Aug. 7, 1951 W. M. STRATFORD ET AL 2,562,961

PROSPECTING

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FIG. 1.

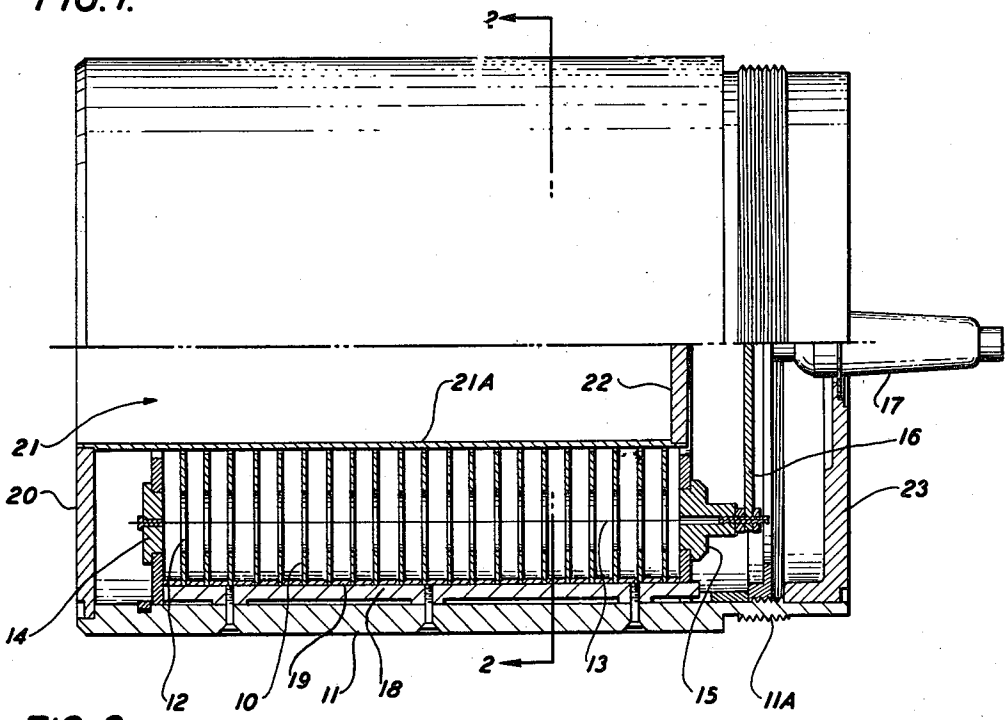
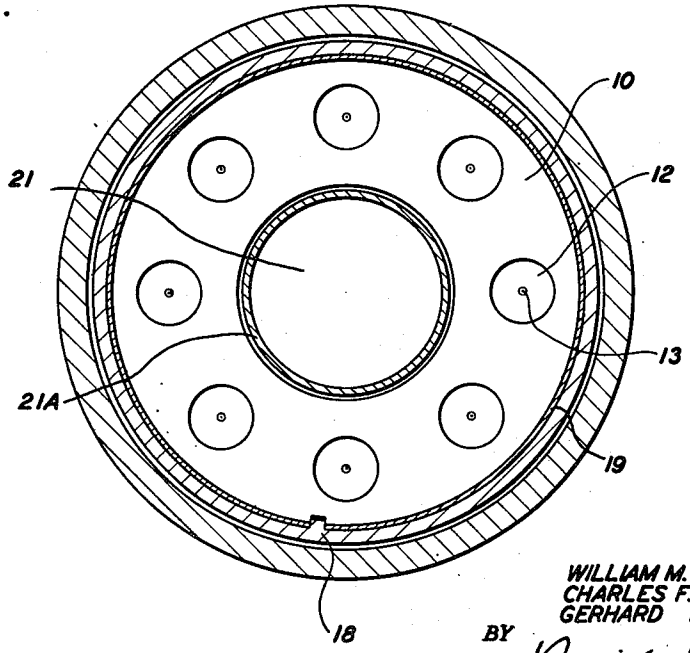


FIG. 2.



