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GEOCHEMICAL SURVEY FOR DETERMINING GOLD CONTENT USING X-RAY DIFFRACTION METHOD IN GUNONG UJEUN OF KRUENG SABEE DISTRICT ACEH JAYA

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ABSTRAK: Survei geokimia dilakukan untuk mendeteksi kandungan dari berbagai jenis mineral yang ada. Identifikasi emas pada batuan dari lokasi penambangan emas rakyat di Gunong Ujeun, Krueng Sabee, Aceh Jaya telah dilakukan menggunakan metode *X-Ray Diffraction* (XRD). Pada penelitian ini, proses identifikasi mineral dilakukan pada beberapa lokasi di Krueng Sabee. Sampel batuan yang terkumpul diproses untuk mendapatkan bubuk berbutir halus yang sesuai untuk dianalisis. Selanjutnya sampel tersebut dianalisis kadar emasnya menggunakan alat *X-Ray Diffractometer*. Data pengujian menggunakan XRD kemudian dianalisis menggunakan aplikasi Match!3. Mineral utama yang diidentifikasi dalam sampel batuan termasuk kuarsa, illit, magnetit, zircon, albit, dan hastingsit. Mineral-mineral ini umumnya terkait dengan mineralisasi emas. Hasil analisis menunjukkan bahwa kandungan emas tertinggi terdapat pada lokasi BT-02 dengan kadar 1,746% dan lokasi terendah yaitu lokasi BT-04 dengan kadar 0,029%. Pengujian dilakukan menggunakan Cu-Ka dengan panjang gelombang 1,542 Å. Hasil akhir tersebut diinterpretasikan dalam bentuk peta kadar emas.

Kata kunci: Kandungan emas; Krueng Sabee; Silika; Survei Geokimia; *X-Ray Diffraction*

ABSTRACT: Geochemical surveys have been conducted to detect the content of various types of minerals. The identification of gold in rock from the traditional gold mining in Gunong Ujeun, Krueng Sabee, Aceh Jaya using X-Ray Diffraction (XRD) method has been carried out. In this study, the mineral identification process was conducted at several locations in Krueng Sabee. The collected rock samples were processed to obtain fine-grained powder suitable for analysis. Subsequently, the gold content in the samples was analyzed using X-Ray Diffractometer. The XRD data were then analyzed by Match!3 software. The main minerals identified in the rock samples included quartz, illite, magnetite, zircon, albite, and hastingsite. These minerals are commonly associated with gold mineralization. The results indicate that the highest gold content was found in sample BT-02 at 1.746%, while the lowest was in sample BT-04 at 0.029%. The test was conducted using Cu-Ka with a wavelength of 1.542 Å. The final results was interpreted as a gold grade map.

Keywords: Geochemical Survey; Gold content; Krueng Sabee; Silica; X-Ray Diffraction

1. INTRODUCTION

Surveys are crucial in mining processes. Good surveys yield good results, which in turn dictate the actions to be taken in the mining process. One emerging survey method is geochemical survey. Geochemical surveys are vital in mining, guiding actions based on their results. One such method, geochemical surveying, utilizing chemical analyses to identify anomalies hinting at potential mineralization. This approach,

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complemented by geological data, aids in prospecting for mineral-rich areas. By understanding the concentration and migration of mineral, geochemical surveys facilitate targeted exploration efforts. Techniques include soil and water sampling, chosen based on survey objectives and area characteristics. These surveys have advanced mineral exploration significantly, with applications ranging from identifying mineral deposits to environmental assessments.

Assistance from other survey method data is crucial, especially geological data. After a survey stage is completed, evaluation is necessary for decision-making in the subsequent actions [1]. Detailed measurements can be performed to obtain several element dispersions, known as anomalies, with the hope of indicating economic mineralization [2]. Geochemical anomalies are abnormal concentrations of certain elements that contrast sharply with their environment, believed to indicate the presence of mineral deposits or ores. Nonlinear properties have been observed in the distribution of geochemical anomalies in secondary media such as river sediments, soils, tills, and water caused by various mineralization processes [3]. The formation of these anomalies is caused by the mobility and dispersion of concentrated elements in mineralization zones [2].

