RADIOMETER-ANALYZER FOR FIELD USE

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In carrying out geological surveys at radioactive-ore sites it is extremely desirable to be able to assay the radioactive ores directly at the deposit.

In a number of papers [1] - [3] it has been shown that the nature of the energy spectra of γ-radiation from radioactive elements of the uranium and thorium series makes it possible to carry out such a determination.

According to the theory given in Ref. [3] the equation for γ-rays emitted by a rock which contains elements of the radioactive families of uranium and thorium is of the form:

\[ N^\gamma = aR_{Ra} + bR_{Th} \]

for the total γ-ray spectra and

\[ N^\gamma = ax_{Ra}R_{Ra} + bx_{Th}R_{Th} \]

for γ-rays with energies above a given value, where \( a \) and \( b \) are constants which characterize the rock and the instrument, \( R_{Ra} \) and \( R_{Th} \) are the radium and thorium content of the rock, \( N^\gamma \) is the counting rate for all γ-quanta, \( N^\gamma \) is the counting rate for γ-rays with energies higher than a given value, and \( x = N^\gamma / N^\gamma \).

It follows from these equations that

\[
\begin{align*}
R_{Ra} &= \frac{N^\gamma - N^\gamma x_{Th} - N^\gamma x_{Ra}}{a(x_{Th} - x_{Ra})} \quad (1) \\
R_{Th} &= \frac{N^\gamma - N^\gamma x_{Ra}}{b(x_{Th} - x_{Ra})} 
\end{align*}
\]

The relative thorium and uranium content of radioactive ores can be characterized by the quantity

\[ \gamma = \frac{R_{Th}}{R_{Ra} + R_{Th}} \quad (2) \]

where \( R_{Th} \) is the thorium content and \( R_{Ra} \) is the radium content, which is proportional to the uranium content at radioactive equilibrium between uranium and radium. Substituting Eq. (1) in Eq. (2) we obtain an expression for \( \gamma \) in terms of measurable quantities

\[ \gamma = \frac{x - x_{Ra}}{\frac{x}{a(x_{Th} - x)} + \frac{x}{x_{Ra}}} \quad (3) \]
where $k = N_\gamma/N_\alpha$ for a given deposit and the ratio $b/a$ is easily determined experimentally and remains constant in all measurements.

The considerations given above apply when radioactive equilibrium obtains between the thorium and uranium ores and when the relative spectral composition of the $\gamma$-radiation is independent of the matter in the rock.

As a rule thorium ores are in equilibrium under natural conditions. In a number of uranium ores equilibrium may not obtain; however, we shall assume that equilibrium does, in fact, exist.

It has been shown in Ref. [4] that the $\gamma$-radiation spectrum changes slightly in passage through a layer of matter. However, if the detection instrument is surrounded by a layer of material having a high atomic number (thickness 1-2 mm) which intercepts a large part of the $\gamma$-quanta with energies of approximately 200-300 kev the reading of the instrument is practically independent of the chemical composition and thickness of the material above the ore deposit and these effects can be neglected.

The detection and analysis of the spectral composition of $\gamma$-radiation can be realized by various methods; of these the most convenient for field use are the scintillation method and a method in which a threshold spectrometer, using a Geiger-Müller counter is used, as suggested by Bothe. The latter method has been used in the present work because it is more reliable and simpler.

In the instrument being described here the role of the fixed radiator of the Bothe scheme is played by the walls of the counters which make up the system. Using this disposition of the counters, all the secondary electrons (rather than only a small part incident in a rather narrow solid angle) produced by the counter and the fixed radiator are used. This is an advantage over the apparatus. The detection unit of the instrument is the system of Geiger-Müller counters, consisting of the one central counter which is surrounded by a ring of six counters. Coincidences between the central counter and the ring which surrounds it are detected. This system, equivalent to 6 Bothe systems, has high sensitivity and can be used, comparatively weak fields of $\gamma$-radiation. If, in addition, we record coincidences between any neighboring pairs of counters in the external ring, this system becomes the equivalent of twelve pairs of counters, connected in a Bothe system. A system of this kind has the maximum possible efficiency for detection of coincidences for a given number of counters.

Fig. 1. Schematic diagram of the instrument. The range switch is in the "Off" position; the toggle-switch $T_1$ is in the "Analyze" position; the toggle-switch $T_2$ is in the "Count Coincidences" position.