INVENTORS.
WILLIAM M. STRATFORD
CHARLES F. TEICHMANN
GERHARD HERZOG

BY Daniel Strykes

ATTORNEY

Aug. 7, 1951 W. M. STRATFORD ET AL 2,562,961

PROSPECTING

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FIG. 3.

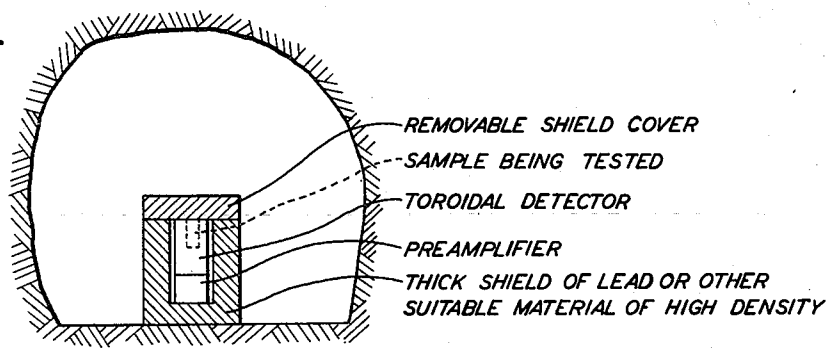


FIG. 4.

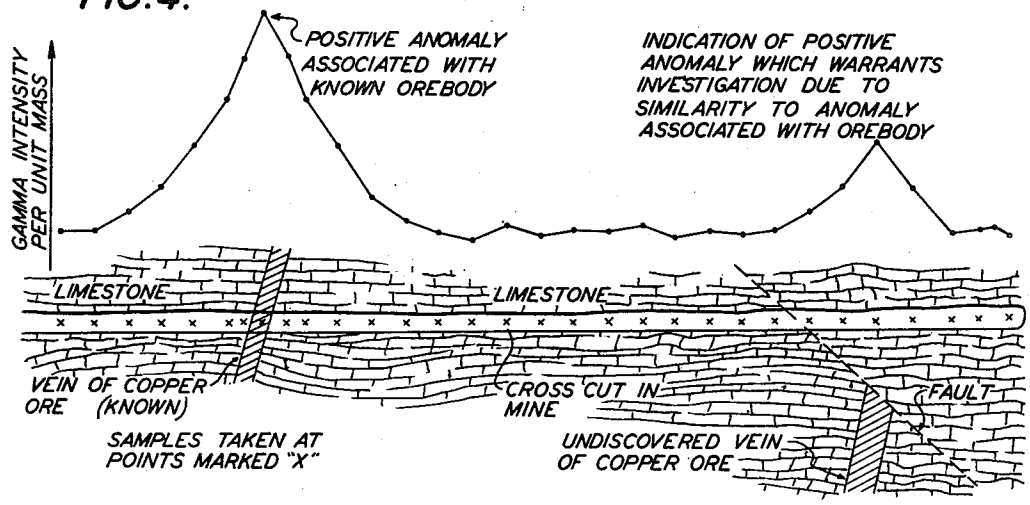
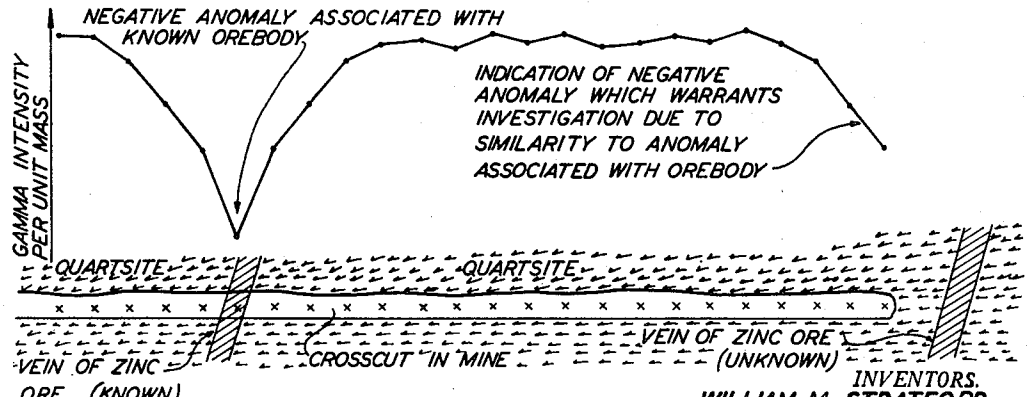


FIG. 5.