The predetermined target areas are usually divided into intervals with the help of Geographic Information System, and these intervals are determined based on exploration knowledge. For example, alteration around rock samples that can be used to determine the minimum distance boundary, or using variogram method for geostatistical reasons [4]. Knowledge about the geology or geophysics of an area emerges from new maps whether they are self-conducted mapping or Geological Survey maps [5].

Geochemical exploration has played a significant role in mineral discoveries [6]. It plays a critical role in the discovery of unknown mineral deposits [7]. Geochemical exploration fundamentally consist of two methods: those using mechanical dispersion patterns and those based on chemical dispersion pattern recognition. Mechanical dispersion patterns are usually applied to minerals that are relatively stable. For groundwater flow, molecular diffusion typically becomes a factor in low pore water velocities such as in dense soil or clay; mechanical dispersion geerally dominates species transport [8]. Chemical dispersion patterns are less apparent compared to mechanical dispersion [1].

According to the basic principles of geochemistry in surveys, knowing the concentration of metals and compounds in ore deposits is essential. Geochemical prospecting is the earth science that applies the knowledge of geochemistry to discover mineral deposits, through the study of the primary and secondary dispersion of elements, lithogeochemistry, stream sediments, surface water, solid, and other methods [9]. Geochemical surveys can provide tangible benefits in technological advancements towards a better understanding of mineral migration. Geophysical data needs to be integrated with other exploration methods such as drilling, sampling, and geochemical analysis to overcome various limitations [10]. Thus, understanding of mineral migration has improved. The distribution of clay minerals around rocks can provide information about burial depth, thermal history, fluid interactions, significant factors in formation, and hydrocarbon migration [11].

Geochemical survey techniques encompass various methods, including soil, water, and sampling, as well as the analysis of vegetation, and even the use of aerial surveys. Samples such as bedrocks, sediments, soils, drill cores, and water samples are collected depending on the type of the study being conducted [12]. There are three main applications of geochemistry in the mining indutsry: (1) Geochemical chemistry; (2) Geometallurgy

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(mining geochemistry); (3) Environmental geochemistry. These three applications have different objectives, but their techniques and applications are almost the same [13]. During the last three decades, ming geochemistry methods have been applied to recognize geochemical anomalies related to blind mineralization, mineral prospect mapping, and gold mineralization.

Gold, being one of the most sought-after metals, has been the focus of numerous geochemical surveys worldwide. Gold ores containing carbon are also known as refractory ores and are difficult to process because part of the gold is bound to organic matter and the dissolved gold is adsorbed by the carbon present in the pore [14]. The presence and concentration of gold in the rock samples were determined through X-ray diffraction analysis. Conventional X-ray methods cannot be used to study the disorder between isoelectronic ions such as Pb and Bi; however, anomalous dispersion diffraction methods can distinguish between these two elements [15].

In general, atomic, mass, and nuclear analytical techniques used to determine the concentrations of major, minor, trace, and ultra-trace elements/isotopes in geological material have undergone significant advancements [16]. In crystallography, the wavelength used ranges from 0.5 to 2.5 Å [17]. XRD provide insights into the composition of rock. The XRD method is widely used for identifying the existing phases (qualitative analysis) and for determining their respective quantities (quantitative analysis) [18].

Based on the previous explanation, this study aims to identify and analyze the presence of gold deposits collected from different locations in Gunong Ujeun. The distribution of gold content across the study area is mapped based on the analysis results. The geological significance of the identified minerals and their association with gold mineralization in Gunong Ujeun are also assessed.

