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Integrated Radiometric Mapping using Field Based and Remote Sensing Techniques for Uranium and Thorium Exploration at Mamuju Region, West Sulawesi, Indonesia

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Abstract

Mamuju Region in West Sulawesi, Indonesia is a "green" field area of uranium/thorium in Indonesia. High radiometric concentrations were located in Adang Volcanic Rocks. This formation is grouped as basaltic to intermediate rock and composed by lava, pyroclastic rocks, and tuff. Regional field radiometric mapping, including radiation dose rates, potassium, uranium, and thorium contents of soil and rock was conducted to identify the existence of radioactive minerals and prospect zones. Some radiometric anomalies are detected and probably related to hydrothermal alteration, leaching, and precipitation processes. Uranium anomaly (97,261 ppm) located in Mamuju River upstream, Botteng, Takandeang and Ahu area. The anomaly related to uranium leaching and precipitation processes in leucite basalt lava. Thorium anomaly (369,461 ppm) located in Pangasaan, Takandeang, Ahu, and Taan area. To expand this radiometric mapping, we characterized the reflectance of Landsat-8 imagery based on field measurement data. Based on circular structures identification, uranium/thorium anomaly are related to the existence of volcano vents on Adang Volcanic. Based on band rationing, high uranium contents distributed in the area with less ferromagnesian mineral, while thorium did not affected. These field based and remote sensing characterization results could be used as preliminary parameters to identify wide and detail prospects.

Keywords: radioactive, uranium, thorium, mamuju, Landsat-8.

Introduction

Mamuju Region in West Sulawesi, Indonesia is a "green" field area of uranium/thorium exploration in Indonesia. High radioactivity dose rate are found in this area from the environment radioactivity measurement done by BATAN in 2007. Radioactivity dose rate recorded 100-2,800 nSv/h which is higher than other places in West Sulawesi (Iskandar et al, 2007). High radioactivity in environment usually comes from the existance of high concentration of potassium (K), uranium (U), and thorium (Th) and their daughter products in rock/soil. High radioactive dose rate in this region was found in leucite basalt of Adang Volcanic Rocks in an area of 840 km^2.

Remote sensing and general radiometric mapping are powerful tools to help to identify the distribution of radioactive mineral in a wide area. In this study, remote sensing technology was used to identify the existence of hydrothermal alteration mineral, while radiometric mapping was used to identify and localize the distribution of radioactive mineral. The integration between remote sensing and radiometric mapping techniques is aimed to identify minerals related to uranium and thorium element.

Data and Method

Preliminary study in this area has been carried out through desk studies. Landsat-8 imagery is used to identify the distribution of volcanic rocks containing hydrothermal alteration mineral. Band rationing 4/2, 5/6, and 6/7 commonly used to identify mineral group of iron oxide, ferrous magnesium silicate, and alunite/clay respectively (Sabins, 1999).

General radiometric measurements were also conducted to collect information related to radioactive dose rate including potassium, uranium, and thorium contents. Potassium elements were detected from their decay energy, while uranium and thorium are detected from decay energy of uranium and thorium daughter products emitting gamma radiation (IAEA, 2003). Radiometric measurement using gamma spectrometry scintillation type, model RS-125.

Result and Discussion

Regional Geology of selected study area (Figure 1) based on Ratman and Atmawinata (1993) consists of Talaya Volcanic Rocks (Tmtv), Adang Volcanic Rocks (Tma), Mamuju Formation (Tmm), Tapalang Member of Mamuju Formation (Tmmt), Corraline Limestone (Ql), and Alluvial (Qa). Talaya Volcanic rocks consist of andesitic-basaltic volcanic breccia, tuff and lava, with intercalations of sandstone and marl, locally coal. Adang Volcanic Rocks mainly consist of leucite basaltic lava and volcanic breccia, tuff, partly micaceous. Mamuju Formation deposited above Adang volcanic, consist of marl, calcarenite, coraline limestone with tuff and sandstone intercalations, locally

conglomerate, Mamuju Formation has interfingering relation with Tapalang Member which consist of Reef limestone, fragmental limestone, and marl.

