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Host-rock characteristics and geochemistry of the Rongkong Opal-C Mineraloid, North Luwu Regency, South Sulawesi Province, Indonesia

Introduction

Opal is found globally, with Australia now being the top producer of black opal. Other places where opal is found include America, Tanzania, Brazil, Mexico, East Africa, Indonesia and Tanzania (Federman 1990; Banerjee and Wenzel 1999; Lynne et al. 2005; Costanzo 2019; Štubňa and Hanus 2020). Opal is a gem included in the precious gems category (Boboň et al. 2011). One of the most famous and economically valuable opals is opal from Australia, *Cainozoic weathered profiles* (Watkins 1985; Olliver and Townsend 1993). Opals in Indonesia are found in the Banten Province, precisely in Lebak Regency. Vuggy in the rock is filled with colloidal silica and fossilized wood (Ansori et al. 2003; Ansori 2008, 2010).

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Opal is categorized as a mineraloid because its composition consists of silicates and does not have a crystal structure or can also be referred to as amorphous (Graetsch et al. 1994; Ansori 2010; Boboň et al. 2011). Almost all the opal-forming material comes from the weathering of the young mantle (Vysotsky et al. 2010). When viewed from the shape of the atomic structure, opal is categorized into three types, namely Opal C, Opal CT, and Opal A (Jones and Segnit 1971; Kano and Taguchi 1982; Kuramoto et al. 1992; Davies and Cartwright 2002; Lynne and Campbell 2004; Lynne et al. 2005; Jones and Renaur 2007; Day and Jones 2008; Wilson 2014; Megaw et al. 2018; Fröhlich 2020; Curtis et al. 2022). In the Rongkong area, Opals are found in volcanic igneous rock hosts, namely andesite rocks (Thamsi et al. 2021). Opal in the area is formed by hydrothermal action, like mineraloids in Nevada, USA and Reduzhone, Primorsky Krai, Russia. Mineral formation begins with the formation of the mineral's biotite, plagioclase, k-feldspar, muscovite, quartz and opal. The classification of opal in the Rongkong area is opal-C (Thamsi et al. 2021).

Opal is categorized as a gem with economic value in the opal mineraloid, so it is necessary to conduct more detailed research on the characteristics of opal found in the Rongkong area. The scientific information on opal mineraloids that still needs to be added is information regarding the morphology of hot rock and the geochemistry of Rongkong opal. Based on this, the researchers investigated the area by taking the research title on host-rock characteristics and geochemistry of the Rongkong opal-C mineraloid, North Luwu Regency, South Sulawesi Province.

1. Method

The sampling location is in Rongkong District, North Luwu Regency, South Sulawesi Province. The research was conducted in three stages: the data collection stage, the data analysis stage, and the conclusion drawing stage (Azarine et al. 2022). Sampling in the field was conducted by collecting data on opal outcrops found in the Rongkong District, North Luwu Regency, South Sulawesi Province. The number of samples obtained was three. The three samples were one host-rock sample and two opal mineraloid samples. The data obtained included host-rock data, samples, the megascopic identification of rocks in the field and the documentation of outcrops. Samples were taken from outcrops at the research location. The rock samples obtained were then sent to the laboratories of the Indonesian Muslim University and Hasanuddin University. Data analysis was performed using SEM-EDS (scanning electron microscopy – energy dispersive X-ray spectroscopy) analysis at the Indonesian Muslim University and XRF (X-ray fluorescence) analysis, and petrographic analysis at Hasanuddin University. SEM-EDS analysis was carried out to determine the morphology of the host-rock in the study area (Mishchenko 2012). XRF analysis was conducted to determine the geochemistry of opals in the study area (Munasir et al 2012; Silvia et al. 2020). Petrographic analysis was performed to identify the types of rocks in the study area. This analysis was also conducted at Hasanuddin University.

