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Radioelement distributions and analysis of microtopographical influences in a shallow covered area, Inner Mongolia, China: Implications for mineral exploration

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ABSTRACT

Gamma-ray spectrometry is one of the most cost-effective prospecting methods for investigating anomalies in potassium, uranium, thorium and alteration indexes associated with hydrothermal and radioactive ore deposits. In this work, we selected an arid grass covered landscape micro-region in Inner Mongolia as the study area to examine the radioelement distributions and microtopographical influences on a gamma ray spectrometry survey. In general, concentrations of K, U, Th and TC (total count) of intrusive rocks are higher than the overburden cover. Overburden mixing with the eolian dust and in-situ weathered material reduces the gamma radiation penetrating into the Earth's surface. Similar to overburden, the thin layers of eolian dust in the concave areas of intrusive rock also reduce the measured radioelement concentrations. The decreasing order of radioelement concentrations in the study area is: Jurassic granodiorite > Carboniferous biotite porphyry > overburden. Th, U, K and TC increase with elevation, and all show positive correlations with elevation. The Th and TC have stronger correlations with elevation than K and U. Thus, K and U show relative local enrichment in low-lying areas, whilst Th and TC do not; alteration indices proposed to improve the discrimination of potassic alteration also generate false anomalies, caused by local enrichment of the K and U in low-lying areas. Therefore, the geological interpretation of gamma ray surveys for mineral exploration needs to consider the topography in order to reject false anomalies and retain the true anomalies associated with ore deposits.

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1. Introduction

Radiometric gamma ray spectrometry, which has almost the same accuracy in analysis of concentrations of radioelements (i.e., potassium, uranium, and thorium) as inductively coupled plasma mass spectrometry (ICP-MS) (Chiozzi et al., 2003), is a powerful and cost-effective tool for geological mapping (Carneiro et al., 2012; Chen et al., 2007; de Souza Filho et al., 2008; Liu et al., 2003), mineral prospecting (Airo, 2002; Dickson and Scott, 1997, 1998; Eberle and Paasche, 2012; Hattula and Rekola, 2000; Shives et al., 2000; Tourliere et al., 2003), as well as in environmental (Kowatari et al., 2014; Saito et al., 2015; Warnery et al., 2015) and land management (Lausch et al., 2013; Martelet et al., 2013). Gamma-ray spectrometry, regardless of the associated mineral species (Shives et al., 2000), has been widely used in mineral prospecting for uranium and thorium deposits, porphyry Au–Cu deposits, VHMS deposits, and polymetallic magmatic-hydrothermal deposits (Dickson and Scott, 1997; IAEA, 2003; Shives et al., 2000) in Australian, Canada, the former Soviet Union and other countries during the past few decades. Furthermore, element distribution between soil and underlying parent rock (Dickson and Scott, 1997), radioelement erosion and production in catchment basins (Carrier et al., 2006; Dickson et al., 1996), radioelement signatures of mineralization events (Dickson and Scott, 1997) have also been studied, and which provide some background principals for use of gamma ray survey in mineral prospecting.

Quaternary overburden (e.g., laterite, glacial till, loess, forest soil, Gobi desert, and steppe soil) is a challenge in geological mapping and mineral prospecting, as it masks the underlying and concealed bedrock geology information. Gamma-ray survey results measure variation in K, U and Th concentrations at the Earth's surface, and these can be influenced by many exogenic geological factors, such as weathering or topography. As stated earlier, gamma ray spectrometry has been widely used in geological mapping and mineral prospecting. In many case studies pertaining to the application of gamma ray in mineral

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prospecting, the most of attention was focused mostly on to the successes, and ignored the influence landform in generating false anomalies. The influence of topography and eolian dust on gamma ray survey results for mineral prospecting in the overburden covered areas have not been studied in detail before. In this work, we selected a micro-region of arid grass-covered landscape in Inner Mongolia as the study area, in order to examine radioelement distributions and microtopographical influences on gamma ray spectrometry surveys.

2. Study area and methods

2.1. Geological setting

The study area is located in the Xing'an-Mongolia orogenic belt between the Northern China block and the Siberia block, and is a part of the giant metallogenic belt of the China-Mongolia border region (Nie et al., 2007; Wu et al., 2005).

Carboniferous biotite porphyritic granite, Jurassic medium- and fine-grained granodiorite, a few Carboniferous metasandstone and breccia lava are exposed on positive landforms, but are also locally covered by overburden. The geological map is given in Fig. 1, and shows that most areas are covered by Quaternary overburden.

2.2. Geographical landscape

The geographical landscape of Xing'an, Inner Mongolia, where the study area is located, is influenced by a continental monsoon climate (Fig. 2). Physical and chemical weathering, and wind-blown migration (i.e., by saltation and creep) are widespread at the Earth's surface. The particle size of eolian dust migrating from Mongolia by the prevailing wind (Dickson and Scott, 1998; Wang et al., 2008) is finer than the local eluvia. The soil is a product of overburden altered by in-situ weathering and eolian dust. It is completely covered by grassland on slopes and base of negative landform. Although the labeling of the geological map indicates bedrock on the positive landforms, some local concave areas of bedrock are also covered by a thin veneer composed of fine wind-blown dust and physical weathering fragments of intrusive rock (e.g., feldspar, quartz).

