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Research Article

Alteration and Mineralisation of Sulphide Deposits in The Lipukasi Area, Barru Regency, South Sulawesi Province

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Abstract: In the Lipukasi area, Barru Regency, South Sulawesi Province, sulphide deposits and complex alteration processes have been discovered. However, information regarding the alteration and mineralisation that has developed in this area is not yet available, so further research is needed to identify the types of alteration and mineralisation present in the Lipukasi area, Barru Regency, South Sulawesi Province. The purpose of this study was to determine the type of hydrothermal alteration and mineralisation that developed in the study area. The analytical method used in this research first carried out megaskopis analysis to determine the physical properties of the sample. After that, laboratory analyses of mineragraphy and X-Ray Diffraction (XRD) were carried out. The results of megascopic analysis of the two research samples are an igneous rock with a fresh grey colour, a weathered yellowish-brown colour, a massive structure, an intermediate rock type, a crystalline texture, namely holocrystalline, a granularity, namely phaneroparabolic, a relationship, namely equigranular, and a crystal shape, namely euhedral. The minerals found from the results of mineralographic and XRD analysis are Hematite, mafic mineral, goethite, silica mineral, sulphide mineral (galena, chalcopyrite, pyrite, covellite), quartz, and kaolinite. So it can be concluded the minerals found in the study area are hematite (Fe_2O_3), mafic minerals, silica minerals, goethite (FeO_2H), galena (PbS), covellite (CuS), chalcopyrite ($CuFeS_2$), pyrite (FeS_2), kaolinite and quartz (SiO_2). Based on the indicated mineral composition, the type of alteration that developed in the study area is propylitic.

Keywords: Hydrothermal alteration, Mineralisation, Sulphide deposits, Mineragraphy, XRD.

1. Introduction

Indonesia is a country with diverse natural resources, both metallic and non-metallic. Metallic minerals are often referred to as ores because they have economic value that can be extracted and processed for use according to their intended purpose. Ore minerals are often found in sulphide deposits, both high sulphide and low sulphide.

In general, the formation of both metallic and non-metallic minerals is the result of mineralisation caused by heat from hydrothermal solutions reacting with wall rocks along fractures, resulting in changes in mineralogical composition commonly referred to as alteration [1]. Factors that influence the hydrothermal alteration process include fluid chemistry, temperature, pressure, parent rock composition, duration of hydrothermal activity, and permeability. Although these factors are interrelated, temperature and fluid chemistry are the dominant factors that influence hydrothermal changes [2], [3]. An alteration zone is a specific zone that shows the distribution of a particular group of minerals formed as a result of the alteration process [4].

Previous research on the types of alteration and mineralisation in sulphide deposits, particularly in Sulawesi, has been conducted and focused on the Cindakko area, Maros Regency, South Sulawesi. In this area, various sulphide minerals have been found, such as pyrite, chalcopyrite, sphalerite, galena, bornite, tenanite, tetrahydrite, arsenopyrite, and covellite. The types of alteration identified are propylitic and advanced argillaceous [5].

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In the Lipukasi area, Barru Regency, South Sulawesi Province, sulphide deposits and complex alteration processes have also been found. However, information regarding the alteration and mineralisation that has developed in this area is not yet available, so further research is needed to identify the types of alteration and mineralisation present in the Lipukasi area, Barru Regency, South Sulawesi Province.

2. Methodology

This research began with direct sampling of rock outcrops in the study area. The type of sample taken was a chip sample of 2 samples weighing about 2 kilograms. Sampling in the field is in the form of hand specimens [6-8]. In addition to collecting samples at several points were also made on the geological conditions around the study area, and descriptions of rock samples to obtain information in the form of rock position, direction of rock distribution, outcrop coordinates, and mineral content of rocks megascopically [9]. The sampling pattern is a random stratified. Samples that have been obtained in the field are then prepared to be sent to the laboratory [10], [11].