2. RESEARCH METHOD

2.1 Sample Collection

The study was conducted on artisanal mining located in Gunong Ujeun, Krueng Sabee District, Aceh Jaya Regency, Aceh Province in October (Figure 1). Predetermined measurement locations were found using the correlation between Global Positioning System (GPS) and Google Earth maps. Geochemical surveying involves the systematic collection and analysis of geological samples, namely rocks, to determine the distribution of chemical elements in particular area.

Figure 1. Location map of the research

2.1 Sample Collection

Rock sample was collected from several gold processing locations. Rocks can be collected by hand in ecavations [19]. Sampling was done at several different locations as much as possible until a sufficient sample was obtained at each location. After obtaining rock samples, separation was done between fine-grained and coarse-grained rocks using a sieve with a minimum 200 mesh. Screening was done until only fine-grained samples were obtained. After obtaining fine-grained rock samples, samples were taken from large rocks. Then, large rocks were first reduced in size using a geological hammer, after which these small-sized rocks were crushed to a finer form. The finely sized rocks were then taken to the laboratory to be ground into 40 g powder using a ball mill, which

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would then be analyzed using XRD method.

2.2 Laboratory Analysis

Measurements are performed at the tekMIRA (Mineral and Coal Technology Research and Development Center) Mineral Physics Testing Laboratory using the Phylips PW3710 BASED X-Ray Diffractometer. The use of XRD in sample allows the phases and contents of various samples to be tested, but to determine their percentage content, additional analysis using the Match!3 application is required. After analysis using the XRD instrument, the results would be used in the next stage, which was the creation of geochemical survey distribution maps. These surveys help identify anomalies or abnormal concentrations of elements that may indicate the presence of mineral deposits.

3. RESULTS AND DISCUSSION

In this study, geochemical methods are applied, considering the use of geochemical surveys suitable for gold mining areas, especially in artisanal mining. In the Gunong Ujeun mining area, the use of chemicals such as cyanide and mercury, which can be harmful to the surrounding environment, was found, but in this geochemical survey, the author focused only on rock geochemistry and active river sediment geochemistry. The application of geochemical methods in this study is because the author will examine the chemical properties of gold-bearing rocks from mining locations in Gunong Ujeun, Krueng Sabee District, Aceh Jaya Regency.

3.1 Mineral Composition

After the process of taking samples with rock geochemical surveys, the rocks will ground into powder. This will be followed by testing using the XRD instrument. Analysis is carried out step by step for each sample from each measurement point location.

Gold is often associated with specific minerals known as gold-bearing minerals. Gold-bearing minerals are usually associated with gangue minerals such as quartz, carbonate, pyrite, chalcopyrite, arsenopyrite, sphalerite, galena, tourmaline, fluorite, and illite. They are also associated with oxidized sulfide deposits, and for a clearer understanding of the minerals contained in rocks from the artisanal mining locations of Krueng Sabee, they can be seen in Table 1. Based on the analysis results of several sample points, it is generally found that the main content of rocks from mining locations in Gunong Ujeun is quartz and illite.

Table 1. XRD Test Results

Sample Code	Mineral Composition
BT-01	Quartz, Illite
BT-02	Quartz, Magnetite, Zircon, Albite, Hastingsite
BT-03	Quartz, Illite, Ankerite
BT-04	Quartz, Illite
BT-06	Quartz, Albite, Illite
BT-07	Quartz, Albite, Hastingsite, Illite

According to Agency of Personnel and Human Resource Development [20], the geological structure of the Aceh Jaya region is composed of various types of rocks, especially metamorphic rocks and tuff, including the Krueng Sabee area, which is one of the mineral-rich areas in Aceh Jaya. Observations from locations BT-01 to BT-07 also indicate that generally in artisanal mining locations in Krueng Sabee, the rocks consist of quartz. By identifying the mineral in rock samples, it can be inferred the potential presence of gold in the area. The identification of the mineral also can the types of geological environments conducive to gold deposition.

a. Mineral Content

The results of processing the six sample points through Match!3 are shown in Figures of 2 to 7.

