EINSTEIN (e-Journal)
Jurnal Hasil Penelitian Bidang Fisika
Available online http://jurnal.unimed.ac.id/2012/index.php/einsten
e-issn: 2407 – 747x, p-issn 2338 – 1981

ANALYSIS OF GRANITE ROCK WEATHERING IN THE PARMONANGAN AREA USING LANDSAT 8 SATELLITE IMAGERY

Rita Juliani, Rahmatsyah[1], Togi Tampubolon[1], Erniwati Halawa[1], Silvia Dona Sari[1], and Rama Yana Purba[1]
[1]Jurusan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Medan
julianiunimed@gmail.com

Submit: August 2024. Approved: September 2024. Published: October 2024.

ABSTRACT

A research has been conducted to analyze the weathering of granite rocks in the Parmonangan area using Lansat 8 satellite imagery which aims to determine the distribution of rocks, weathering processes, and types of rock forming elements in Parmonangan District, North Tapanuli Regency. The method used is using shp geologic map data and Lansat-8 image data processed using Arcgis Map 10.6.1 to determine the distribution of rocks and land cover. XRF is used to identify compounds and rock-forming elements. The results obtained by the rock distribution of the parmonangan area are in the form of the Kluet Formation, Sibolga Complex and Toba Tuff. Land cover in the parmonagan area has differences from 2016 to 2024. Open land in 2024 has increased and the cloud cover obtained has also increased. The rock elements found are Al_2O_3 (25.31), SiO_2 (24.97), K_2O (1.56), TiO_2 (0.81), Mn_2O (30.66), Fe_2O3 (4.66), ZrO_2, (0.21), Sb_2O_3 (0.16), and BaO (0.17).

Keywords: Weathering, Land Cover, XRF, Granite, Parmonangan

INTRODUCTION

North Tapanuli is a regency located in the province of North Sumatra, geographically situated at coordinates 1020'00"–2041'00" N and 98005'–99016' E, with an area of approximately 3,800.31 km². The districts located in North Tapanuli are Parmonangan, Adian Koting, Sipoholon, Tarutung, Siatas Barita, Pahae Julu, Pahae Jae, Purba Tua, Simangumban, Pangaribuan, Garoga, Sipahutar, Siborongborong, Pagaran, and Muara.

Parmonangan District has an area of 257.35 km² and consists of 14 villages. Geographically, Parmonangan District is bordered to the north by Pagaran District, to the south by Central Tapanuli, to the west by Humbang Hasundutan, and to the east by Sipaholon and Adiankoting Districts. (BPS, 2023).

Parmonangan District is situated at an altitude of 500-1,500 meters above sea level. The morphology of the Parmonangan District is classified into two types: high rolling hills (1,300-1,650 meters above sea level) and low hills (1,000-1,200 meters above sea level). The northern hill is called Siimbo Hill, with an elevation of 1,300-1,450 meters above sea level, and the southern hill is named Siliolio Hill, with an elevation of 1,450-1,650 meters above sea level (Kisman and Widodo, 2011). Parmonangan District consists of rocks and land cover with different characteristics.

Rocks are solid objects that naturally form from mineraloids. The lithosphere layer is composed of three main types of materials, with magma as the basic material for rock formation. Different formation processes result in different types of rocks. The types of rocks in Earth's lithosphere are generally divided into three: igneous rocks, sedimentary rocks, and metamorphic rocks. Magma that undergoes a cooling process forms igneous rocks. Igneous rocks that experience geomorphological processes and are affected by time, break down, and settle to form sedimentary rocks. Igneous rocks that undergo changes in temperature and pressure form metamorphic rocks (Akmalia, A. R., *et al*, 2017).

Rocks consist of various types of materials that make up the Earth's crust. Rocks are solid substances composed of elements or compounds formed through inorganic processes and have a specific chemical composition, with atoms arranged in what is known as a crystal structure. The types of rocks that are commonly found are influenced by the minerals that compose them (Widiyastuti, 2016). Rocks found on the Earth's surface undergo various changes and have different types of land cover.

