recent years, it is still far more of an art than a science. Most of the large deposits of the base and precious metals owe their discovery to chance observation rather than to scientific surveys. Consumption of metals increases and ore reserves decrease, thus increasing the incentive for discovering new deposits.

Nevertheless, discovery has not kept pace with depletion, probably because the prospecting art has not kept pace with scientific development in other fields and is, in the majority of instances, inadequate for the location of ore bodies which do not disclose themselves through surface manifestations such as outcrops, gossan and the other ancient indicia employed by prospectors the world over. In a few special instances, such as pronounced magnetic, electrical or gravimetric anomalies, concealed ore bodies have been discovered by geophysical methods, but many ore bodies are not accompanied by such anomalies. Exploration by means of raises, cross cuts and other mine openings and by core or churn drilling is expensive and far from certain, for valuable ore bodies frequently are missed by a matter of a few feet. In short, there is a distinct need for improvements in ore finding. The instant invention supplies such need, at least in part.

As disclosed in co-pending application Serial No. 13,842, filed March 9, 1948, by Gerhard Herzog, it has been discovered that many ore bodies, which may or may not be radioactive themselves are accompanied by detectable radioactive auras in the substantially barren country rocks in which they occur. By carrying an efficient gamma ray detector along a traverse in the general neighborhood of a suspected mineral deposit and determining the intensities of gamma rays emitted by the ground at different locations along the traverse, anomalies in gamma ray intensities which indicate the presence and location of the ore body may be discovered. The gamma rays detected originate in the barren country rock and they may appear at distances far in excess of the range of penetration of significant amounts of radiation originating in the ore body

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itself. Gamma ray surveys conducted as described above, both underground and on the surface, have successfully located ore bodies through as much as two hundred feet of barren country rock, which constitutes a barrier capable of absorbing any detectable amounts of even the hardest gamma radiation.

It is disclosed in the parent application, Serial No. 13,845, filed March 9, 1948, that the auras described above are also detectable by another method, which is frequently more convenient, since it need not involve the movement of gamma ray detectors in the field to determine radiation intensities emanated from the undisturbed rock. It is stated in the parent application that gamma ray anomalies indicative of the presence of ore deposits may be discovered by taking rock or soil samples at a plurality of spaced points on or under the earth's surface, measuring accurately the intensity of the radiation (particularly gamma radiation) emitted by the individual samples and determining the intensity of radiation per unit mass (weight or volume) of the individual samples. These latter values are then related to the geometry of the survey, for example by plotting them at the respective points on a map representative of the area in which the samples are taken and drawing contours through points of equal intensity to form so-called "isoradins," or by plotting the values as ordinates with the traverse along which they were taken as abscissa. Anomalous zones of high or low gamma ray intensities may thus be revealed.

In general, weight represents sample mass more accurately than volume, but the latter may be used when dealing with samples of approximately the same specific gravity and screen analysis.

I have discovered that gamma ray anomalies indicative of an ore deposit lying within a stream drainage system may be discovered by determining the approximate average intensity of gamma rays per unit mass emitted by the rocks in the area of the drainage system, taking a first earth detritus sample at a starting point downstream in the drainage system and determining the intensity of gamma rays per unit mass of said detritus sample. Thereafter, the determined intensity of the detritus sample is compared with the average intensity determined for the rocks of the drainage system so as to find which intensity is higher. Earth detritus samples are taken from each branch of a fork in the drainage system upstream from the starting point to determine which of these upstream samples emits the higher intensity of gamma radiation per unit mass. The

prospecting is continued up the branch whose sample has the higher relative intensity of gamma radiation per unit mass when the intensity per unit mass of the detritus sample from the starting point is higher than the average intensity per unit mass of the rocks, but proceeds up the other branch when the intensity per unit mass of said detritus sample is lower than the average intensity per unit mass of the rocks.

Although theoretically any type of gamma radiation detector might be employed in the practice of the invention, provided that the observation time was sufficiently long to determine accurately the intensity of the gamma radiation emitted by each sample, practical considerations require the use of a detector of high efficiency for gamma rays—several times that of the conventional Geiger-Mueller counter. The samples are of necessity relatively small so that the source of radiation is minute. In many cases, small but significant differences in intensity cannot be detected at all with a Geiger-Mueller counter and other detectors of the same order of efficiency, no matter how long is the period of observation, because the variations in "background" which occur from one observation period to another are greater than the difference in intensity to be determined. Even when the difference in gamma ray intensity between samples is relatively large, required observation times for each sample with a Geiger-Mueller detector may be a matter of days and hence beyond all limits of practicality.