The analytical method used in this study was macroscopic analysis to determine the physical characteristics of rocks exposed in the study area, such as colour, texture, rock type, and so on. In addition, mineralographic analysis was carried out to determine the mineral content in samples from the study area. Furthermore, testing was carried out using the X-ray diffraction (XRD) method to determine the mineral composition of the samples. Based on Bragg's Law, diffraction data were used to calculate the distance between atomic planes that produced a certain angle magnitude [10]. Most explanations of XRD discuss techniques for analysing and identifying the crystalline phases of materials. The crystalline form varies greatly in each material or mineral, so this is used as an anomaly characteristic of certain minerals [11]. The entire analysis of both Mineragraphy and XRD was carried out at the Rock Preparation Laboratory, Department of Geological Engineering, Faculty of Engineering, Hasanuddin University.

3. Results and Discussion

3.1 Megascopic Analysis

Megascopic analysis is aimed at analysing the physical characteristics of rocks, such as: colour, texture, mineral composition that can be seen with the eye, and so on [12]. This analysis used two rock samples found at the study site. Megascopically, the two samples are characterised as follows.

3.1.1. Sample 1

Macroscopically, sample 1 is an igneous rock with a fresh grey colour, a weathered yellowish-brown colour, a massive structure, an intermediate rock type, a crystalline texture, namely holocrystalline, a granularity, namely phaneroparabolic, a relationship, namely equigranular, and a crystal shape, namely euhedral. Its mineral composition is plagioclase, quartz, and clay minerals such as kaolinite. The rock name is Quartz Diorite Porphyry [13]. The appearance of sample 1 can be seen in Figure 1.

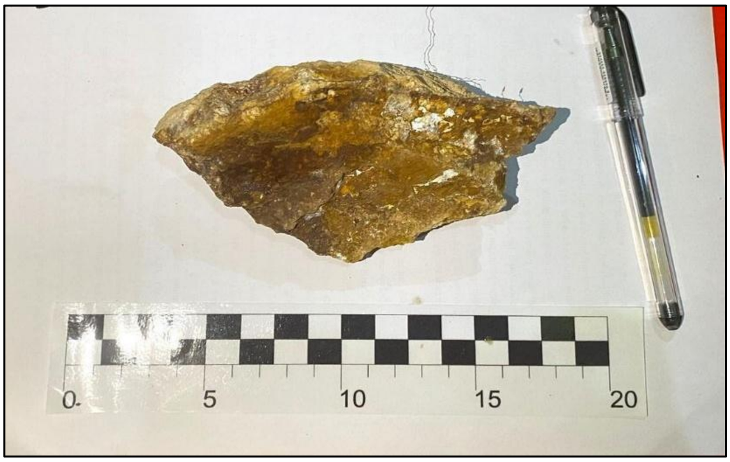

Figure 1. The appearance of sample 1

3.1.2. Sample 2

Macroscopically, sample 2 is a type of igneous rock, which has a fresh grey colour, weathered brown colour, massive structure, intermediate rock type, texture crystallinity, namely holocrystalline, granularity, namely fanero porphyritic, relation, namely equigranular, and crystal shape, namely euhedral. Its mineral composition is plagioclase, quartz and pyroxene. The rock name is Quartz Diorite Porphyry [13]. The appearance of sample 2 can be seen in Figure 2.

Figure 2. The appearance of sample 2

3.2 Mineragraphy Analysis

Mineralographic analysis was conducted using a Nikon Eclipse LV 600D polarising microscope to identify rock-forming minerals, secondary minerals, and the relationships between minerals or rock textures. Mineralographic analysis is conducted to determine the minerals contained in a sample using a polarising microscope. A polarising microscope can also identify mineral textures through thin sections of rock samples [14].

3.2.1. Sample 1

Based on mineralographic analysis, the minerals in sample 1 are dominated by hematite (Fe_2O_3), goethite (FeO_2H), galena (PbS), chalcopyrite ($CuFeS_2$), pyrite (FeS_2), and quartz (SiO_2). The crystal size ranges from 0.02 to 0.14 mm. Sulfide minerals in the form of galena, covellite, chalcopyrite, and pyrite were formed from hydrothermal processes that created epithermal deposits and filled the edges of quartz veins (characterised by crustiform or colloform textures). The presence of hematite and goethite minerals in these rocks was caused by mineralisation processes in mafic minerals, followed by hydrolysis and oxidation processes (Figure 3).