Land cover refers to the physical form of objects that cover the land, without considering the impact of living organisms on these objects. Land cover changes over space and time, similar to how rocks undergo changes due to environmental factors. Landsat 8 is a remote sensing satellite imagery used to identify rock types and distribution based on visual characteristics. Landsat 8 imagery, launched by NASA (National Aeronautics and Space Administration), features channels that aid in creating composite images to display Earth's surface geology (Bahar, 2016).

Igneous rocks contain both primary and secondary minerals. Secondary minerals, constituting less than 10% of the total rock volume, play an important role in rock classification. Primary minerals in igneous rocks, particularly granite, include economically valuable elements such as Ta, Nb, Be, Sn, W, Li, F, Cs, radioactive elements, and rare earth elements (REE) found in minerals like monazite, xenotime, zircon, and apatite (Hahendra, 2015).

The composition and concentration of elements or minerals in rocks can be measured qualitatively, semi-quantitatively, and quantitatively in powdered form and compounds quickly, without damaging the sample and in an environmentally friendly manner using X-Ray Fluorescence (Vansla *et al.*, 2023). The study was conducted to analyze the distribution of rocks, the rock weathering process, and the types of elements that form granite rocks in Parmonangan District, North Tapanuli Regency.

RESEARCH METHOD

Location and Time of Research

The research was conducted at the Physics Laboratory of Medan State University. The study area includes rock types in Parmonangan District, North Tapanuli Regency. The administrative map of Parmonangan is shown in Figure 1.

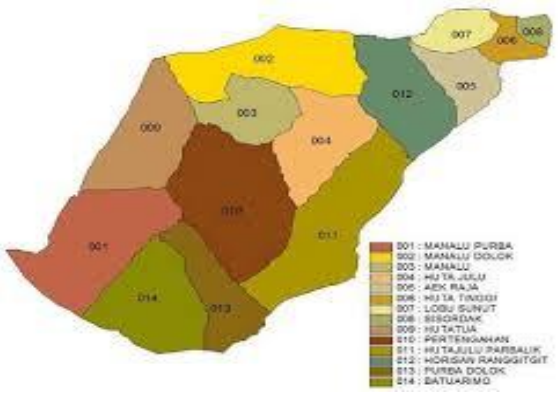

Figure 1. Administrative Map of Parmonangan District

Equipment and Materials

The equipment used includes a laptop that supports the use of ArcGIS applications. The materials used are geological data of Parmonangan District, North Tapanuli in shapefile (shp) format.

Research Procedure

Creation of Geological Map:

1. Download the base map of Indonesia, North Sumatra Geology, and the Administrative

Map of North Tapanuli from the INDONESIA GEOSPASIAL website for 2024.

2. Process the data by adding it using ArcGIS Map 10.6.1 software.
3. Clip the data to focus only on the area of Parmonangan District, North Tapanuli by specifying input and output features.
4. Change the geological colors.
5. Layout the geological map and add a legend to the map.
6. Analyze rock types by observing the colors on the geological map with the legend.

Sample Testing Using X-Ray Fluorescence:

Samples were collected in the form of outcrop rocks in Parmonangan District. The rocks were cleaned, ground, and sieved using a 200 mesh sieve. The samples were tested using X-Ray Fluorescence.

Land Cover Creation Process Using ArcGIS Map:

1. Download Landsat 8 data from the USGS website for Parmonangan District, North Tapanuli, recorded in 2016 and 2024.
2. Process the data by adding Landsat and administrative shapefile (shp) data using ArcGIS Map 10.6.1 software.
3. Perform a composite band, converting bands to band 4, band 3, and band 2. Clip the data to the Parmonangan area. Change bands to band 4, band 3, and band 2. Perform image sharpening. Conduct an unsupervised analysis and add a legend to the map.

RESULT AND DISCUSSION

Rock Geology

The results of processing the basic data for Parmonangan District, North Tapanuli Regency, using ArcGIS produced the geological map shown in Figure 2.

