USE OF GAMMA-RAY SPECTROMETRY FOR IDENTIFYING WEAKLY MAGNETIC DIAMONDIFEROUS KIMBERLITES

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Diamondiferous kimberlites are the most important source of bedrock diamond deposits. The goal of the study is to analyze the use of gamma-ray spectrometry techniques to explore weakly magnetic diamondiferous kimberlites. The result of this research is the justification of prospects of using gamma-ray spectrometry to identify weakly magnetic diamondiferous kimberlites.

Exploration of diamondiferous kimberlites is highly relevant, because they are the main source of industrial diamonds. Their proportion is 90 % of the diamond reserves in bedrock deposits. More than 1500 kimberlite bodies are known today, 8–10 % of which are diamondiferous rocks. Some kimberlite fields of Yakutian and Arkhangelsk diamondiferous provinces (Mirny, Nakyn, Zolotitsa) have minimum values of magnetization intensity. Use the magnetic method to explore weakly magnetic diamondiferous kimberlite pipes and fields has displayed low efficiency [5].

The goal of this research is to identify and analyze the relationships, possibilities and prospects of using gamma-ray spectrometry to identify weakly magnetic diamondiferous kimberlites.

Gamma-ray spectrometry methods are based on measuring the spectral composition of the natural gamma radiation of the mantle rocks, followed by identifying of the contents of natural radioactive elements such as uranium, thorium, and potassium in these formations. This method is adopted in land, airborne and laboratory versions. Gamma-ray spectrometry methods belong to geophysical methods in essence, methodology and observation techniques, but they also solve geochemical issue. The field methods have shallow depth of investigation due to the rapid absorption of gamma rays by air and rocks. They are widely used in lithological, tectonic plotting, as well as in explorations of non-radioactive minerals that are paragenetically or spatially linked with the natural radioactive elements [2]. Identifying radioactive elements by gamma spectrometry in the field is distinguished by unique mobility, rapidity, high sensitivity and accuracy in solving radiogeochemical issue. This method allows the use of statistical approach in radiogeochemical research, to regulate behavior of the field acquisition, observe and evaluate the dynamics of the radiogeochemical parameters of rocks, ores and minerals in their geological study, and produce reliable sampling to identify the three natural radioactive elements [3].

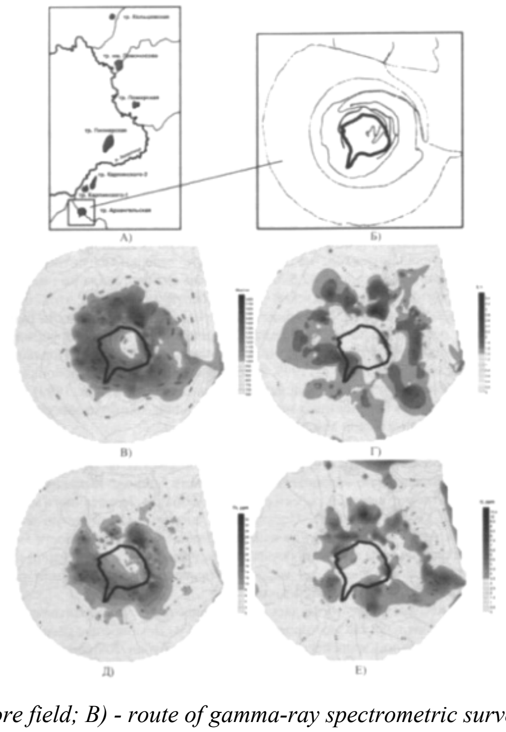
Metamorphism, metasomatism and hydrothermal processes cause changes in an enclosing rock, accompanied by a transformation of the structure of radiochemical fields, which causes the formation of anomalous concentrations of natural radioactive elements. The reason for this phenomenon are the different migration properties of uranium, thorium and potassium. These changes disrupt the equilibrium ratio of natural radioactive elements, followed by the formation of radiogeochemical zonation, which is equivalent to a specific conversion type and that creates the methodological basis of the gamma-ray spectrometry's application in radiogeochemistry.