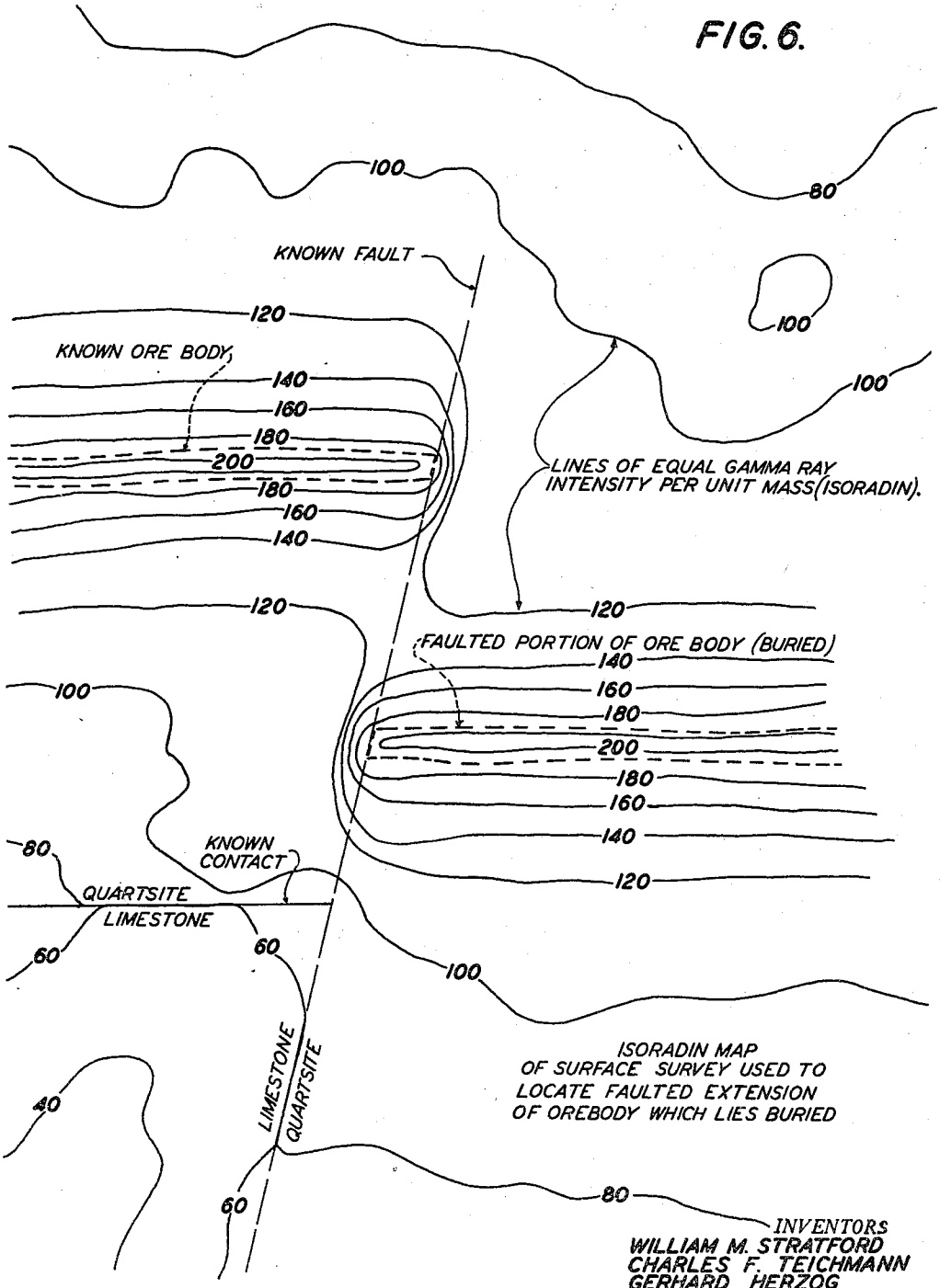
INVENTORS.
WILLIAM M. STRATFORD
CHARLES F. TEICHMANN
GERHARD HERZOG
BY Daniel Strykea
ATTORNEY

Aug. 7, 1951 W. M. STRATFORD ET AL 2,562,961

PROSPECTING

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FIG. 6.