According to Hazen et al., (2009), the existence of radioactive mineral related with acid igneous rocks, either plutonic (granitic) or volcanic (ryolitic). These rocks are rich in potassium content. In Mamuju region, high radioactivity was detected only in the leucite basaltic Adang Volcanic Rocks, mainly in Botteng and Takandeang Area. Leucite mineral present as phenocryst on basalt rock is an indication of feldspathoid lava with high potassium content. Most of the lava in Adang volcanic has been hydrothermally altered. At Botteng and Ahu, high uranium content came from uranium secondary mineral gummite and autunite (Figure 2). These mineral originated from the leaching and precipitation process of high uranium host rock, which is altered leucite basalt. Meanwhile, high uranium content originates from altered leucite basalt rock and its lateritic soil (Figure 3).

From the radioactivity measurements, most of altered leucite bearing rocks has higher radioactivity than others. Andesite and sedimentary rock are less radioactive. Dose rate anomalies in the area as much as 1,693.6 nSv/h are located in Mamuju River upstream, Pangasaan, Botteng, Takandeang, Ahu, and Taan (Figure 4). High radioactivity related to high uranium/thorium content. Uranium anomalies as much as 97.261 ppm eU are located in Mamuju River upstream, Botteng, Ahu, and Takandeang area (Figure 5). Meanwhile, thorium anomalies as much as 369.5 ppm eTh are located in Pangasaan, Takandeang, Ahu, and Taan area (Figure 6).

Landsat-8 multispectral imagery analysis is using combination of several bands to obtain rock characteristic related to hydrothermal alteration. The imagery was recorded on July 23rd, 2013 with WRS-Path=115 and WRS-Row=62, downloaded from USGS website www.earthexplorer.usgs.gov.

After some geometric and atmospheric corrections, the image was clipped on the interest area. Image composite from band 5, 6, 7 (R, G, B respectively) pan-sharpened with panchromatic band was used to identify the circular features in Adang volcano. As much as 21 circular features are interpreted as crater and lava dome. These features related to ancient volcanic activities. Dose rate and uranium and thorium anomalies also related to the existence of the circular features (Figure 4, 5, 6). Dose rate anomalies are located near the circular features as well as uranium and thorium anomalies. The hydrothermal alteration intensity is occurred mostly near the crater or lava dome.

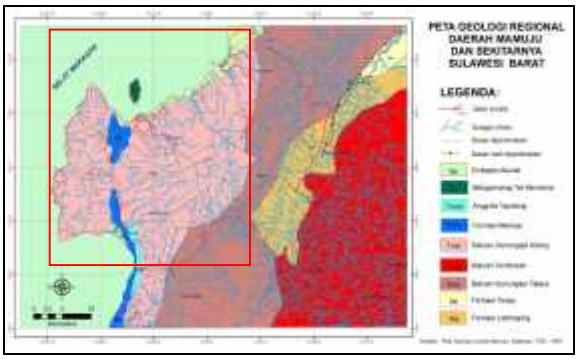

Figure 1: Geological map of Mamuju region (Ratman dan Atmawinata, 1993). The selected study area is bordered by red rectangle.

Figure 2: Gummite (yellow) and autunite (inset, 100x magnification) as radioactive minerals in leucitic basalt rock.

Figure 3: Altered leucite basalt rock (left) and lateritic soil (right) containing high concentration of thorium.

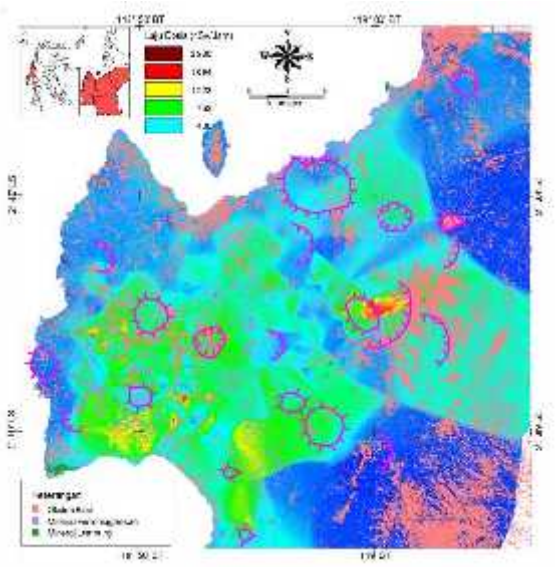

Figure 4: Location of circular features and hydrothermal alteration minerals overlaid on the dose rate map from field measurements.

