AIRBORNE GAMMA-RAY SPECTROMETRIC DATA ENHANCED BY IMAGE PROCESSING METHODS IN GOLD EXPLORATION IN THE KUUSAMO AREA, NORTHEASTERN FINLAND

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ABSTRACT

Digital image processing techniques have been applied to airborne gamma-ray spectrometric data in the Kuusamo area in northeastern Finland. The airborne gamma-ray data, when converted to digital images, can be treated as multispectral remote sensing data. In glaciated and poorly exposed terrain, as in this study, the ratios between different energy channels proved to be the best variables for characterizing uraniferous gold occurrences. The study of feature space formed by ratios shows a clear grouping among the occurrences. This grouping indicates that ratios can be used to classify gamma-anomalies in order to find new potential targets for gold exploration.

1. INTRODUCTION

Airborne gamma-ray spectrometry has been applied extensively since 1960 for geological mapping and mineral exploration. This method has often been ranked within the same category as remote sensing methods. Gamma rays are the only form of natural radioactive radiation that can be used in remote sensing. The main sources of gamma radiation in crustal rocks are potassium (K^{40}), uranium (U^{238}) and thorium (Th^{232}) isotopes. Each of these isotopes when decaying emits a range of radiation at discrete energy levels which can be measured using gamma-ray spectrometry. The multichannel and statistical nature of gamma radiation allows the effective use of digital image processing techniques in enhancing and analysing the data.

The concentration of gold in rocks is always too low to be detected directly by geophysical methods. Indirect geophysical indications may occur through the association between gold and a specific range of minerals and geological environments (Doyle 1990). Iron sulphides are the most common minerals associated with gold deposits and generate small but distinctive magnetic and electromagnetic anomalies. The association of radioactive minerals with gold deposits or their hostrocks, as in the Kuusamo district of northeastern Finland, is possible to recognize by gamma-ray spectrometry. Ore forming processes can also lead to the crystallization of minerals such as Ca and Mg carbonates, which may promote the grouth of distinctive or luxuriant vegetation near the deposit. This fertilizing effect may be discernible by airphotos or satellite images.

The association of gold mineralization with bedrock structures such as faults and shear zones is also common. Geophysical data as well as satellite and radar data have proven very useful in obtaining information about structures controlling the gold deposits. Image processing techniques have been valuable tools in visualizing these structures.

Studies based on image processing and visualizing the feature spaces of different kind of geophysical and other remote sensing data in gold exploration in the Kuusamo area have been carried out in 1990's (Kuosmanen et al. 1991, Laaksonen 1991, Arkimaa 1996, 1997).

2. THE STUDY AREA AND DATA

The bedrock of the study area in Kuusamo is mainly composed of early Proterozoic sedimentary and volcanic rocks. Exploration activity in recent years has been directed towards the gold potential of the area (Pankka et al. 1991).

Low-altitude airborne geophysical surveys have been flown by the Geological Survey of Finland since from year 1972 with an average terrain clearance of 30m and a line spacing of 200m. During these survey flights magnetic, electromagnetic and gamma-ray measurements are carried out simultaneously. Gamma radiation is measured in 120 channels within an energy range of 0.41-2.81 Mev. Recorded digital raw data are combined in four windows: K, U, Th and total count (Fig. 1). After corrections for background, altitude and scatter the recorded count values are converted to equivalent concentrations (ppm for U and Th, % for K and Ur for total count). Operative corrections are not always able to eradicate the background level differences in data between flight lines. Therefore in this study, median type filtering of the data was carried out. For image processing purposes grids with cell size of 50m*50m were interpolated (Fig. 2, p. 29).

Approximately 90% of the measured gamma radiation is from the upper 0.5m of the ground (Grasty 1976). The usefulness of the data is not, however, limited only to areas of extensive outcrop since the composition of overburden is strongly influenced by the composition of underlying bedrock. In glaciated area the use of gamma radiation is comparable to the use of geochemical data. By considering the transport distances for till due to ice movement, the bedrock source can be found. In Finland such transport distances, based on geochemical studies, are known generally to be of the order of a few hundred meters (Salminen 1993). The presence of overburden as well as the moisture content of soils both tend reduce the amplitude of the radioactivity of the underlying bedrock. These effects can, however, be minimized by using the ratios between different radioelements (Charbonneau et al. 1976).