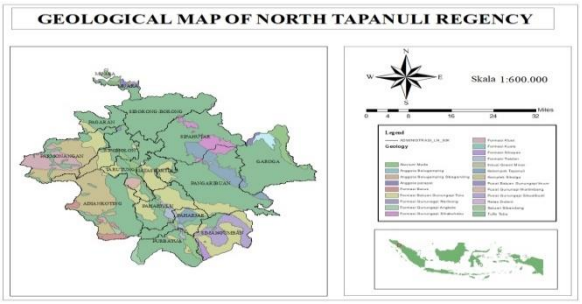

Figure 2. Geological Map of Parmonagan District

Parmonangan District is dominated by the lithology of the Kluet Formation (pink), the Sibolga Complex (light brown), and Toba Tuff (dark green). The Kluet Formation consists of quartz sandstone, claystone, siltstone, and conglomerate sandstone. The Kluet Formation is a rock type that formed due to the occurrence of a dextral transcurrent fault movement, which triggered low-grade regional metamorphism that altered previously deposited sediments. (Lumbanbatu *et al*, 2009). The Sibolga Complex features the Sibolga granitoid, which outcrops on the west coast of Sumatra, approximately 300 km from the Eastern Province Granite of the Malay Peninsula. Based on texture and mineralogical identification, the Sibolga granitoid complex has four facies: biotite granite, biotite syenite, hornblende syenite, and metavolcanic rocks. Toba Tuff is characterized by a light grayish-brown color, is hard and non-friable, and appears brownish-yellow. Toba Tuff is the result of volcanic eruptions from Mount Toba and consists of rhyodacitic tuff, partially explained, dating back to the Pleistocene epoch. (Sembiring *et al.*, 2023).

Parmonangan District is the result of extensive rock weathering found on top of granitic igneous rocks with a wide distribution, known as exposed Sibolga Granite (Vansla et al., 2023). Granitic rocks are acidic plutonic rocks with phaneritic granularity, containing quartz, alkali feldspar, and plagioclase (Streckeisen, 1976).

Land Cover

The land cover from Landsat 8 imagery for 2016 and 2024, using a color composite, shows that the geological and geomorphological conditions of the

Parmonangan area are predominantly covered by forest and vacant land (Figures 3 and 4). Cloud cover and shadow observed in the imagery indicate a tropical region with high rainfall, which impacts the weathering process of outcrop rocks (Fauzi, M.*et,al* , 2022).

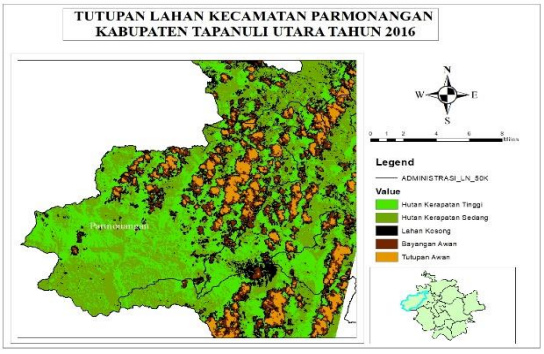

Figure 3. Land Cover Map of 2016 for Parmonangan District

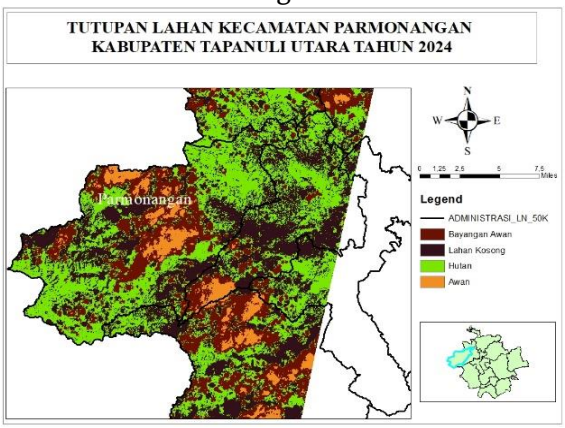

Figure 4. Land Cover Map of 2024 for Parmonangan District

The processed data shows that the land cover in 2016 consisted of forest with high to moderate density. By 2024, the forest cover has decreased, and vacant land cover has increased compared to 2016.