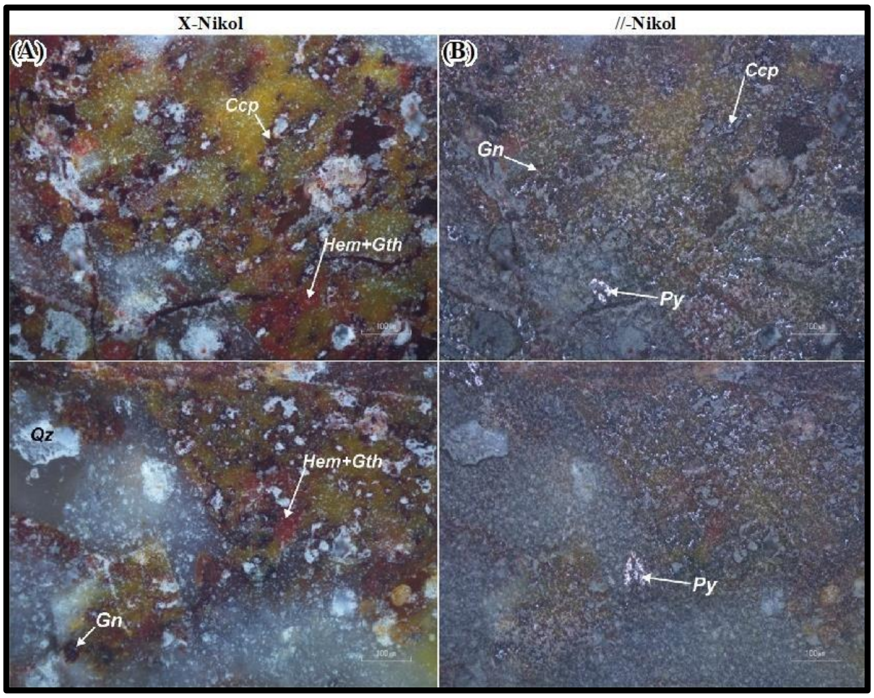

Figure 3. (A) Photomicrograph of Sample 1 (X-Nikol). (B) Photomicrograph (//-Nikol) showing a collection of hematite (Hem), goethite (Gth), galena (Gn), chalcopyrite (Ccp), pyrite (Py) and quartz (Qz) minerals.

In Figure 3, the minerals found in the sample can be described as follows:

a. Hematite (Hem): Yellowish to pale yellow in colour, no pleochroism (-), anisotropic, and brownish-red internal reflections.
b. Goethite (Gth): Brown to reddish in colour, no pleochroism (-), generally acicular in shape, irregular crystal form with finer grain size, and red internal reflections.
c. Galena (Gn): reddish brown to black in colour, isotropic, no pleochroism (-), and blackish red internal reflections.
d. Chalcopyrite (Ccp): yellow to golden in colour, no pleochroism (-), anisotropic, and no internal reflections.
e. Pyrite (Py): Pale yellow in colour, no pleochroism (-), anisotropic, and no internal reflections.
f. Quartz (Qz): Transparent (colourless), no pleochroism (-), sub-anhedral in shape, conchoidal fracture, and no internal reflections.

Hematite minerals are formed from the mineralisation of mafic minerals, which then undergo oxidation and form goethite. Cracks in the rock are then filled with silica minerals, followed by the formation of sulphide minerals. This is indicated by the appearance of galena, chalcopyrite, and pyrite on the edges of gangue minerals and quartz veins.

3.2.2. Sample 2

Based on mineralographic analysis, the minerals in sample 2 are dominated by hematite (Fe_2O_3), goethite (FeO_2H), galena (PbS), covellite (CuS), chalcopyrite ($CuFeS_2$), pyrite (FeS_2), and quartz (SiO_2). The crystal size ranges from 0.02 to 0.27 mm. Sulphide minerals such as galena, covellite, chalcopyrite, and pyrite were formed from hydrothermal processes that created epithermal deposits and filled the edges of quartz veins (characterised by crustiform or colloform textures). The presence of hematite and goethite minerals in these rocks is due to the mineralisation process in mafic minerals, followed by hydrolysis and oxidation processes (Figure 4).