ISORADIN MAP OF SURFACE SURVEY USED TO LOCATE FAULTED EXTENSION OF OREBODY WHICH LIES BURIED

INVENTORS
WILLIAM M. STRATFORD
CHARLES F. TEICHMANN
GERHARD HERZOG
BY
Daniel Stryker
ATTORNEY

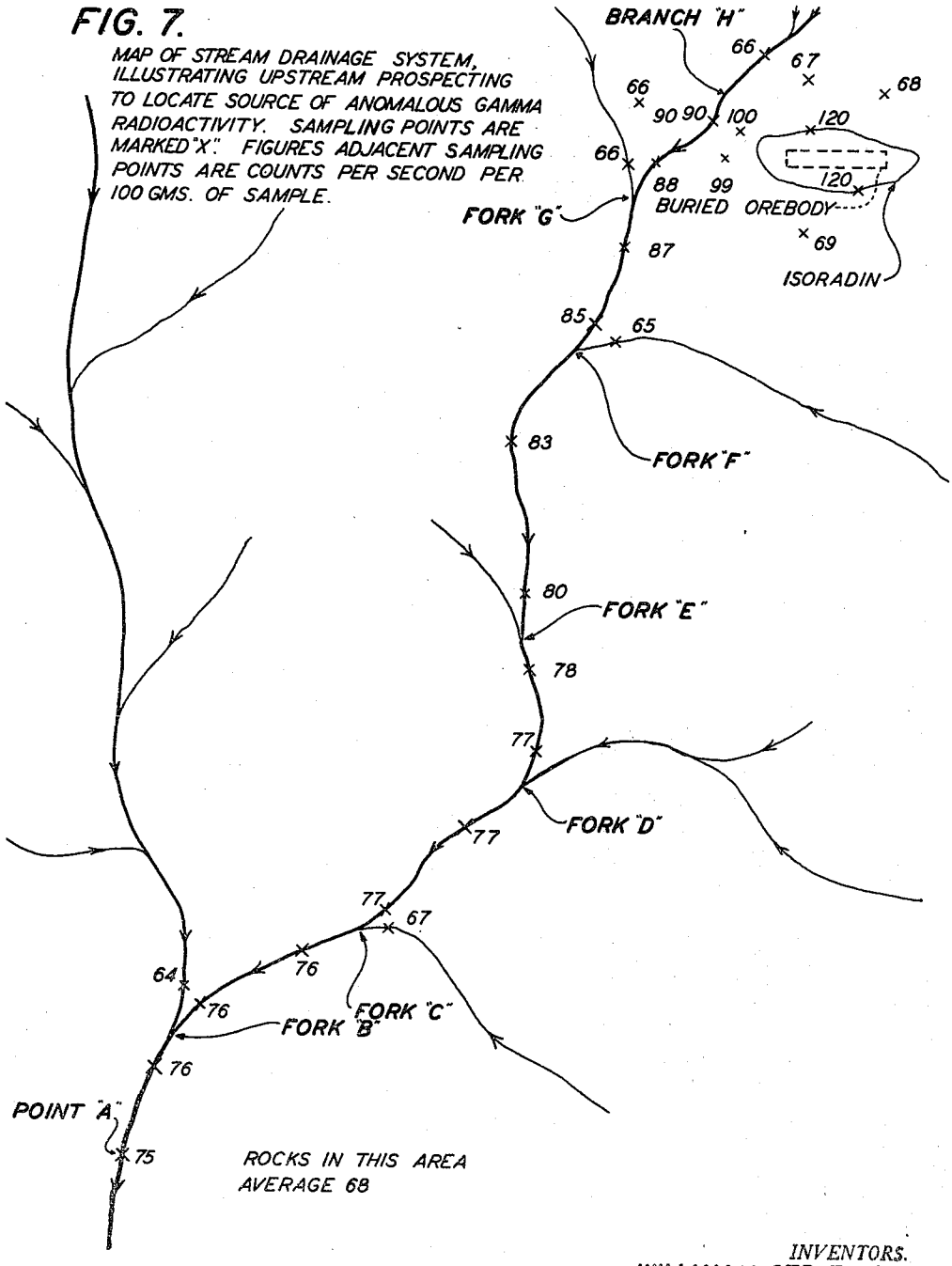
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PROSPECTING

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FIG. 7.