Parmonangan District, with its hilly and valley topography and temperatures ranging from 12°C to 28°C, has high cloud cover and shadow. The high cloud cover is caused by the climate and rainfall, which affect surface or exposed rocks, leading to weathering. Weathering of volcanic soil parent material (as a natural influence) and anthropogenic activities contribute to the enrichment of compounds or elements in the soil (Rahmatsyah, et al., 2020)Parmonangan features granite that has undergone weathering (Badan Pusat Statistik Kabupaten Tapanuli Utara, 2023) in the northern region with a northwest direction. The weathering of granitoid originates from biotite and hornblende granite (Hidayati, A. *et al.*, 2022).

Weathering produces laterite, which undergoes instability due to water to form new, more stable minerals. Laterite is a component with economic value, including LTJ (Evans, 1993). The developing laterite is of the oxide type.

X-Ray Fluorescence

The X-Ray Fluorescence method is used for the qualitative and quantitative determination of elements in rocks. The content and elements of the rocks determine the formation and presence of rare earth metals. The results from the X-Ray Fluorescence S6 Jaguar Bruker are used to identify elements in oxide form. The dioxide compounds from the samples are identified along with the concentration of compounds and elements in the rocks. The concentration of major compounds and elements in the rock samples is presented in Table 1.

Table 1. Analysis of Rock Compounds and Elements

Compound	Concentration (%)	Element	Concentration (%)
Na_2O	0,00	Na	0,00
MgO	0,00	Mg	0,00
Al_2O_3	25,31	Al	13,4
SiO_2	24,97	Si	11,67
P_2O_5	0,00	P	0,00
K_2O	1,56	K	1,29
CaO	0,00	Ca	0,00
TiO_2	0,81	Ti	0,49
Mn_2O_3	0,66	Mn	0,46
Fe_2O_3	4,66	Fe	3,26
ZrO_2	0,21	Zr	0,16
Sb_2O_3	0,16	Sb	0,14
BaO	0,17	Ba	0,15

Geochemical minerals decrease as a result of the weathering of biotite granite, including Na_2O, SiO_2, P_2O_5, and K_2O in the soil, showing a reduction in mineral content compared to the parent rock, as soil exhibits mobile properties. The composition of SiO_2 (24.97%) and Al_2O_3 (25.31%), which is higher than Fe_2O_3 (4.66%), indicates that the rock sample is a weathered granitic igneous rock formed on the continent(Ngadenin, *et al.*, 2020). The higher composition of SiO_2

(24.97%) compared to the low P_2O_5 (0.00%) indicates the accumulation of silica minerals, which carry rare earth elements, while phosphate minerals carrying rare earth elements are found in smaller quantities. The composition of Al_2O_3 and Fe_2O_3 represents the residual elements during weathering, thus their higher concentrations (Hidayati et al., 2020). The low concentrations of Na_2O, MgO, CaO, and K_2O in weathered rocks are due to the solubility of Ca, Na, Mg, and K during the weathering process.

CONCLUSION AND SUGGESTION

Conclusion

The conclusions drawn from the analysis and discussion are as follows:

1. The rock distribution in the Parmonangan area includes the Kluet Formation, Sibolga Complex, and Toba Tuff. The Kluet Formation consists of quartz sandstone, claystone, siltstone, and conglomerate sandstone. The Sibolga Complex features textures and mineralogy with four facies: biotite granite, biotite syenite, hornblende syenite, and metavolcanic rocks. Toba Tuff is characterized by a light grayish-brown color, hardness, and a brownish-yellow, non-friable appearance.
2. In 2016, the land cover included forests with high and moderate density. By 2024, forest cover decreased, while vacant land increased. High cloud cover is caused by the climate and rainfall, which affect surface or exposed rocks, leading to weathering. Weathering of volcanic soil parent material (as a natural influence) and anthropogenic activities contribute to the enrichment of compounds or elements in the soil.
3. The concentration of major compounds and elements in granitic rocks includes Al_2O_3 (25.31%), SiO_2 (24.97%), K_2O (1.56%), TiO_2 (0.81%), Mn_2O (30.66%), and Fe_2O_3 (4.66%).ZrO_2, (0,21), Sb_2O_3 (0,16), and BaO (0,17).

