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Interpretation and Analysis of Hydrothermal Alteration Minerals Distribution Zone Based on Remote Sensing and Geographic Information System (GIS) for Mount Patuha and Surrounding Area, Bandung Regency, West Java

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***Abstract*— *The area of Mount Patuha and its surroundings is an area of hilly and mountainous morphology with a slope of around 15%–45%. Administratively, this area is included in three subdistricts, namely Rancabali Subdistrict, Pasir Jambu Subdistrict, and Ciwidey Subdistrict. The Mount Patuha area and its surroundings are included in the Quaternary Volcanoes, part of Java Island's southern mountains. This area shows many manifestations, such as hot springs, gases, fumaroles, and hydrothermal altered rocks caused by the reaction of hydrothermal fluids with rocks. The Patuha Geothermal Field in this area has been and is being developed by PT. Geo Dipa Energi as a geothermal power plant. This study aims to map the distribution of hydrothermal altered rocks or alteration minerals in the study area. The remote sensing method is carried out by combining the wavelengths of the Landsat 8 OLI/TIRS image band channels to obtain the zoning distribution of hydrothermal or mineral alteration rocks, while DEM (Digital Elevation Model) SRTM data is interpreted to obtain morphological information in the study area. The combination of Landsat imagery that has been carried out is a composite RGB (red, green, and blue) band and Composite Band Ratio to obtain information on the recorded image. RGB band composite 5-6-7 provides information on the geological structure, rock texture, and the presence of altered rock; composite band 4-3-2 natural color provides information on geomorphology, geology, and vegetation; ratio band 4/2 provides information related to minerals Ferrugination (Limonite); ratio bands 5/6 provide information regarding Ferromagnesian minerals; Ratio Bands 6/7 provide information regarding Clay and Carbonate Minerals; and RGB 4/2, 6/7, 5, or 10 provide information regarding hydrothermal alteration minerals, vegetation in drainage, and altered rocks, as well as composite band 10-11-7, which provides information on silica-rich rocks. The results of this study can be used to obtain information on the distribution of hydrothermal alteration rocks or their alteration minerals in the study area. From this study, it can be concluded that the application of remote sensing methods can provide information on the distribution of hydrothermal alteration rocks or alteration minerals in the study area on a regional basis, so this data can be used as initial data in conducting exploration prior to field mapping.*

***Keywords*— *Hydrothermal alteration, landsat, hydrothermal, remote sensing*.

I. INTRODUCTION

The research area is located in the Mount Patuha area and its surroundings, Bandung Regency, West Java Province (Figure 1). The area of Mount Patuha and its surroundings is an area with hilly and mountain morphology with a slope of around 15%-45%. Administratively, this area is included in three subdistricts, namely Rancabali Subdistrict, Pasir Jambu Subdistrict, and Ciwidey Subdistrict and geographically, the research is located at 107º21’ 20” E – 107 º 26’ 36” E dan 7 º 07’ 36” S - 7 º 12’ 51” S.

Geologically, the area has its own characteristics that make the author interested in conducting a study on it. One of the characteristics is the presence of geothermal manifestations in the study area, one of these manifestations is found in the Mount Patuha area.

The research area is a Tertiary-Quaternary volcano (M. Koesmono et al., 1996). The geothermal potential is characterized by manifestations such as emergence of hot springs, fumaroles, and altered rocks that occur in several locations.