Airborne gamma-ray spectrometry allows to determinine the concentration of radiogeochemical elements in rocks and ores with the required precision. The results of airborne gamma-ray spectrometry show its high efficiency in solving geological problems such as geological mapping, prospecting hydrothermal deposits (uranium, rare earths, non-ferrous and precious metals), and the research of the intensity and nature of occurrences (manifestations) of superimposed processes. These results allow obtaining high-quality information that is comparable with the scale-adjusted (corresponding scale) foot-borne surveys. According to the estimates, aerial survey of similar problems is 2.5-10 times cheaper than work on land [1]. The high sensitivity of the method can effectively detect Clarke content of natural radioactive elements in the upper layer of rocks. If there is even a slight differentiation of these elements, the method manages to dissect stratified bodies, detect and determine the heterogeneity of the structure of the intrusive assemblages (acid, alkali). The faulted zones, which were affected by metasomatic and hydrothermal transformations, have the disturbance of their equilibrium state of the natural radioactive elements. Gamma-ray spectrometry can determine reliably this faulted zone as the results of calculating above-background concentrations of the radioactive elements or their relationships. Airborne gamma-ray spectrometry is independent and as more effective in combination with other geophysical methods, and is applied widely for prospective assessment of ore-bearing and ore-controlling structures, for exploration of deposits of radioactive, rare, non-ferrous and precious metals [2].

The first practice of using airborne gamma-ray spectrometry to identify kimberlite pipes has demonstrated that many kimberlite pipes have elevated thorium concentrations and reduced concentrations of potassium in contrast to enclosing rocks. However, attempts to open these anomalies up by drilling were unsuccessful, and the method was rejected. However, the following surveys on reference fields and geological interpretations have found that the method did not identify the kimberlite bodies themselves, but their secondary geochemical halos. Radiogeochemical halos of the Mirny kimberlite field confirm this. Their radiogeochemical halos were almost equivalent to the maps of mineral distribution from kimberlites. The only difference is in the time: one season of the aerial survey against several decades of drilling and surface excavation.

It is known that the use of magnetometry helped to explore more than half of Yakutia's kimberlite pipes and most kimberlites of the Arkhangelsk region, but it also is known that magnetic measurements did not identify diatremes of the Nakyn field, which are the unique in their diamond content. The Internatsionalnaya pipe, richest in diamond content per ton in the Mirny field, has low level and small size of its local magnetic anomaly. If a substance-indicator module used in the exploratory method fails, effectiveness of magnetometry is largely determined by the work of four other modules used in the exploratory method (landscape and geological, technical and metrological, geological and interpretive, and certifying), which have lower efficiency in exploration of diamond kimberlites. There are also studies on the analysis of the quality and reliability of the magnetometric method, which identified a number of possible and actual situations where primary deposits of diamonds can be overlooked [4].

The geoscientists carried out a ground gamma-ray spectrometry survey in the area of the Arkhangelskaya pipe of the Zolotitsa field on the Arkhangelsk diamond province. The results of the survey were maps of the total intensity of gamma radiation (pulses/sec), potassium content (%), concentration of uranium and thorium (ppm), which show the specifics of the spatial location of radioactivity in the rocks (Fig. 1) [6].



A) – Layout of the Zolotitsa ore field; B) - route of gamma-ray spectrometric survey; B) - total intensity of gamma radiation (pulses/sec); D) - distribution of the potassium content (%); D) - thorium concentration (ppm); E) - uranium concentration (ppm)

Figure 1 – Layout of the studied area and distribution of radioactive elements in the rocks of Arkhangelsk pipe (according to Yakovlev E. Yu., 2015)

A contrast anomaly forms around the pipe contour in terms of total radioactivity (pulses/s), which extends to the crateral facies rocks and enclosing deposits, and exceed the background by an average of about 2 orders. The central part of the pipe has decreased values of gamma field.

Similarly, anomalies of thorium, uranium and potassium have high values around the pipe contour. Concentrations of uranium and thorium vary within an average of 3 to 10 ppm and 8 to 32 ppm at this area, respectively. Potassium content also tends to have high values. This indicates that the kimberlites, which are forming the diatreme of the Arkhangelsk pipe, are depleted in uranium and other radioactive elements. Furthermore, uranium isotopes activity ratio is equivalent to one, which indicates the absence of conditions here for the separation of isotopes and long-term stable state rock. At the same time, we can observe active fractionation processes of uranium isotopes in rocks of the annulus, the apparent deficit of 234U, accumulation of the other radioactive elements. This is due to the radiation exposure of uranium and its infiltration oxidation transportation and deposition near kimberlites, which have reducing properties [6].

These regularities and processes justify the possibility of using gamma-ray spectrometric surveys to assess the prospectivity of ore-bearing and ore-controlling structures, for the exploration of non-radioactive minerals that are paragenetically or spatially linked with natural radioactive elements, particularly for the exploration of weakly diamondiferous kimberlite pipes.

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