Fortunately, suitable gamma ray detectors which permit accurate determination of the difference of gamma ray intensities between small samples have been developed. One such detector is described and claimed in U. S. Patent No. 2,397,071, granted March 19, 1946. An even more desirable detector is that described and claimed in U. S. Patent No. 2,397,072. Both of these detectors are of the multiple plate cathode type and consist essentially of a stack of perforated disks disposed coaxially and spaced parallel to each other, with one or more anode wires running through the perforations transverse to the disk surfaces. The large cathode area per unit of active volume thus obtained increases the efficiency for gamma rays several times, without increasing efficiency for the detection of "background" proportionately. Thus counters of this type have a gamma ray counting efficiency of 2.5% or more as compared with an efficiency of about ½% for the conventional Geiger-Mueller counter.

All known detectors capable of detecting gamma radiation are also capable of detecting other radiation, including alpha and beta rays and cosmic radiation. This other radiation thus detected constitutes the "background" against which the gamma radiation intensity must be measured. Alpha and beta rays have low penetrating power and the entry of these rays into the counter from outside sources may be prevented by appropriate shielding. However, alpha and beta rays originating in the detector itself due to slight contamination of the materials of which the counter is made cannot be eliminated and contribute to the background. Cosmic rays also contribute to the background. Their gamma ray components may be prevented from contributing substantially to the background by adequate shielding, say several inches of lead or other high density metal, but the so-called "penetrating particles" of cosmic radiation are many times more penetrating than gamma rays and cannot be stopped with practical amounts of shielding, as witness their occurrence several thousand feet underground. In short, it is possible to decrease, but not eliminate background by shielding.

The radiation which constitutes the background is emitted sporadically and at random. In the practice of the invention it is desirable to reduce the background as much as practicable in order to reduce error arising from this fluctuation as well as to increase contrast between measured intensities. The approach to uniformity of background is also furthered by selecting a place where the background is naturally low and conducting comparative tests while the detector remains at that place protected by a constant amount of shielding. Thus, during a given survey, the detector should be kept at a point to which the samples are brought and should be protected on top, bottom and sides by adequate shielding, say several inches of lead. If the survey is being conducted in a mining district, an underground location in rock of low radioactivity and selected for its low background is desirable, since in this way the effect of cosmic rays may be reduced.

The background should be checked frequently by observing the activity of the detector with no sample present, since it is necessary to subtract the background value from the total observed radiation in order to determine which part is due to the sample.

Since gamma ray detectors in general do not detect with anything approaching 100% efficiency, the measurements of gamma rays which are made in the practice of the invention are comparative rather than absolute, but this presents no obstacle if detection efficiencies are substantially uniform from sample to sample.

These and other aspects of the invention will be clearly understood in the light of the following detailed description of presently preferred practices, taken in conjunction with the accompanying drawings, in which:

Fig. 1 is an elevation, partly in section, of a preferred form of radiation detector for the practice of the invention;

Fig. 2 is a horizontal section taken through the apparatus of Fig. 1 along the line 2—2;

Fig. 3 is a diagram illustrating the shielding of the detector of Figs. 1 and 2; and

Fig. 4 is a map illustrating the systematic sampling of a drainage system undertaken to discover an upstream mineral deposit.

A toroidal or cup-shaped detector constructed in accordance with U. S. Patent No. 2,397,072, granted March 19, 1946, and particularly adapted to the practice of the instant invention is illustrated by Figs. 1 and 2. It comprises a spaced stack of annular silver cathode plates 10 disposed in an annular envelope 11 and electrically connected together in parallel. Conveniently, at least the outer wall of the envelope is metallic and the cathodes are electrically connected thereto. Each cathode plate has a series of symmetrically disposed holes 12, the holes in the several plates being in alignment to permit the passage through the plates of a plurality of tungsten anode wires 13. These wires are parallel to each other and perpendicular to the plates and are disposed respectively on the axes of the several rows of holes. The wires are stretched taut between insulators 14, 15 at their ends and are connected in parallel with each other to a common conductor 16 in plate form. A lead from this plate passes through an insulator bushing 17

and thence to a conventional counter circuit (not shown) including a D. C. high voltage supply, a pre-amplifier, an amplifier, a scaling circuit, and a recorder. Each cathode plate is provided with a notch to aid in alignment of the holes in the plates and a rib 18 fastened to the outside wall of the envelope passes through the several notches and prevents the plates from turning within the envelope. Spacers 19 are disposed between the plates immediately inside the envelope to hold them apart in fixed relationship with each other, say on $\frac{3}{16}$ inch centers.