In the early stages, the researcher performed a literature study by looking for references to opal mineraloids in journals, books, and proceedings. The researcher conducted an overview of previous research journals that discussed opal mineraloids so that they could identify what had yet to be done by previous researchers. At the data collection stage, it was performed in the Rongkong District area, North Luwu Regency, South Sulawesi Province. The sample obtained is host-rock data, the place (container) for forming opal mineraloids. Sampling was also conducted on opal mineraloids found in the area. Coordinate data and documentation data were also taken to obtain location data and data to determine field conditions. After data collection, the next step was laboratory analysis: SEM-EDS analysis and XRF analysis. SEM analysis data EDS in the form of opal mineraloid morphology data and chemical composition. XRF analysis data is in the form of major element chemical data. After analyzing the samples at the SEM-EDS laboratory and the XRF laboratory, the data was processed to determine the morphology of the opal mineraloid host-rock and determining the elemental and compound composition of the opal mineraloid so that conclusions could be obtained to answer the research objectives.

2. Results and discussion

2.1. Geology of the Research Area

The rocks found in the Rongkong area are grouped into sixteen units from old to young, consisting of Malihan Rock (Km), Old Granite (Togt), Biotite Granite (Togb), Biotite Granodiorite (Tmgd), Porphyry Granite (Tmgp), Inseparable Volcanic (Ptlv), Sienite (Tps), Granodiorite (Tpgd), Granite – Aplit (Tpga), Diorite (Qd), Andesitic Lava Flows (Qla), Pyroclastic Falls (Qjp), Dasitic Lava Flows (Qld), Pyroclastic Flows (Qap), Lava Domes (Qkl), and Alluvium (Qal). A local geology map of the research area can be seen in Figure 1. In addition to andesitic lava flows, there is old granite (Tgogt). Microphotograph (petrography) of andesitic rocks can be seen in Figure 2. This granite is widely spread in the North Luwu district. There are three main faults in the study area. Hot springs, mountainous ridges, joints, marks, and rock-crushing zones exist. This indicates that the study area is a region that has the potential to contain opal mineraloid deposits (Thamsi et al. 2021). The study area includes a hilly zone with a gently sloping to slightly steep plain morphology. A large river in the research area is the Rongkong River. The river flows along the area of North Luwu Regency.

Most people use the land at the research location as plantation land and rice fields. Some of these areas remain in protected forest conditions. The site of the rock samples is in the mountainous region of Tana Masakke Rongkong, which is over an altitude of 1588 meters above sea level, with slopes that are not too steep or gentle. The sampling location can be seen in Figure 3.