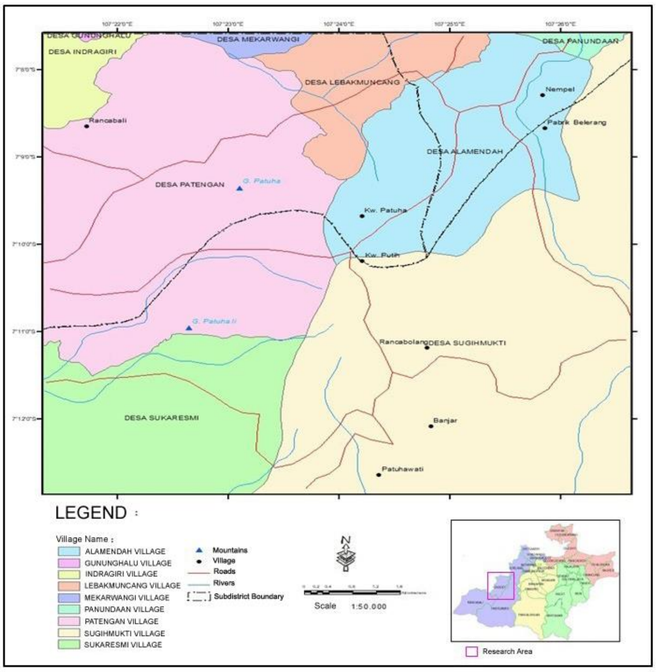

Fig. 1. Research Area

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There are three kinds of alteration that occur as a reaction between the geothermal fluid and the rocks in its path: 1) Mineral replacement; 2) Space-filling; and 3) Rock dissolution (Browne, 1998; Utami, 2011). This process can be an important guide in mapping geothermal potential, especially around manifestations indicating that there is an active geothermal system (Browne, 1970).

One of the initial methods used in mapping for various needs is remote sensing, especially for mineral exploration. This is done because remote sensing can provide a preliminary comprehensive picture of geomorphology, geology, vegetation, and other conditions. The satellite imagery is one of the most frequently used in remote sensing, such as utilizing the Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS). Landsat 8 OLI/TIRS imagery (Table 1) were launched in America and have 11 kinds of channels (bands) with spatial resolutions ranging from 15 x 15 meters to 100 x 100 meters (United States Geological Survey, 2016).

TABLE I. Characteristics of Landsat 8 OLI/TIRS

Band Landsat 8	**Spektral Range**	**Uses for maps**	**Resolution**
Band 1 - Aerosol/Coastal	0.43-0.45	Coastal areas and airborne aerosols	30 m
Band 2 - Blue	0.45-0.51	Bathymetry (seafloor) mapping, distinguishing soil and vegetation	30 m
Band 3 - Green	0.53-0.59	Brightens growing vegetation	30 m
Band 4 - Red	0.64-0.67	Distinguish the slope of the vegetation	30 m
Band 5 - Near Infrared (NIR)	0.85-0.88	Brightens the differences in the amount of biomass and coastal areas	30 m
Band 6 - Short wave infrared (SWIR) 1	1.57-1.65	Distinguishing the water content of the soil (soil wetness) and vegetation, passing through the light clouds	30 m
Band 7 - Short wave infrared (SWIR) 2	2.11-2.29	Improved capacity to differentiate between wet soil and vegetation, passing through light clouds	30 m
Band 8 - Panchromatic (black and white)	0.50-0.68	For a clear image	15 m
Band 9 - Cirrus (cirrus clouds)	1.36-1.38	Improved contamination detection in cirrus clouds	30 m
Band 10 - Thermal Infra Red (TIRS) 1	10.60-11.19	Forecast soil heat and moisture mapping	100 m and (30 m)
Band 11 - Thermal Infra Red (TIRS) 2	11.50-12.51	Improved forecasting of soil heat and moisture mapping	100 m and (30 m)

Analysis of Landsat imagery is generally used to determine conditions on the earth's surface by looking at the reflectance and adsorption characteristics of electromagnetic waves from objects on the earth's surface (Sabins, 1999). In this study, the Landsat imagery were used to determine the existence of regional scale hydrothermal alteration.

II. DATA AND METHODOLOGY

The data used in this study are Landsat 8 OLI/TIRS satellite imagery data and secondary data in the form of geological maps and mineral alteration in the study area. The software used for image data processing is Er-Mapper, while ArcGIS is used to make the full map.

The method used in this study is the Image Composite Method. The composite image is a new image which is a combination of 3 channels and able to display the advantages of the constituent channels (Sigit, 2011). This image composite is used considering the limitations of the eye in distinguishing color gradations, for this reason, it is easier to understand by giving color.

III. RESULT AND DISCUSSION

A. *Interpretation of Geological Conditions, Geomorphology, and Land Cover*

In the RGB 432 composite image, where the red band is filled with band 4 with a wavelength of 0.636-0.636 μm, the green band is filled with band 3 with a wavelength of 0.533 – 0.590 μm and the blue band is filled with band 2 with a wavelength of 0.452 – 0.512 μm. By combining these three bands, we can see the condition of the vegetation, geomorphology, and geology of the study area regionally. Apart from that, we can see some geological features, such as non-crystalline rocks or sedimentary rocks appearing in finer textures and crystalline rocks appearing in coarser textures. More details on the image map resulting from the RGB 432 composition can be seen in Figure 2 below.