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.



INVENTORS.
WILLIAM M. STRATFORD
CHARLES F. TEICHMANN
GERHARD HERZOG
BY
Daniel Stryker
ATTORNEY

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2,562,961

UNITED STATES PATENT OFFICE

2,562,961

PROSPECTING

William M. Stratford, New York, and Charles F. Teichmann, Mount Vernon, N. Y., and Gerhard Herzog, Houston, Tex., assignors to The Texas Company, New York, N. Y., a corporation of Delaware

Application March 9, 1948, Serial No. 13,845

2 Claims. (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.

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 itself. Gamma ray surveys conducted as described above, both underground and on the surface, have successfully located ore bodies through as much as

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two hundred feet of barren country rock, which constitutes a barrier capable of absorbing any detectable amounts of even the hardest gamma radiation.

We have determined 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. Thus we have determined 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.

The invention may be applied by sampling rock in place or through the investigation of "float" samples. Thus detritus eroded from the deposit or its aura and transported substantial distances frequently marks a trail which can be followed to its source, as described in detail hereinafter.

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 oc-

cur 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.

By examination of known mineral deposits in a given district in accordance with the invention, it may be determined that a particular type of occurrence in that district, say a copper-lead vein in granite, is accompanied by a particular type of anomaly, say a positive one manifested by country rock in the neighborhood of the vein. Once this fact is established, possibly by surveys conducted across a number of such known deposits that are cut by mine workings or which outcrop, prospecting proceeds in accordance with the invention, either underground or at the surface, in an attempt to locate similar anomalies which are not accompanied by an exposed ore body but may be indicative of a buried one.

In one aspect of the invention the ratio of intensity of radiation to unit mass may be supplanted by another ratio, namely that of the intensity of one kind of radiation to the intensity of another kind of radiation, both being emitted by the sample. Thus, the ratio of the intensity of alpha or beta radiation to gamma or to each other may be determined, and these ratios employed in much the same way as the ratio of gamma ray intensity to unit mass, this latter term being employed throughout to mean both unit weight and unit volume.

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.

The intensity of the samples is of a low order, and in the case of the gamma radiation the efficiency of detection is with practicable detectors substantially less than the efficiency for other types of radiation, say the penetrating portion of cosmic radiation. The gamma radiation is emitted in all directions from the samples. In a preferred practice of the invention, the majority of the gamma rays emitted by each sample are caused to enter the active volume of a gamma ray detector, for example, by employing a detector having an active volume of annular cross section, the sample being disposed within the annulus.

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;

Fig. 4 is a diagram illustrating a positive anomaly (indicative of the existence of an unknown vein) such as may be determined by an underground survey in accordance with the invention;

Fig. 5 is a diagram similar to Fig. 4 except that it illustrates the discovery of an unknown ore

body or mineral deposit through the detection of a negative anomaly;

Fig. 6 is an isoradin map illustrating a surface survey such as may be carried on to discover the extension of a known faulted ore body; and

Fig. 7 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 is threaded in its lower portion 11A so that 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.

To consider a typical underground survey conducted in accordance with the invention, say along a cross cut which is suspected of being near an ore body, representative samples are taken at spaced intervals, say 20 feet, from the rock along one side of the cross cut. These samples should be sufficiently large to be representative. Samples of a kilogram or more are recommended.

The individual samples 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, prefably the weight, to give a figure for intensity per unit mass. The values thus determined are plotted along a longitudinal section of the cross cut along which the survey is made.