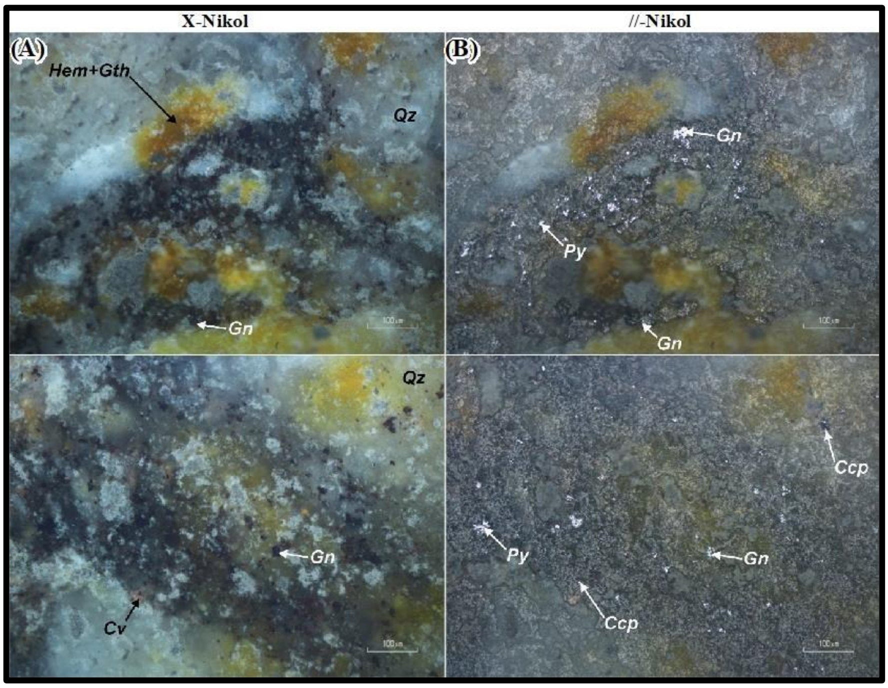

Figure 4. (A) Photomicrograph of Sample 1 (X-Nikol). (B) Photomicrograph (//-Nikol) showing a collection of hematite (Hem), goethite (Gth), galena (Gn), covellite (Cv), chalcopyrite (Ccp), pyrite (Py) and quartz (Qz) minerals.

In the image above, the minerals contained in the sample can be described as follows:

a. Hematite (Hem): Yellowish to pale yellow in colour, no pleochroism (-), anisotropic, and red internal reflection.
b. Goethite (Gth): Pale brown to reddish in colour, no pleochroism (-), generally acicular in shape, irregular crystal form with finer grain size, and red internal reflection.
c. Galena (Gn): Purple-brown to black in colour, isotropic, no pleochroism (-), and blackish-red internal reflections.
d. Covellite (Cv): Brownish-yellow to reddish in colour, no pleochroism (-), low intensity, isotropic, and reddish-yellow internal reflections.
e. Chalcopyrite (Ccp): Yellow to golden in colour, no pleochroism (-), anisotropic, and no internal reflections.
f. Pyrite (Py): Pale yellow in colour, no pleochroism (-), anisotropic, and no internal reflection.
g. Quartz (Qz): Transparent (colourless), no pleochroism (-), sub-anhedral in form, conchoidal fracture, and no internal reflection.

3.3 X-Ray Diffraction Analysis

XRD analysis was conducted to determine the mineral content of rock samples. Minerals that are not visible microscopically were then analysed using the XRD (X-Ray Diffraction) method. The working principle of the mineralogical analysis method known as XRD (X-ray diffraction) is to use Xrays originating from metals with specific wavelengths, thereby forming a detectable angle of light reflection. According to Bragg's law, diffraction data is used to calculate the distance between atomic planes that produce a certain angle [15]. Most explanations of the XRD technique are aimed at analysing and identifying the crystal phase of a material. Crystal forms vary greatly in each material or mineral, so they are used as characteristic anomalies of certain minerals [16].