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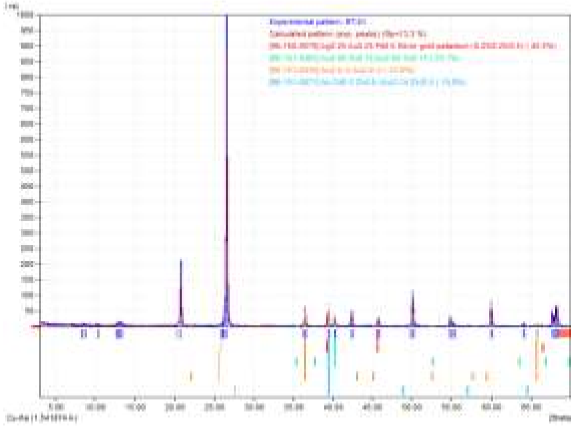

Figure 2. Curve of sample BT-01 analysis results

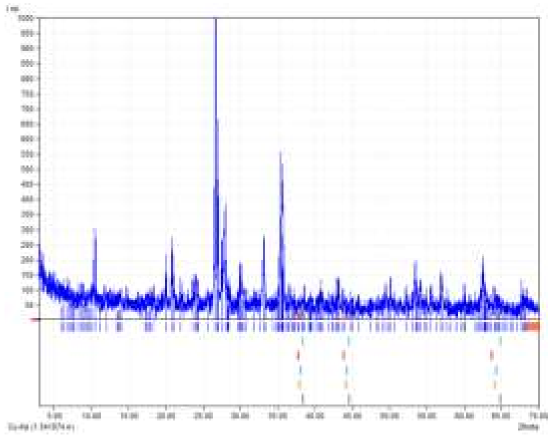

Figure 3. Curve of sample BT-02 analysis results

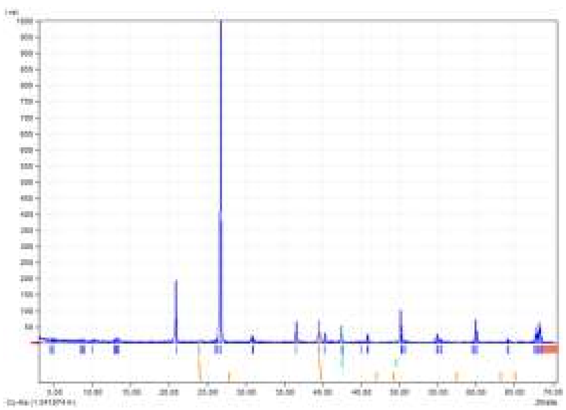

Figure 4. Curve of sample BT-03 analysis results

Geographically, the BT-01 sample is located at coordinates 4°40'30.30" North Latitude and 95°43'17,20" East Longitude.

Table 2. Diffraction Data on Sample BT-01

Data	Number of Particles	Content (%)
Overall particles	76682	100.000
Scattered radiation	18785	24.500
Number of peaks	57897	75.500
Selected peak particles	288	0.375
Particle peak A (Gold)	115	0.150
Particle peak B (Gold)	68	0.090
Particle peak C (Gold)	63	0.090
Particle peak D (Gold)	42	0.040

Table 3. Diffraction Data on Sample BT-02

Data	Number of Particles	Content (%)
Overall particles	50544	100.000
Scattered radiation	24500	48.470
Number of peaks	26044	51.530
Selected peak particles	883	1.746
Particle peak A (Gold)	270	0.540
Particle peak B (Gold)	249	0.490
Particle peak C (Gold)	180	0.360
Particle peak D (Gold)	184	0.360

The location is an area dominated by quartz and illite rocks, and the measurement results for point BT-01 are shown in Table 2.

Geographically, the BT-02 sample is located at coordinates 4°40'21.65" North Latitude and 95°43'41.96" East Longitude. It is a new mining location with a depth of about 5.5 meters. This location is very rich in various types of minerals but is generally dominated by quartz, magnetite, zircon, albite, and hastingsite minerals. The measurement results for point BT-02 are shown in Table 3.