Fig. 4 illustrates such a survey along a cross cut in limestone. A known vein of copper ore is cut by the cross cut and it is suspected that another similar vein has been faulted off so that it is not penetrated by the cross cut. A survey along the cross cut is made by taking samples at spaced points as shown. Each of these samples is then treated as described above to determine the intensity per unit mass of gamma rays emitted by the sample and the values thus determined are plotted as shown. The known vein of copper ore is associated with a strong positive anomaly. This anomaly is apparent in the country rock on both sides of the known vein and as the vein is approached from either side, the intensity of gamma rays increases. In the unaltered limestone well removed from the vein, the intensity is relatively low.

On the right side of the plot of gamma ray intensity along the cross cut there is another positive anomaly less marked than that associated with the known vein, but still sufficiently strong to warrant investigation, say by cross cutting or drilling. In other words, this positive anomaly may indicate the presence of a hitherto unknown ore body. Since valuable ore bodies frequently are missed by a matter of a few feet, this clue to location of such an ore body is important.

Anomalies detected in accordance with the instant invention may be either positive or negative. Negative anomalies are sometimes associated with zinc sulphide ore bodies in quartzite and a survey for the detection of such a negative anomaly is illustrated in Fig. 5. In this case a known vein of zinc ore which manifests a negative anomaly is crossed by a cut in a country rock of quartzite. The presence of this negative anomaly associated with a vein of known zinc ore is detected by taking samples along the cross cut at spaced intervals as shown and the survey is continued to the face of the cross cut shown at the right. The intensities of the unaltered quartzite samples are relatively high, but as the unknown vein is approached these intensities decrease, reaching a minimum in the neighborhood of the vein itself. This indicates that the cross cut should be extended, and that a mineralized zone possibly is being approached.

Surveys similar to those of Figs. 4 and 5 may be made by examining a series of core samples from known locations in a bore hole, even those of such small size that logging by passing a radiation detector along the bore would be impractical.

A surface survey to determine the extension of a known ore body which has been lost through faulting is illustrated in the map of Fig. 6. The known ore body is indicated on the upper left. This ore body does not outcrop and ends at a fault. It has been mined out.

The country rock for the most part is quartzite, but contacts with limestone occur in the lower left hand corner, where a fault and a contact meet.

There is reason to believe that there is an extension of the known ore body in the general neighborhood. In an effort to discover this extension, the survey is made by taking rock samples at spaced known locations on the surface of the ground in the general vicinity. These samples are treated as in the case of the underground surveys and the gamma ray intensities per unit mass for each sample are plotted on the map at points corresponding to those from which the samples came. After these intensities have been plotted on the map, lines of equal intensity (which we call "isoradins") are plotted on the map as shown. The isoradins above the known ore body disclose a positive anomaly and form a recognizable pattern. A similar isoradin pattern occurs below and to the right of the known ore body in Fig. 6, thus indicating the position of the faulted portion or extension of the ore body.

The isoradins cross the fault in the quartzite in a smooth fashion, but at the contact between the limestone and the quartzite, the isoradins are interrupted and show the lines along which these dissimilar rocks meet.

Fig. 7 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. 7, 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 outcropping 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 can be carried out, this to be followed by drilling or sinking if the results seem to justify such a step.

The method of the invention is adapted to the reconnaissance of large areas, by taking samples of rocks from the surface at random known points or at the intersections of a grid laid out over the area. In this fashion areas of anomalous low or anomalous high gamma ray intensities which warrant further investigation may be discovered. For example, it may be that a routine sample taken from a stream bottom in such large scale reconnaissance may be much higher in intensity than the general run of samples from the area. If such a situation is discovered, it is desirable to carry on a survey such as that illustrated in Fig. 7 proceeding upstream with a view toward determining the site from which the high intensity rock is being eroded.

In the application of the invention to 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 intensiity 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. 7, except that the direction of low intensity, as indicated by successive sampling at forks, is pursued upstream.

Samples taken in the practice of the instant invention may emit alpha and beta rays in addition to gamma rays. In some instances, the ratios between alpha, beta and gamma intensities emitted may be significant and the invention contemplates the determination of one or more of these for a series of samples.