3.3.1. Sample 1

The XRD analysis results for sample 1 show the presence of alteration minerals such as: Kaolinite (62.6%), Quartz (35.3%), and Iron oxide hydroxide Goethite (2.2%). The diffractogram for sample 1 can be seen in Figure 5.

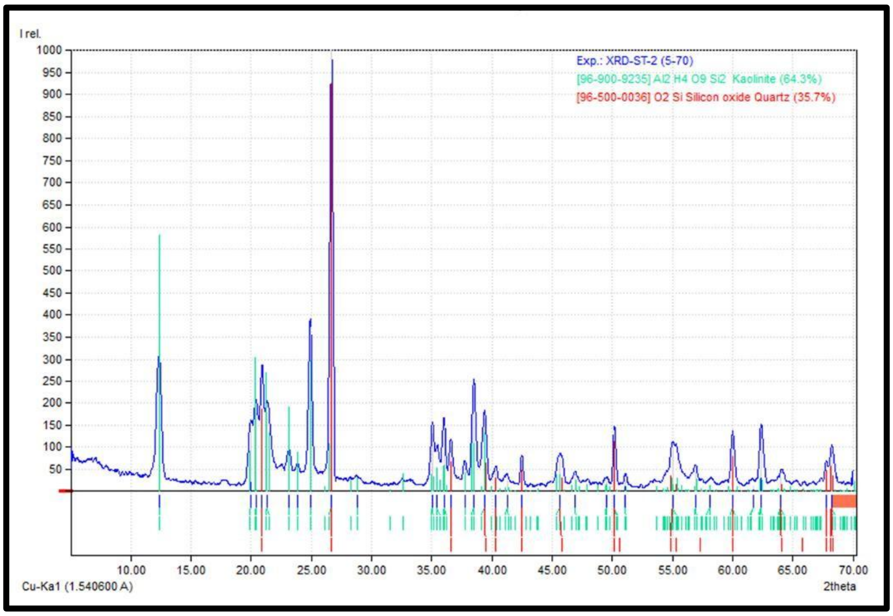

Figure 5. X-Ray Diffraction (XRD) graph of sample 1

3.3.2. Sample 2

The XRD analysis results for sample 2 show the presence of alteration minerals such as aolinite (64.3%) and silicon oxide quartz (35.7%). The diffractogram for sample 2 can be seen in Figure 5.

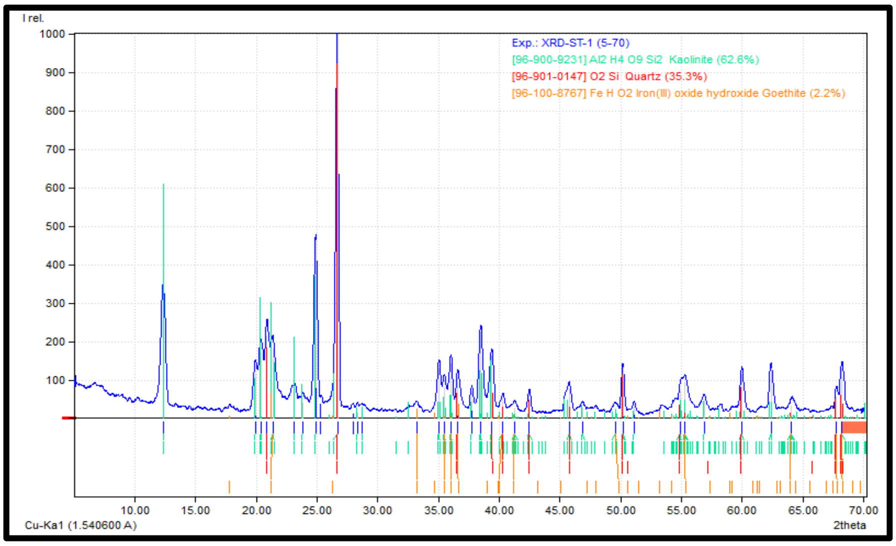

Figure 6. X-Ray Diffraction (XRD) graph of sample 2

3.6 Type of Alteration

Based on the results of mineralographic and XRD analyses, a collection of minerals was found in the study area, namely hematite (Fe_2O_3), mafic minerals, silica minerals, goethite (FeO_2H), galena (PbS), covellite (CuS), chalcopyrite ($CuFeS_2$), pyrite (FeS2), kaolinite and quartz (SiO2). These minerals can be classified into two main groups: ore minerals and alteration minerals.