Geographically, the BT-03 sample is located at coordinates 4°41'0.38" North Latitude and 95°40'51.57" East Longitude. The sample is taken from active river sedimentation dominated by quartz, illite, and ankerite rocks. The measurement results for point BT-03 are shown in Table 4.

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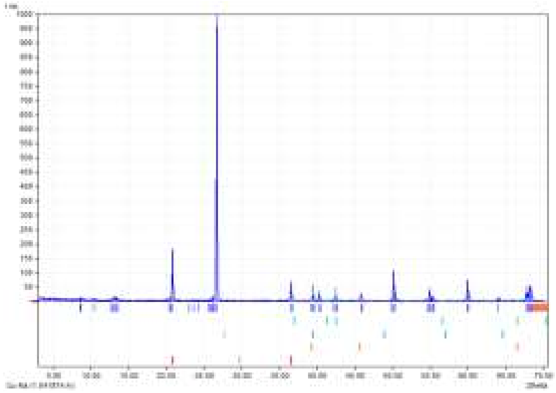

Figure 5. Curve of sample BT-04 analysis results

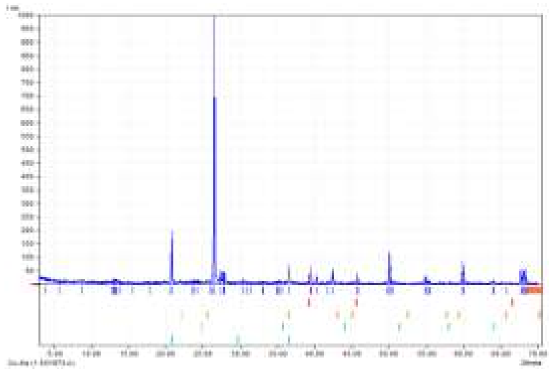

Figure 6. Curve of sample BT-06 analysis results

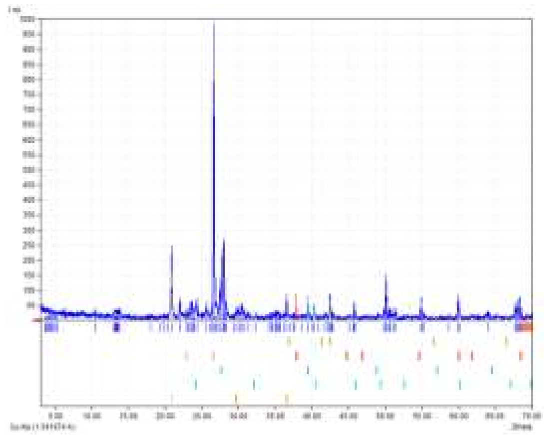

Figure 7. Diffraction data on sample BT-07

Geographically, the BT-04 sample is located at coordinates 4°40'11.67" North Latitude and 95°40'25.30" East Longitude. The sample is taken from active river sedimentation dominated by quartz and illite rocks. The measurement results for point BT-04 are shown in Table 5.

Table 4. Diffraction Data on Sample BT-03

Data	Number of Particles	Content (%)
Overall particles	70124	100.000
Scattered radiation	19147	27.300
Number of peaks	50977	72.700
Selected peak particles	52	0.074
Particle peak A (Gold)	29	0.040
Particle peak B (Gold)	23	0.030

Table 5. Diffraction Data on Sample BT-04

Data	Number of Particles	Content (%)
Overall particles	74774	100.000
Scattered radiation	17972	24.040
Number of peaks	56802	75.960
Selected peak particles	22	0.029
Particle peak A (Gold)	8	0.010
Particle peak B (Gold)	14	0.020

Table 6. Diffraction Data on Sample BT-06

Data	Number of Particles	Content (%)
Overall particles	65062	100.000
Scattered radiation	23288	35.790
Number of peaks	41774	64.210
Selected peak particles	258	0.396
Particle peak A (Gold)	115	0.170
Particle peak B (Gold)	99	0.150
Particle peak C (Gold)	44	0.060

Geographically, the BT-06 sample is located at coordinates 4°40'35.12" North Latitude and 95°42'40.15" East Longitude. The sample is taken from an artisanal mining location dominated by quartz, albite, and illite rocks. The measurement results for point BT-06 are shown in Table 6.