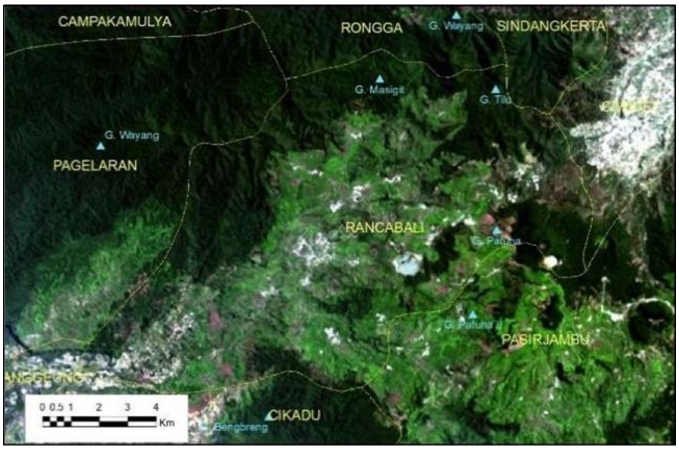

Fig. 2. RGB 432 Composite Imagery showing the condition of the vegetation, geomorphology, and geology of the study area

In RGB 567 composite image processing, the appearance is different from RGB 432 and can show more detailed geology. With this combination of bands, we can see rocks with a coarser and finer texture, where the coarser textured rocks are scattered around the body of the volcano, while the finer textures are spread over areas with lower elevations. Apart from that, you can also observe some of the main lineaments in the area with the main directions NW-SE and NE-SW. Vegetation can also be seen with differences in plant density which can be seen from the difference in color from light brown to dark brown. Apart from that, the drainage patterns, water bodies, and residential areas are clearly different in the image. More details on the image map resulting from the RGB 567 composition can be seen in Figure 3 below.

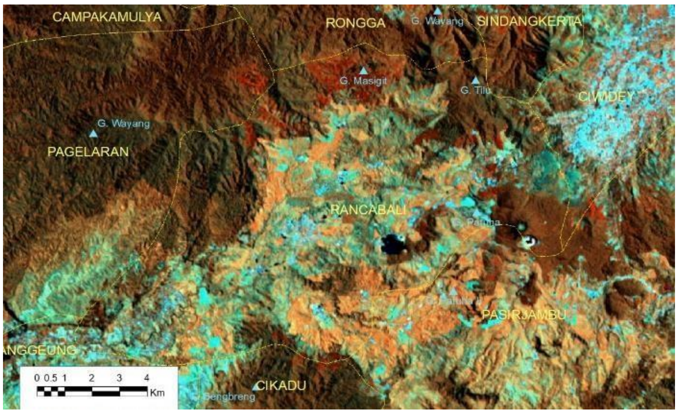

Fig. 3. RGB 567 Composite Imagery showing the geological conditions of the study area

B. Displays Hydrothermal Alteration Mineral Distribution

To identify the distribution of hydrothermal alteration minerals in the study area, RGB image composites were used in bands 4/2, 6/7, 5, and 10. These minerals are recognized by the appearance of light gray to dark gray colors in the RGB image composites 4/2, 6/ 7, and 5, as well as pink on RGB composites 4/2, 6/7, and 10 (Pour and Hashim, 2014). The distribution of this alteration mineral is mostly found in hilly areas and slopes of Mount Masigit, Mount Tilu, Bengbreng, and is most widely spread in the Mount Patuha area which is a geothermal manifestation in the study area.

In the RGB composite image with a combination of band ratios 4/2, 6/7, and 10, the appearance of the altered minerals is shown in light brown and yellow colors (Figure 4), and vegetation appears in green and bluish-green, which are scattered in hilly areas and geothermal manifestation area.

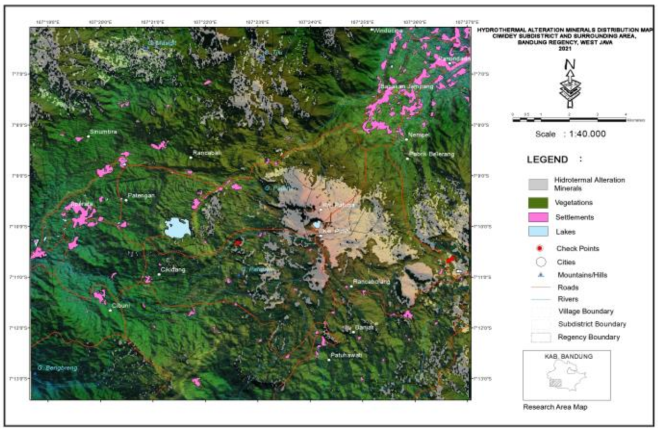

Fig. 4. Composite Imagery RGB band ratios 4/2, 6/7, and 10 which provide the main information about hydrothermal alteration minerals with gray color