Ore minerals are minerals that contain metals of economic value that can be extracted. In the study area, examples of ore minerals found include galena (PbS) as the main ore mineral for lead, covellite (CuS) as a copper ore mineral that usually forms as an alteration product of primary copper minerals, chalcopyrite ($CuFeS_2$) often found in various hydrothermal deposits as the main ore mineral for copper, pyrite (FeS_2), which although generally considered a gangue mineral, can contain small amounts of gold or silver, giving it economic value in some deposits, and hematite (Fe_2O_3), a primary ore mineral required in the metal industry, often formed under oxidative conditions as a result of the alteration of other iron minerals [17].

In addition, there are also alteration minerals formed as a result of mineralogical changes through interaction with hydrothermal fluids or specific geochemical conditions. For example, the mineral hematite (Fe_2O_3) often forms in oxidative conditions as a result of the alteration of other iron minerals. Mafic minerals that can be altered to chlorite or epidote in hydrothermal processes also fall into this category. Silica minerals, including quartz (SiO_2), often form in hydrothermal veins as a result of silica precipitation from hydrothermal fluids. goethite (FeO_2H) is formed as a result of the alteration of iron minerals such as pyrite in an oxidative environment, while kaolinite is a clay mineral formed through weathering and hydrothermal alteration in an acidic environment.

Hydrothermal alteration types are generally classified into several types based on the alteration mineral assemblage. The results of the analysis then show that several minerals can be classified as characteristics of alteration types. Based on the presence of existing alteration minerals, the alteration mineral assemblage and alteration type can be tabulated based on the alteration type diagram [2] as shown in Table 1. The alteration type that developed in the study area was propylitic.

Table 1. Mineral Alteration Assemblages and Alteration Types

No	**Name**	**Mineral Assemblages**		**Mineral Main**	**Alteration Type**
		Mineragraphy	**XRD**		
1.	Sample 1	Hematite, mafic mineral, goethite, silica mineral, sulphide mineral (galena, chalcopyrite, pyrite) and quartz.	Kaolinite, quartz and goethite.	Kaolinite, quartz, and pyrite.	Propylitic
2.	Sample 2	Hematite, Mafic mineral, goethite, silica mineral, sulphide mineral (galena, covellite, chalcopyrite, pyrite) and quartz.	Kaolinite and quartz	Kaolinite, pyrite and quartz	Propylitic

Mineragraphy is the analysis of ore/metal minerals using a reflected light microscope, which provides results on ore mineral types, ore texture, grain size and shape, while XRD is an instrumental method for identifying minerals based on their crystal structure through X-ray diffraction patterns, which yields the following results: Identification of crystalline minerals (ore & non-ore), diffraction peaks (2θ and intensity), crystal structure information, and mineral percentage. Therefore, a combination of mineralography and XRD is necessary for comprehensive ore analysis results.

4. Conclusion

Based on the research conducted, the following conclusions can be drawn: The minerals found in the study area are hematite (Fe_2O_3), mafic minerals, silica minerals, goethite (FeO_2H), galena (PbS), covellite (CuS), chalcopyrite ($CuFeS_2$), pyrite (FeS_2), kaolinite and quartz (SiO_2). Based on the indicated mineral composition, the type of alteration that developed in the study area is propylitic.

5. References

[1] Pirajno, Franco. 2009. *Hydrothermal Processes and Mineral Systems. Springer – Geological Survey of Western* Australia, Perth, Australia Barat.

[2] Corbett G.J, Leach T.MA.1996. *Southwest Pacific RimGold-Copper System: Structure,Alteration and Mineralization. Workshop in* Jakarta, Indonesia.

[3] Maulana, A., 2017. Endapan Mineral. Yogyakarta: Penerbit Ombak.

[4] Lowell, J.D., Guilbert, J.M., 1970. Lateral and vertical alteration mineralizationzoning in porphyry ore deposits. Economic Geology, 65, 373-408.