2.3. Material and methods

2.3.1. Gamma ray spectrometer and setting

In this study, the spectrometer GS-512, a 512 channels gamma ray spectrometry equipment with NaI detector designed and produced by SatisGeo, was used to measure the gamma ray energy spectra. K, U, Th and their total count (TC) were determined by detection of gamma rays in four regions of interest. Determination of K is based on the detection of 1461 keV gamma rays, which are emitted by radioactive isotope ^{40}K. U is measured by the detection of ^{214}Bi gamma rays at 1764 keV, which is a product of ^{238}U disintegration series. Th is realized by detection of 2615 keV ^{208}Tl gamma rays, which is a product of ^{232}Th decay series. The total count (TC) aggregates summarizing the instrument response to all source of gamma radiation in broad energy window, and is expressed in equivalent uranium concentration.

Measurements recorded on four traverses (i.e., sections L248, L260, L420, and L430), across intrusive bedrock outcrop and overburden, were planned and carried out in the microtopographical study area. The interval of the survey points is 20 m, although a few local sampling intervals are 5 m. Elevation differences in the L248 and L260 sections are 10 m and 16 m, whereas these are 27 m and 23 m in L420 and L430 sections, respectively. Therefore, the topographies of sections L248 and L260 are less rugged than those of L420 and L430. The southeast part of L420 and L430 contains a gully, which drain a catchment from higher altitude, in contrast to steady slopes of L248 and L260.

The measuring time for gamma ray spectrometer during filed surveys is adjustable and hence subject to optimization. In order to obtain the optimum measurement time for the survey, we did a series of consecutive tests for equal time intervals of 30 s. The test results are shown in Fig. 3, TC and K concentrations exhibit oscillations before 180 s, and then trend toward stability, whereas U and Th are relatively stable

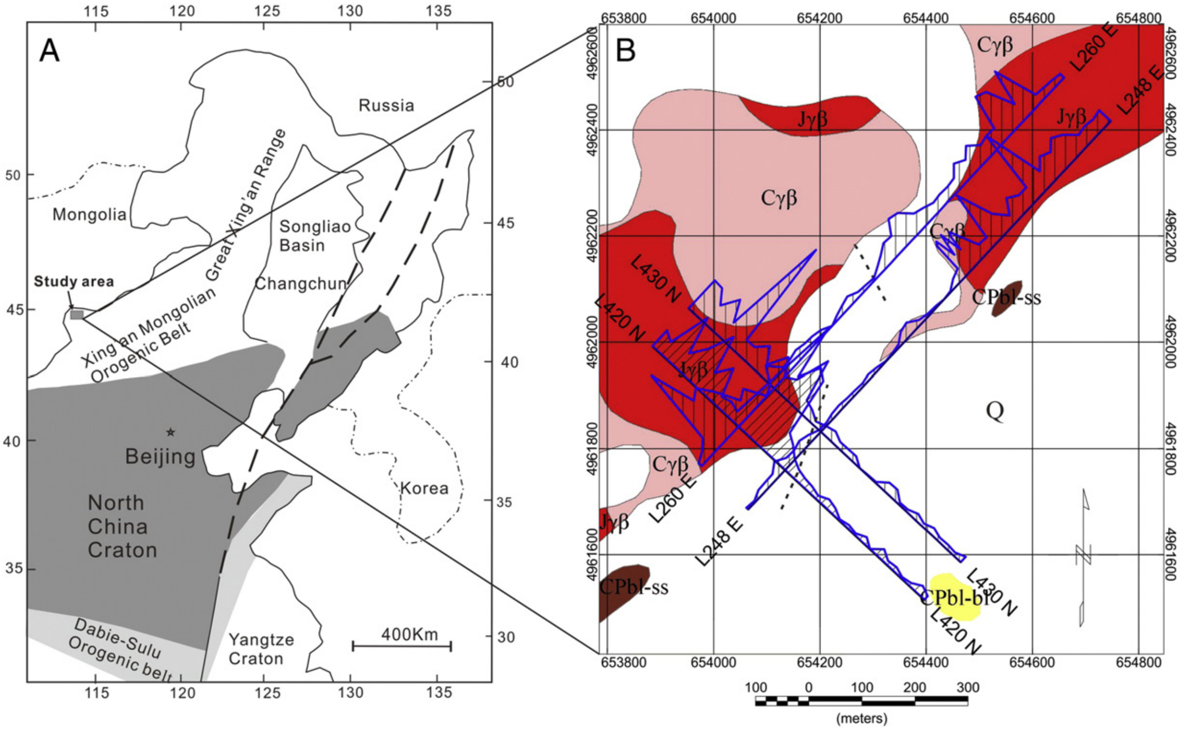

Fig. 1. (A) Location of study area on simplified geological map of eastern China; (B) Geological map and TC section profile of study area: Jγβ - Jurassic medium- and fine-grained granodiorite; Cγβ - Carboniferous biotite porphyry; CPbl-ss - Carboniferous metasandstone; CPbl-bl - Carboniferous metasandstone and breccia lava; Q-Quaternary.

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