C. Displays Silicate Rock or Mineral Information

In RGB imagery with composite bands 10-11-7, where bands 10 and 11 are infrared bands. Band 10 with a wavelength of 10.60 –11.19 μm is placed in the red band, band 11 with a wavelength of 0 11.50 – 12.51 μm is placed in the green band, and band 7 with a wavelength of 2.107 – 2.294 μm is placed in the blue band. The combination of these bands provides information about rocks or the presence of siliceous minerals in the study area as an effect of the strong reflectance of the wavelength of the image band (Pour and Hashim, 2014). Silica content is shown in the image from light yellow to dark yellow. The yellow color is mostly found in peak areas, where the silica content is stronger. High concentrations of silica content are in hilly areas and mountain slopes which show high geothermal manifestations, such as in the Patuha Crater, Ciwidey Crater, and Cibuni Crater. More details on the image map resulting from the composition of RGB 10-11-7 can be seen in Figure 5 below.

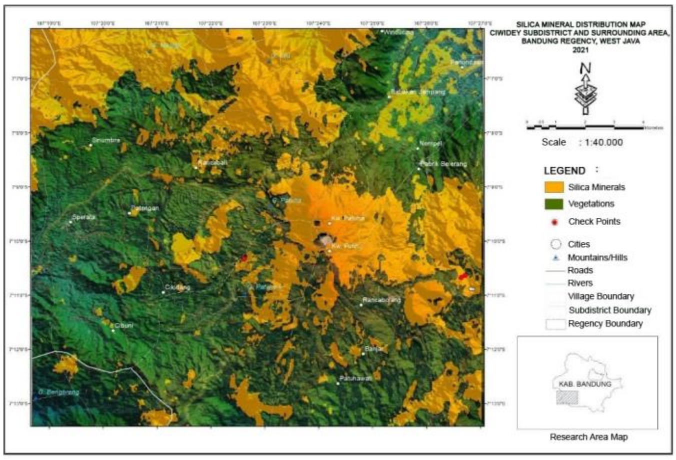

Fig. 5. Composite Imagery RGB 10-11-7 (yellow color) showing Silica content in rocks or the presence of Silica minerals

D. Displays Ferrugination (Limonite) Distribution Information

The ratio of band 4 and band 2 (Figure 6) is shown in red which provides information about the distribution of ferruginated minerals (limonite) in the study area. Minerals are scattered in the Patuha hydrothermal manifestation area in the eastern part of Rancabali and its surroundings, the Mount Masigit, and Mount Tilu areas in the northern part of Rancabali and its surroundings, and the Gunung Wayang area in the northwest of Rancabali and its surroundings.

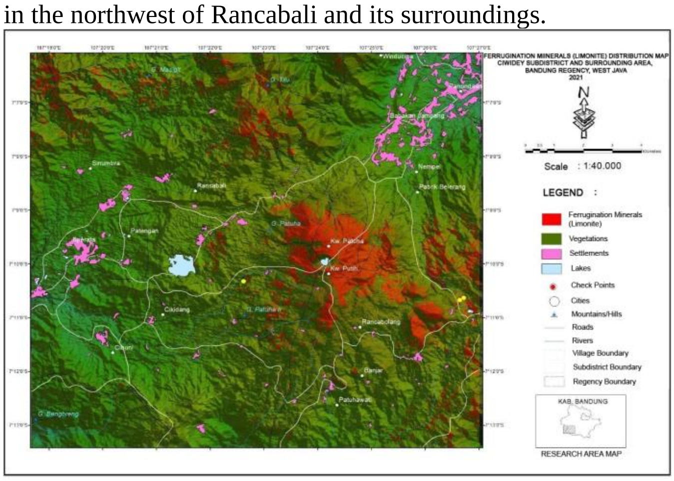

Fig. 6. Composite imagery of band ratio 4/2 (red color) which shows information on the distribution of Ferrugination (Limonite) in the study area

E. Displays Ferromagnesian Distribution Information

The ratio of band 5 and band 6 (Figure 7) is recorded in yellow which provides information about the distribution of Ferromagnesian minerals in the study area. The map shows minerals scattered in mountain and hill areas including the Mount Masigit and Mount Tilu areas in the western part of Ciwidey and its surroundings, and Mount Patuha in the southern part of Ciwidey and its surroundings.