Suggestion

It is suggestion to use Landsat 8 data with cloud cover below 20% to ensure a more accurate land cover analysis.

REFERENCES

Akmalia, A. R., Hidayat, B., & Arif, J. (2017), Identification And Classification of Igneous Rock Based on Texture Using Discrete Cosine, 1915–1922, E-Proceeding of Engineering, 4(2), pp. 1915–1922.

Bahar, H., (2016), Analisis Citra Satelit Penginderaan jauh Lansat 8 untuk Identifikasi Kondidi Geologi Wilayah Vulkanik, Tesis, Fakultas Teknik Sipil dan Perencanaan ITS, Surabaya.

BPS (2023) Kecamatan Parmonangan *2023*, Badan Pusat Statistik KabupatenTapanuli Utara.

Evans, A.M. (1993), Ore Geology and Industrial Minerals: An Introduction, *Blackwell* Publishing: Oxford.Maulana, A. 2017, Endapan Mineral. *Yogyakarta: Penerbit Ombak* [Preprint].

Fauzi, M.Utama H.W, Said. Y.M., (2022), Pengkayaan Unsur tanah Jarang Sc-Y pada endapan laterit pulau Sebuku Provinsi Kalimantan Selatan, Jurnal Teknik Kebumian, 8(1).

Hidayati, A.N., Basuki, N.I, Sulaeman, Sayekti, B., (2022), Distribusi Unsur Utama dan Unsur Tanah Jarang pada Pelapukan Batuan Granitoid di Daerah Parmonangan, Kabupaten Tapanuli Utara, Buletin Sumber Daya Geologi, 17(3).

Kisman and Widodo, W., (2011), Eksplorasi Umum Logam Tanah Jarang (REE) Timah di Kabupaten Tapanuli Utara Provinsi Sumatera Utara. Pusat Sumber Daya Geologi.

M.Lumbanbatu, U. *et al.,* (2009), Pengaruh Tektonik Pada Runtunan Endapan Aluvial Depresi Padangsidempuan, Sumatera Utara, ***Jurnal Geologi dan …***, 19(3), pp. 153–165.

Ngadenin, Karunianto, A.J., Indrastomo, F D., (2020), Penentuan Daerah Prospek

Logam tanah Jarang di pulau Singkep, *Eksplorium*, 42(1), pp. 15–24.

Mahendra, F. H. M., (2015), Accessory minerals in Granitic Rocks.

Rahmatsyah, Juliani, R., Nursyirwan., Lubis, R.H., (2020), Fisika Lingkungan. Bandung12.: Cv. Media Sains Indonesia.

Sembiring, G.N. *et al.,* (2023), Identifikasi Batuan dan Tanah pada Kawasan Longsor di Desa Naman Teran Kabupaten Karo Provinsi Sumatera Utara, VIII(2), pp. 5643–5649.

Widiyastuti, D.A., (2016), Analisa struktur batuan dari Sungai Aranio Kabupaten Banjar menggunakan X-ray Difraction, Jurnal Sains dan Terapan, 04(April), pp. 8–14.

Vansla, T., Rahman, H.A., HAR, R., Fahilah., (2023), Kajian Potensi Logam Tanah Jarang pada Batupasir Formasi Ombilin atas dan Formasi Ombilin Bawah Menggunakan analisis x-ray fluorescence. Jurnal Bina Tambang, Vol 8 (2), 146-153.