The top of the annular envelope is closed by an annular plate 20 extending from the inside wall of the envelope to the outside wall. The inside wall 21A of the envelope defines the side of a deep cylindrical cup 21 in which a sample to be investigated is placed. The bottom of the cup is defined by a plate 22. The bottom of the detector as a whole is closed by a cylindrical plate 23 through which the bushing 17 passes. The outside wall of the envelope may be screwed onto a container holding a pre-amplifier (see Fig. 2).

The entire envelope is gas tight and is filled with a suitable atmosphere, say a mixture of alcohol and argon.

In operation, a high potential difference is established between the anodes and the cathodes, the potential difference being nearly, but not quite, high enough to cause a discharge to take place. If an ionizing ray passes into the detector, a discharge may take place with resultant current flow which produces a "count." The discharge ceases after a short period of time, after which the counter is again in condition to count ionizing rays.

The toroidal detector is particularly desirable for the practice of the invention since a ray originating in a sample placed in its cup is much more likely to enter the active volume of the detector and be detected than if the sample were placed outside the counter. In short, the sample is substantially surrounded by active detector volume and hence the registered intensity of its radiation tends to be increased.

In the practice of the invention it is important that the background be maintained as low as possible and be uniform from sample to sample in a given survey. In order to bring about this diminution in background and to maintain it uniform, a site should first be chosen at which the background is low. Rock tends to stop cosmic rays and reduce the intensity of background from this source. Accordingly, especially in surveys in known mining districts, it may be convenient to place the detector underground, for example, in an abandoned stope, drift or crosscut. In choosing the location, a preliminary survey should be made with a detector having a high efficiency for the gamma rays emanated from the ground. When an underground space, say a stope, is found in which the background intensity is at a minimum, the toroidal detector is set up as shown in Fig. 3. Thus the toroidal detector is mounted above the preamplifier and both are disposed in a lead shield having a thick bottom, thick walls, and a removable cover, likewise lead. Generally speaking, the thicker the lead the better, although a shield of two to six inches is sufficient. It is convenient to build the bottom and the walls of the shield with lead blocks of a weight which may be handled conveniently. As shown, the shield and the detector of Fig. 3 are disposed in a cave with a substantial thickness of rock, preferably several hundred feet, above the detector in order to reduce the effect of cosmic radiation as much as possible.

Individual samples, obtained in a manner hereinafter described, are kept separate and each is crushed to approximately the same maximum size and size distribution. Crushing to minus 10 mesh is desirable and even finer crushing may give better results. After the samples have been crushed a representative portion of each is placed in the counter. A thin walled glass test tube may be employed to hold the sample and the test tube dropped into the cup of the toroidal detector.

Samples of 100 grams have been used with good results, although generally speaking, the bigger the sample the better. In any case, each sample tested in the detector should have approximately the same mass. Conveniently, the same volume of sample is taken each time and the weight of each sample is taken.

In carrying out the measurements of gamma radiation intensity in accordance with the invention, it is essential to know the background count. Consequently, with the detector empty the background is measured to discover its intensity, which varies sporadically within limits and may also vary with the time of day. This latter variation is known as the diurnal variation and should be determined by taking measurements of the background intensity at intervals during the day. The background count should be checked frequently, at least once a day.

After the background has been established, each sample in turn is placed in the detector and left there until a fixed number of counts has been recorded, the time for this standard count being accurately determined in each case. When using a detector equipped with a scale of 16 scaler circuit, good results are obtained by taking 3200 counts for each sample. The procedure of taking a constant number of counts eliminates variations in statistical error. The appropriate background count for the duration of the observation and for the particular time of day is then subtracted in each case. This background, as already indicated, varies with the time of day. The corrected count, i. e. the total count minus the background is now divided by the observation time to give a value for gamma ray intensity, i. e. counts per unit time. This result is in turn divided by the weight or volume of the sample, preferably the weight, to give a figure for intensity per unit mass.