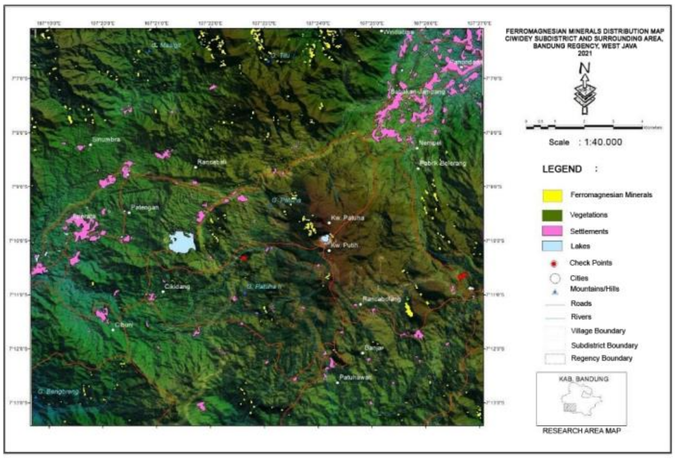

Fig. 7 Composite imagery of band ratio 5/6 (Yellow Color) which shows information on the distribution of Ferromagnesian in the study area

F. Displays Information on The Distribution of Clay and Carbonate Minerals

The ratio of band 6 and band 7 (Figure 8) is recorded in pink to dark red which provides information about the distribution of clay and carbonate minerals in the study area. The map shows minerals scattered in the hydrothermal manifestation area in the eastern part of the Rancabali area and its surroundings, the Mount Masigit and Mount Tilu areas in the northern part of Rancabali and its surroundings, and the Gunung Wayang area in the northwest and southern part of Rancabali and its surroundings.

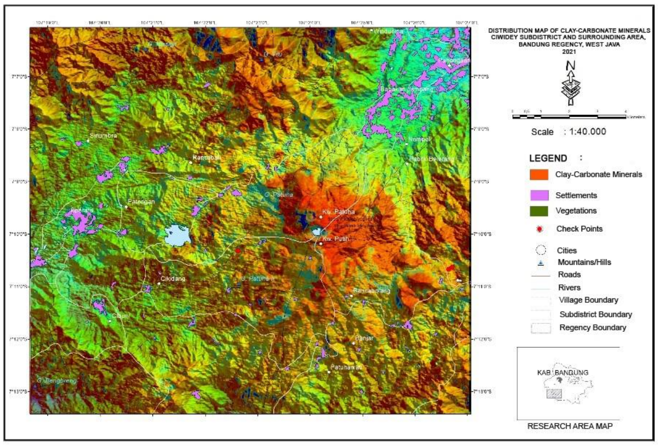

Fig. 8. Composite imagery of 6/7 band ratio (red color) which shows information on the distribution of Clay Minerals and Carbonates in the study area

IV. Conclusion

Interpretation and analysis of Landsat 8 OLI/TIRS imagery is a preliminary mapping in knowing the distribution of Hydrothermal Alteration minerals in exploring geothermal, mineral and other potentials.

The combination of several bands that have a different pixel range can represent alteration rocks or hydrothermal alteration minerals in the study area. The alteration minerals are recorded in different colors. In the composite image with a band ratio of 4/2, the red color shows the distribution of Ferrugination Minerals (Iron Oxides and Hydroxides).

In the composite image with a band ratio of 5/6, it also shows a red color which indicates the distribution of Ferromagnesian Minerals. In the composite image with a band ratio of 6/7, it displays a light pink to dark red color which shows the distribution of Clay and Carbonates Minerals. While the composite image with the RGB 10-11-7 band displays a yellow color which shows the distribution of Silica Minerals.

Preliminary mapping using Landsat 8 OLI/TIRS imagery in knowing the distribution of hydrothermal alteration minerals can be used for the exploration of geothermal potential, mineral exploration, etc. However, it needs to be considered in selecting imagery, which is necessary to avoid image locations with lots of clouds and vegetation because it can lead to misinterpretation and cause errors in analysis so that it doesn’t match the expected results.

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