Geographically, the BT-07 sample is located at coordinates 4°40'48.33" North Latitude and 95°42'43.68" East Longitude. The sample is taken from an artisanal mining location dominated by quartz, albite, hastingsite, and illite rocks. The measurement results for point B-07 are shown in Table 7.

Table 7. Diffraction Data on Sample BT-07

Data	Number of Particles	Content (%)
Overall particles	68756	100.000
Scattered radiation	25782	37.500
Number of peaks	42974	62.500
Selected peak particles	774	1.126
Particle peak A (Gold)	275	0.400
Particle peak B (Gold)	251	0.360
Particle peak C (Gold)	161	0.230
Particle peak D (Gold)	90	0.130

Table 8. Gold Content in Each Rock Sample

Sample Name	Mass (g)	Content (%)	Gold Content (g)
BT-01	40	0.375	0.1500
BT-02	40	1.746	0.6984
BT-03	40	0.074	0.0296
BT-04	40	0.029	0.0116

The results obtained for all samples are shown in Table 8. After samples from each loation are tested using RD and analyzed using Match!3 software, the test results are interpreted in the form of a map for easier observation. The map-making process uses ArcGIS 10.5 software, and the gold content from each location can be seen in Figure 8. By mapping the distribution of gold-bearing minerals and their associated gangue minerals, it can be identified prospective areas for further exploration. Areas showing favorable mineral assemblages and geological characteristics can be prioritized for detailed exploration activities cush as drilling.

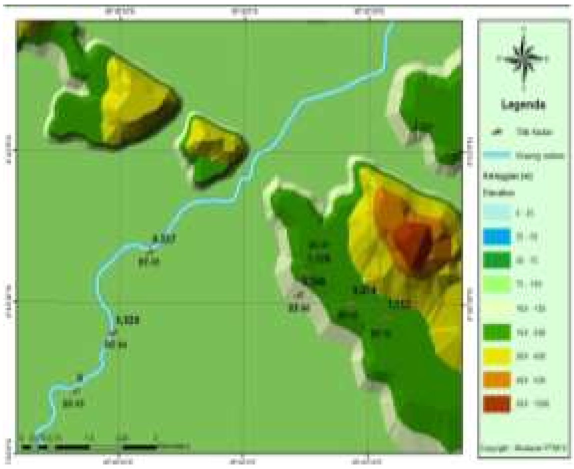

Figure 8. Map of gold content in artisanal mining of Krueng Sabee

4. CONCLUSION

The main minerals identified in the rock samples include quartz, illite, magnetite, zircon, albite, and hastingsite. The analysis revealed varying gold content in the rock samples. The highest gold content was found in sample BT-02 at 1.746%, while the kowest was in sample BT-04 at 0.029%. Active gold mines, particularly points BT-02 (1.746%) and BT-07 (1.126%), showed the highest gold content. Former mining locations, such as BT-01 (0.375%) and BT-06 (0.396%), exhibited lower gold content. Additionally, samples from active river sedimentation (BT-03 and BT-04) showed relatively low gold content. The XRD method was utilized to analyze the rock samples, with firther analysis conducted using Match!3 software to determine the mineral composition and percentage content of gold. The results of the analysis were interpreted to create a map depicting the distribution of gold content in the artisanal mining area of Krueng Sabee.

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6. REFERENCES

[1] Syahroni. Metode Analisis Geokimia. Universitas Islam Bandung. Bandung, 2010.

[2] Chaussier, J. B., Morer, J. Mineral Prospecting Manual. North Oxford Academic Publishers Ltd. London, 1987.