[5] Arif, A., (2020). Studi Alterasi Dan Mineralisasi Endapan Tipe Urat Daerah Cindakko Kabupaten Maros Provinsi Sulawesi Selatan: Implikasinya Terhadap Genetik Dan Eksplorasi (Disertasi Doktor, Universitas Hasanuddin).

[6] Hakim, M. M. Al, Idrus, A., Suryanto, W., Raharjanti, N. A., Ananke, P. D., Ernowo, E., Pardiarto, B., 2024. Ore characteristics and distribution based on geological and geophysical features of the Tambang Sawah low sulfidation epithermal gold prospect in Lebong District, Sumatra Island, Indonesia. Iraqi Geological Journal, 57(2B), 219–239. https://doi.org/10.46717/IGJ.57.2B.15MS-2024-8-25.

[7] Wakila, M. H., Nompo, S., Jafar, N., Thamsi, A. B., Munir, A. S., Heriansyah, A. F., 2024. Analysis of cobalt distribution and Co-Ni correlation in nickel laterite zonation in tropical region. Iraqi Geological Journal, 57(2B), 205–218. https://doi.org/10.46717/IGJ.57.2B.14MS-2024-8-24.

[8] Thamsi, A. B., M. H. Wakila., Ahmad. L., & Aswadi, M., Geochemistry of Iron Ore in Kadong-Kadong, South Sulawesi, Indonesia, 58(1D), 1-17. https://doi.org/10.46717/igj.2025.58.1D.1.

[9] Wakila, M. H., Chalik, C. A., Asmiani, N., Munir, A. S., Idris, M., & Juradi, A. (2021). Quality Analysis of Limestone as Cement Raw Material in Waangu-angu Area, Kab. Buton Prov. Journal of GEOSAPTA Vol.7(1).

[10] Dong, R., 2021. The geology, magnetite geochemistry, and oxygen isotopic composition of the Akesayi skarn iron deposit, Western Kunlun Orogenic Belt, Xinjiang, north west China: Implications for ore genesis. Ore Geology Reviews, 130. https://doi.org/10.1016/j.oregeorev.2020.103854

[11] Wang, C.L., 2022a. Genesis of the Kiruna-type Nixintage iron deposit, Chinese Western

Tianshan, NW China: Constrains of ore geology, geochemistry and geochronology. Journal of Geochemical Exploration, 243. https://doi.org/10.1016/j.gexplo.2022.107094.

[12] Wakila, M. H., Heriansyah, A. F., Rizky Nurul Aulia, & Muhaimin, A. (2025). Mineralogy and Geochemistry of Copper Deposits in Samaenre Village, Tonra Sub-District, Bone District, South Sulawesi Province. *Cognitia : International Engineering Journal*, *1*(2), 69-76. https://doi.org/10.63288/ciej.v1i2.8

[13] Fenton, C.L. 1940. The Rock Book. New York: Doubleday and Compony, Inc.

[14] Thamsi, AB, Aswadi, M., Anwar, H., Bakri, H., Wakila, MH, & Heriansyah, AF (2020). Karakteristik Mineraloid Opal Limbong, Kabupaten Luwu Utara,

[15] Fatimah, NF dan Utami, B., (2017). Sintesis dan analisis Spektra IR, difraktogram XRD, SEM pada bahan katalis berbahan Ni/zeolit alam teraktivasi dengan metode impregnasi.JC-T (Jurnal Cis-Trans): Jurnal Kimia dan Terapannya,1(1).

[16] Heriansyah., (2018), "Identifikasi Fitur Thermal Berdasarkan Zona Mineralisasi Dengan Menggunakan Data Citra Aster Dan Analisis Xrd Di Lapangan Panas Bumi Wayang Windu, Jawa Barat", Institut Teknologi Bandung.

[17] Ferial, D., Natalisanto, A.I. and Lazar, P.A. (2019) 'Identifikasi Sebaran Mineral Bijih Besi Dengan Menggunakan Metode Resistivitas Dan Induced Polarization (Ip) Di Kecamatan Muara Uya, Kabupaten Tabalong, Provinsi Kalimantan Selatan', Jurnal Geosains Kutai Basin, 2(2).