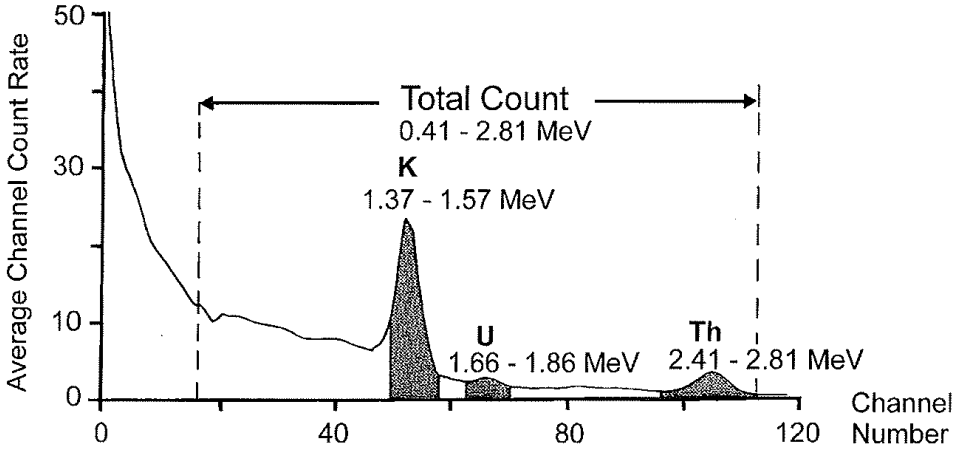

Fig. 1. Airborne gamma-ray spectrum recorded by the Geological Survey of Finland (modified after Grasty & Multala 1991).

3. METHODS AND RESULTS

3.1. Studies at the scale of lithostratigraphical units

During formation of the ore minerals hydrothermal solutions i.e. hot aqueous fluids permeate through and interact chemically with the host rocks, thus altering mineral compositions. Under certain temperature and pressure conditions U-bearing minerals are particularly susceptible to dissolution, and as a result U can be transported and redeposited separately from Th and K. One typical outcome of these hydrothermal processes is the enrichment of host rock alteration zones in K (Darnley & Ford 1987).

In the Kuusamo schist belt the ore-potential unit comprises the Sericite Quartzite Formation, Siltstone Formation and Greenstone Formations I and II. The main surrounding formations are Rukatunturi Quartzite Formation, Archean Granite Gneiss Complex and Greenstone Formation III (Silvennoinen 1972, Pankka et al. 1991). The ratios of eU, eTh and K characteristic of the ore-potential formations were studied using a triangular diagram and compared with the corresponding ratios for the surrounding formations. As the radioelement values are not constant over areas covered by water, these values as well as those measured over wetlands were rejected. In Figure 3 the ratios have been divided into two groups: a) those indicating all ore-potential formations and b) those indicating the surrounding formations.

The centres of the two distributions almost coincide but their spreading directions differ. The most distinctive enrichment of eU and eTh relative to other radioelements characterizes the distribution of the ore-potential formations compared to the surrounding formations. The effect of K-silicate alteration in the host rocks of the gold occurrences in the Kuusamo schist belt is not clear at this scale, and thus studies at a more detailed scale are needed if it is to be identified by a method such as this.

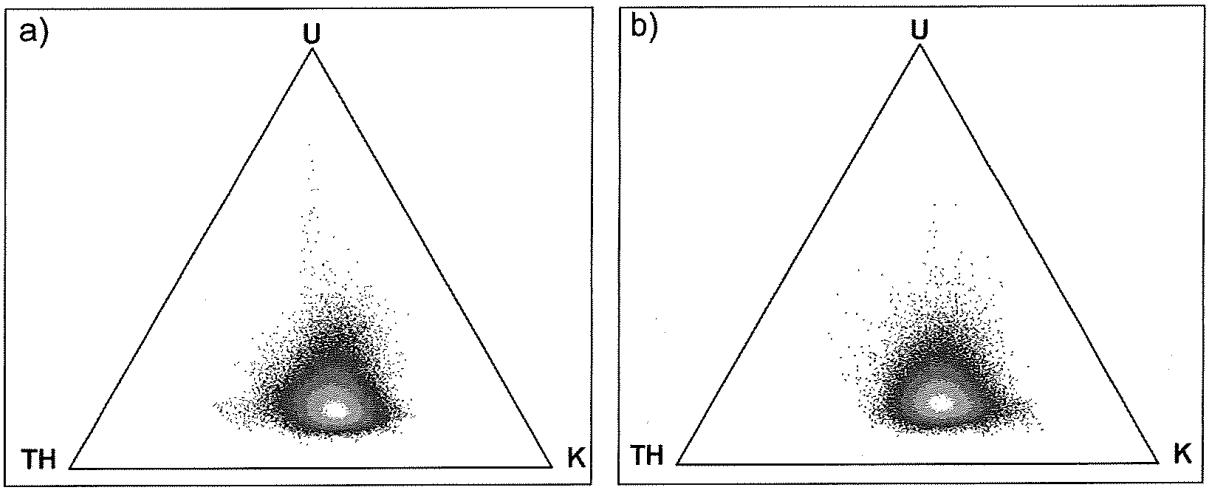

Fig. 3. The ratios of eU, eTh and K indicating a) ore-potential formations and b) non-potential formations. The number of ratios is densest at the centre of the distribution (black area).