Alpha rays have very little penetrating power; beta rays have higher penetrating power, but not nearly the penetrating power of gamma rays. This difference in penetrating power of the rays may be employed to determine the significant ratios of intensities. By way of example, the inside wall of the envelope detector of Figs. 1 and 2 may be made very thin so as to be "transparent" to alpha radiation. Such thin walls or windows require that the pressure of the gas within the envelope be approximately the same as the pressure of the gas outside the envelope, or that the window be reinforced.

Relative intensities of alpha rays emitted by samples are found by placing the sample directly in the cup of the thin walled detector and determining the count as described previously. Thereafter a shield which cuts out alpha rays but is transparent to beta and gamma rays is placed in the cup conveniently by placing the sample in a container (such as a glass test tube) having a wall of such thickness that it will stop alpha rays but will permit beta and gamma rays to enter the counter. The count is determined under these conditions. Lastly, the sample is transferred to a second container which has a wall so thick that it effectively stops alpha and beta radiation while permitting the gamma ray radiation to enter the counter. A count is obtained with the sample in the counter under these conditions. The background is subtracted from each of the three counts described above. Alpha intensity is determined by subtracting the second count from the first. Beta intensity is determined by subtracting the third count from the second. The third count minus background gives the gamma intensity.

In summary, the process is conducted in three stages. In the first stage the counter is made transparent to alpha, beta and gamma rays. In the second stage, wall thickness is increased to eliminate alpha while permitting beta and gamma to enter. In the third stage the wall is transparent only to gamma.

An alternative method for determining alpha intensity involves the investigation of radioactive gases (i. e. radon, actinon or thoron) emitted by the samples. To determine the intensity of alpha rays emitted, for example by radon, the rock sample obtained in the exploration is crushed under vacuum and gas is extracted from the sample. This gas may be flushed directly into the detector itself, for example, by a stream of the gas filling (say argon and alcohol). In this way the alpha rays are emitted within the envelope and the problem of penetration is effectively solved. As in the previous cases alpha intensity is determined in terms of unit mass.

After the radon has been extracted from the sample, the latter is subjected to further tests in the toroidal detector employing first a wall which is transparent to beta and gamma, thereafter a wall which is transparent only to gamma.

In some cases, the pertinent ratio may be between alpha or beta and gamma and in other cases between alpha and beta. In all such cases the ratios of intensities per unit mass are determined and plotted in the same way as intensities in the operations illustrated in Figs. 4, 5, 6 and 7. In the case of a mapping operation, lines of equal ratios are drawn in the same fashion as the isoradins, to aid in interpretation of results. In the case of a traverse, say along a mine working, the ratios are plotted as ordinates along the traverse as in Figs. 4 and 5.

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, actinon 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 raiodactive 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 lay-

ing out a grid in the area and sampling the ground water systematically in bore holes at the grid intersection or at other known locations.

Aeolian mineral concentrations such as may be formed in desert areas by the action of wind alone or with the aid of water may also be revealed through the practice of the invention by taking samples in the surface over the area and plotting the corresponding intensities per unit mass or the ratios of such intensities per unit mass on a map.

We claim:

1. In exploration for mineral deposits involving the taking of earth samples at a series of known points, the improvement which comprises conducting a preliminary survey by determining the intensity of background radiation at a plurality of locations and selecting that location at which the background intensity is the lowest and detecting the comparative intensities of gamma rays emitted by each sample by determining the respective sample masses and at the selected location detecting the intensity of gamma radiation emitted by each sample together with the intensity of the background radiation, and subtracting the separately-determined background radiation from the intensity measurements made for the respective samples.

2. Process according to claim 1 in which the intensity for each sample is determined while the sample is substantially surrounded by counter volume.

WILLIAM M. STRATFORD.
CHARLES F. TEICHMANN.
GERHARD HERZOG.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,330,829	Lundberg	Oct. 5, 1943
2,340,967	Langer	Feb. 8, 1944
2,397,072	Hare	Mar. 19, 1946

OTHER REFERENCES

Heiland: Geophysical Exploration, Prentice Hall, Oct. 1940, pp. 870–875.

Evans et al.: Review of Scientific Instruments, vol. 10, Nov. 1939, pp. 332–336.

Locher and Weatherwax: Radiology, vol. 27, 1936, pp. 149–157.