[3] Cheng, Q. Singularity theory and methods for mapping geochemical anomalies caused by buried sources and for predicting undiscovered mineral deposits in covered areas, *Journal of Geochemical Exploration*, 2012, 122, 55–70, doi: 10.1016/j.gexplo.2012.07.007.

[4] McClenaghan. Drift Exploration in Glaciated Terrain. The Geological Society London. London, 2001.

[5] Marjoribanks, R. Geological Methods in Mineral Exploration and Mining. Springer. Berlin, 2010.

[6] Xuegju, W., Bimin, Z., Xin, L., Shanfa, X., Wensheng, Y., Rong. Y. Geochemical challenges of diverse regolith-vovered terrains for mineral exploration in China, *Ore Geology Reviews*, 2016, 73 (3), 417–431 doi: 10.1016/j.oregeorev.2015.08.015.

[7] Zuo, X., Wang, J., Xiong, Y., Wang, Z. The processing methods of geochemicl exploration data: past, present, and future, *Applied Geochemistry*, 2021, 132, 105072 doi: 10.1016/j.apgeochem.2021.105072.

[8] Chen, J. S., Liu, C. W., Lai, G. X., Ni, C. F. Effects of mechanical dispersion on the morphological evolution of a chemical dissolution front in a fluid-saturated porous medium. *Journal of Hydrology*, 2009, 373, 96–102, doi: 10.1016/j.jhydrol.2009.04.014

[9] Carreno, J. L. M. Geochemistry applied to the exploration of mineral deposits, *Geochemistry and Mineral Resources*, IntechOpen Limited, London, 2022.

[10] Haritha, K. A review of recent advancements in geophysical technologies and their implications for mineral and hydrocarbon exploration, *ASEAN Journal fo Science and Engineering Materials*, 2023, 2(2), 95–108

[11] Wu, L. M., Zhou, C. H., Keeling, J., Tong, D. S., Yu, W. H. Towards an understanding of the role of clay minerals in crude oil formation, migration, and accumulation, *Earth-Science Reviews*, 2012, 115, 373–386, doi: 10.1016/j.earscirev.2012.10.001.

[12] Balaram, V. Current and emerging analytical techniques for geochemical and geochronological studies, *Geological Journal*, 2020, 1–60, 2020, doi: 10.1002/gj.4005.

[13] Kyser, K., Barr, J., Ihlenfeld, C. Applied geochemistry in mineral exploration and mining, *Elements*, 2015, 11(4), 241–246 doi: 10.2113/GSELEMENTS.11.4.241.

[14] Habashi, F. Gold – an historical introduction, *Gold Ore Processing*, 2016, 1–20,

[15] Ismunandar, Hunter, B. A., Kennedy, B. J. Cation disorder in the ferroellectric Aurrivillius phase $PbBi_2Nb_2O_9$: an anomalous dispersion X-ray diffraction study. *Solid State Ionics*, 2006, 112, 281–289 doi: https://doi.org/10.1016/S0167-2738(98)00222-7.

[16] Balaram, V., Subramanyam, K. S. V. Sample preparation for geochemical analysis: strategies and significance, *Advances in Sample Preparation*, 2022, 1, 100010 doi: 10.1016/j.sampre.2022.100010

[17] Pratapa, S. Difraksi Sinar-X. Institut Teknologi Sepuluh November, Surabaya, 2004.

[18] Epp, J. X-ray diffraction (XRD) techniques for materials characterization, *Materials Characterization Using*

Nondestructive Evaluation (NDE) Methods, 81–124, 2016, doi: 10.1016/B978-0-08-100040-3.00004-3

[19] Jacques, M. *In Situ Tests in geotechnical Engineering*, ISTE-Wiley, London, 2015.

[20] Jalil, Z., Sari, K., Safitri, R. Mineral composition in rock from gold mining areas at Gunong Ujeun Krueng Sabee Aceh Jaya, *Jurnal Natural*, 2013, 13 (1), 15–18