3.2. Studies at the scale of individual occurrences

Due to the enrichment of the gold-bearing occurrences in the Kuusamo schist belt in uranium, the uranium anomalies around each occurrence were carefully studied. At sites where the overburden was less than 1 m thick the indicative uranium anomaly was directly above the occurrence. At sites where the soil cover was thicker there were no anomalies directly above the occurrences except at the largest gold deposit, Juomasuo. The main ice flow directions, also shown clearly by gamma-ray data (Fig. 2, p. 29), allows us to assume that the indicative radiometric anomalies are to be found in a direction somewhere between east and south. Within a radius of 250 m of each occurence, the nearest uranium anomaly in the direction of ice flow is considered to indicate the target. If no anomaly was found in that direction, the nearest one in any other direction was selected to indicate the target.

Closer study of the distribution of indicative ratios showed that they could be divided into two main groups. One group contained all the occurrences in which the indicative uranium anomaly lies directly above the occurrence or in a direction between east and south (red dots in Fig. 4, p. 29). The other group comprised all remaining occurrences, that is, those in which no uranium has been found or the overburden is about 10 m thick (green dots in Fig. 4, p. 29). At Juomasuo the sources of the radiometric anomalies are less distinct due to the thickness of the overburden, which, at 10m, may include long-distance material. On the other hand, the position of the dots in the diagram indicating the Juomasuo deposit may reflect also the influence of potassium alteration of the host rocks (yellow dots in Fig. 4, p. 29). The red dots furthest to the right in the diagram in Figure 4 correspond to the Isoaho occurence, where uranium enrichment in the occurence and potassium alteration in the host rocks are known from field studies.

4. Discussion

The enrichment of uranium together with gold in the Kuusamo schist belt makes the use of gamma-ray spectrometric data feasible in exploration. The abundance of sulphides in breccia-type gold occurrences is not always sufficient to be detected by magnetic and electromagnetic methods. Fingerprints are therefore worth seeking in gamma-ray data. Visualized ratio feature space for eU, eTh and K show that ratios can be used to classify gamma-anomalies in order to find potential targets for gold exploration. Statistical classification methods are an effective technique in delineating these potential targets. The gold occurences in the Kuusamo schist belt appear to be controlled by faults. Although detailed features of the airborne gamma-ray data are largely masked by glacial geology, some structural information can be extracted by enhanced images including relief shaded maps or by integrating gamma-ray data with other datasets such as elevation or magnetic data.

Airborne gamma-ray data are affected by many factors, e.g. the distribution of radioactive elements in lithostratigraphical formations, the mineralizing processes modifying these formations, glacial and, in general, surficial geological processes, and the water content of the overburden. Thorough knowledge of this information is necessary if we are to understand the role of these factors. The present type of study, in which not only the absolute abundances but also the ratios of the radioelements are considered, contributes to our understanding of some of the factors.

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Fig. 2. Location of Kuusamo area and additive colour composite image of the airborne gamma-ray data covering the study area (eU=red, eTh=green, K=blue). (After Arkimaa 1997).

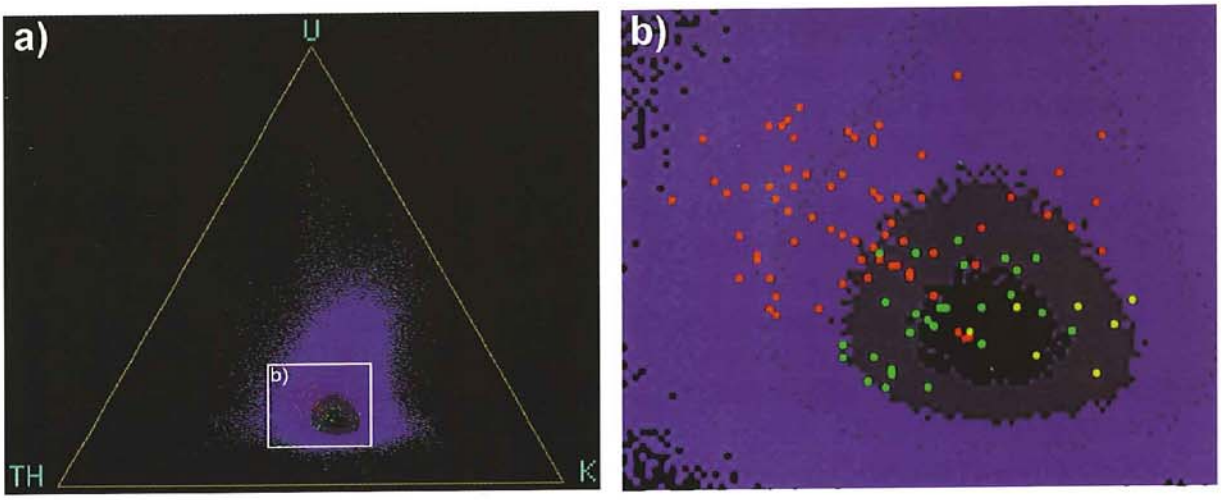

Fig. 4. The ratios from all gamma-ray data (blue dots), and the two main groups of the ratios indicating the known gold occurrences (red and green dots) in the Kuusamo area: a) whole diagram b) partial enlargement. The yellow dots indicate the ratios of the Juomasuo deposit. (After Arkimaa 1997).