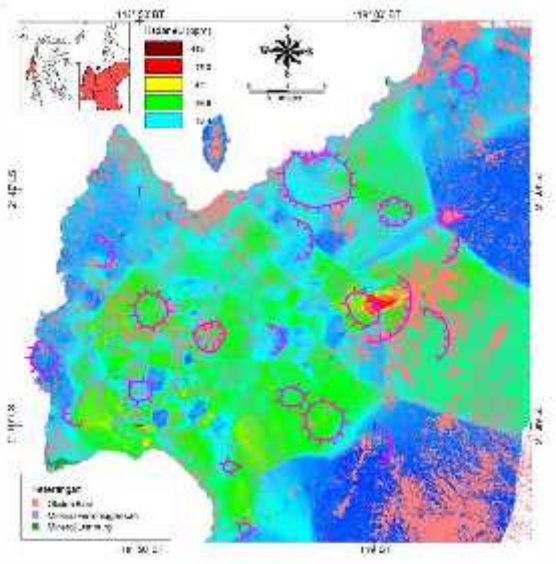

Figure 5: Location of circular features and hydrothermal alteration minerals overlaid on the uranium content map from field measurements.

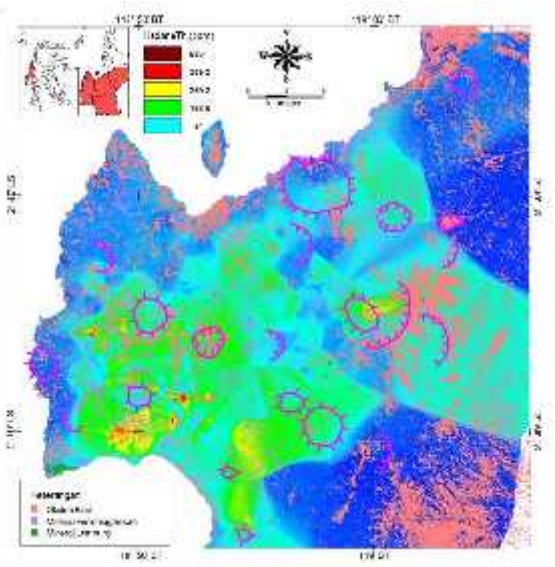

Figure 6: Location of circular features and hydrothermal alteration minerals overlaid on the thorium content map from field measurements.

Band rationing 4/2, 5/6, and 6/7 are used to identify hydrothermal minerals. The ratio 4/2 was suitable to identify the distribution of iron oxide minerals, meanwhile 5/6 to identify the existence of ferrous magnesium silicate mineral. The 6/7 ratio is used to identify alunite and alteration clay minerals. Commonly, at a very late magmatic stage, a change takes place which brings uranium and thorium to parting of the ways, the uranium going with the hydrothermal solution and leaving thorium to crystallize with the final silicate-rich fraction. This change is brought on by a shift towards more oxidizing conditions. It may result from a relief of pressure caused by intrusion of magma into higher earth. Evidence for this shift in oxidation-reduction equilibrium is found in the replacement of early formed ferrous magnesium silicates by magnetite (Larsen and Phair, 1954).

Comparing the distribution of uranium anomalies and ferrous magnesium minerals (Figure 5), it could be seen that uranium accumulates in the area where ferrous magnesium minerals are less in concentration. Meanwhile, thorium distribution did not affected by the existence of ferrous magnesium minerals because thorium is not directly affected by the shift to more oxidizing conditions (Figure 6).

Conclusions

Adang Volcanic was composed by more than one magma vent. Lava in Adang was grouped into leucite basalt and andesite rock. Leucite basalt has higher radioactivity than andesite lava. Uranium and thorium were interpreted as hydrothermal product of Adang volcanic. High content of uranium is caused by the leaching and precipitation processes on leucite basalt lava, creating secondary minerals gummite and autunite. Meanwhile, high accumulation of thorium occurred on lateritic soil of leucite basalt lava rock. Distribution of uranium and thorium anomalies was controlled by the existence of circular features of crater and lava dome. From the band ratio 4/2, 5/6, and 6/7, higher uranium contents are distributed on the area with less ferromagnesian silicate mineral, meanwhile thorium distributions are not affected by the existence of ferromagnesian silicate mineral.

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