Fig. 4 illustrates systematic sampling of a drainage system proceeding upstream to locate sources of anomalous gamma ray intensities found in the sands of a stream bed or in suspended solids carried by the stream some distance below a buried ore body. In the process illustrated by Fig. 4, sampling is begun at a point A down stream in the drainage basin. The rocks in this basin show an average gamma ray intensity of 68 counts per minute per 100 gms. At the first sample point downstream the sample gives an intensity of 75 per minute per 100 gms. Proceeding upstream a value of 76 is noted. Since both of these are above the average for the rock in the area, there is an indication that material of higher gamma ray intensity has been carried into the stream from above, possibly by erosion of the radioactive aura from an ore body which is itself not yet exposed by erosion. When the first fork B in the stream is attained, samples are taken on both branches. The intensity of the sample in the left hand branch is low, indicating that the material of high gamma

intensity is transported by the right hand branch in which an intensity ratio of 76 is noted. Consequently the right hand branch is followed. At the next fork C a similar difference in intensity ratios is noted from the samples of the respective branches and that giving the highest intensity is followed, this procedure continuing upstream toward the head waters past forks D, E, F and G. Finally, as the selected branch H is followed upstream an intensity of 90 counts per minute per 100 gms. is noted, but further progress upstream gives lower intensities indicating that the material of high intensity is being washed into the stream below these points of low intensity. The stream bed is now left and samples are taken uphill along the course that float from an out-cropping radioactive aura would necessarily take. Eventually, an area is reached in which a closed isoradin of say 120 counts per minute per 100 gms. can be plotted, with lower intensities away from this isoradin and higher intensities within it. This is a positive anomaly which may be indicative of an ore body under the surface in the neighborhood of the closed isoradin. The positive anomaly sought having been discovered, a detailed examination similar to that illustrated in Fig. 6 of the co-pending application Serial No. 13,845, filed March 9, 1948, can be carried out, this to be followed by drilling or sinking if the results seem to justify such a step.

In the investigation of a drainage system, the location of both positive anomalies and negative anomalies may be sought by sampling upstream. If a downstream sample shows a low intensity of gamma rays per unit mass as compared with the average intensity per unit mass of gamma rays emitted by the rocks of the drainage basin, the procedure is the same as that described in the case of Fig. 4, except that the direction of low intensity, as indicated by successive sampling at forks, is pursued upstream.

The treatment of wet samples obtained in prospecting with the method of the invention, for example, along a stream course, may be conducted in various ways. The simplest fashion is to take samples of the sand in the stream bottom or a sample of the water itself bearing suspended solids. These samples are then evaporated to dryness and the procedure thereafter is as described for solid rock samples, except that usually no crushing is necessary. In evaporation of the samples to dryness, however, sources of alpha radiation usually are lost, so that if the determination of alpha radiation intensity is important the radioactive gases (say radon, actonon or thoron contained in the wet samples) should be extracted by vacuum and subjected to detection prior to drying the sample.

In desert areas or on steep terrain on which water flow is irregular, deposits may be traced

to their source through the practice of the invention by conducting a sampling program uphill along the course of the float from an outcrop of a radioactive anomaly in the country rock.

Percolating ground waters may also carry dissolved or suspended radioactive material from a mineral deposit or from its aura and it is within the contemplation of the invention to sample the ground water of an area being prospected by laying out a grid in the area and sampling the ground water systematically in bore holes at the grid intersections or at other known locations.

I claim:

In prospecting a stream drainage system to locate therein a gamma ray anomaly associated with a mineral deposit to be found, the improvement which comprises determining the approximate average intensity of gamma rays per unit mass emitted by the rocks in the area of the drainage system, taking a first earth detritus sample at a starting point downstream in the drainage system and determining the intensity of gamma rays per unit mass of said detritus sample, comparing the determined intensity of said detritus sample with the average intensity determined for the rocks of the drainage system so as to find which intensity is higher, taking earth detritus samples from each branch of a fork in the drainage system upstream from the starting point and determining which of these upstream samples emits the higher intensity of gamma radiation per unit mass, proceeding up the branch whose sample has the higher relative intensity per unit mass when the intensity per unit mass of the detritus sample from the starting point is higher than the average intensity per unit mass of the rocks, but proceeding up the other branch when the intensity per unit mass of said detritus sample is lower than the average intensity per unit mass of the rocks.

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