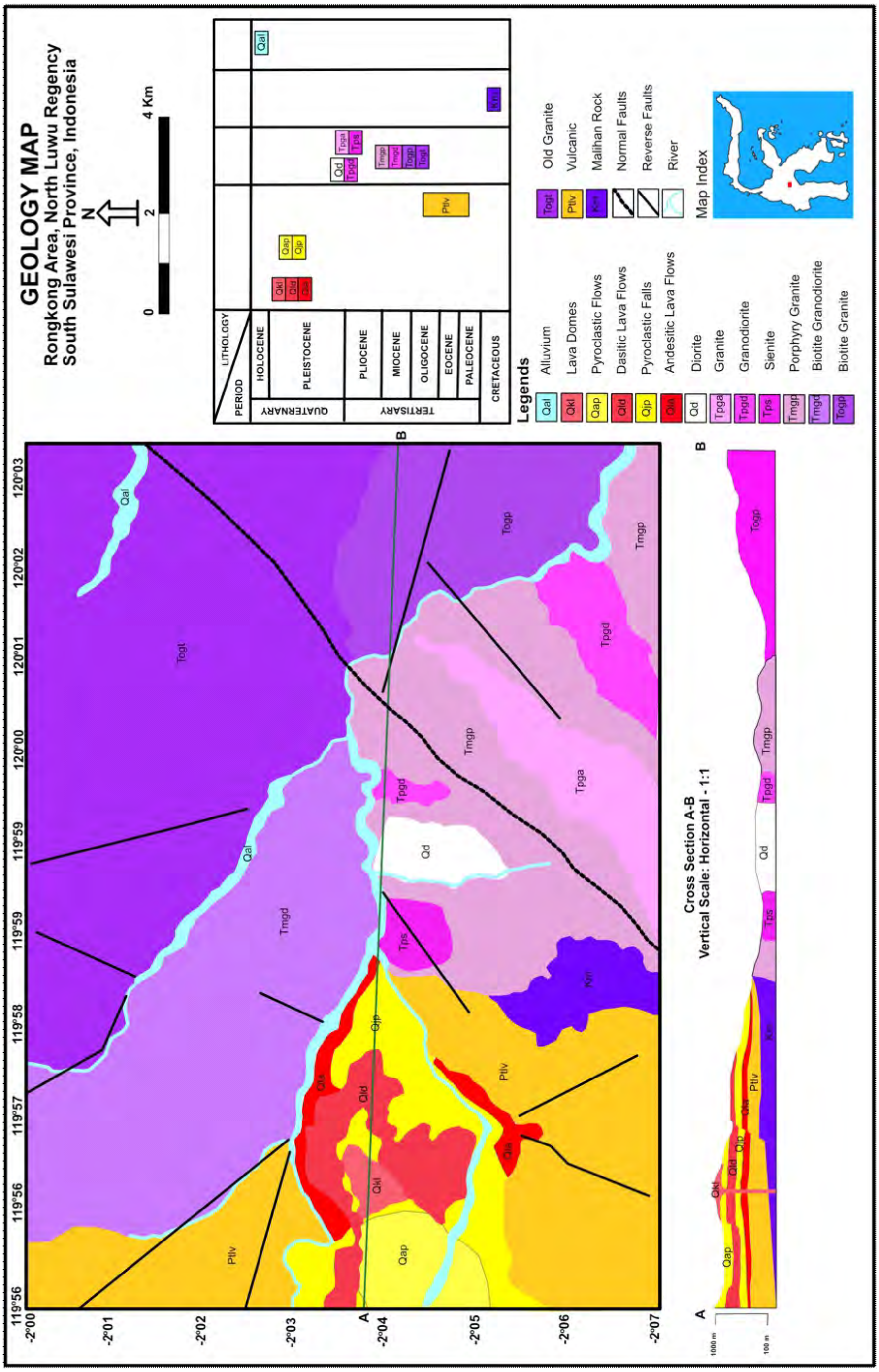

Fig. 1. Geology Map of Rongkong Area

Rys. 1. Mapa geologiczna obszaru Rongkong

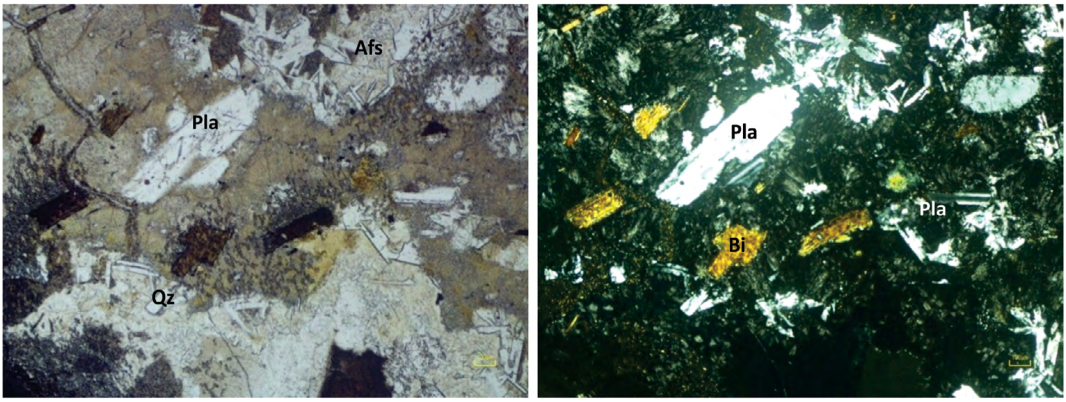

Fig. 2. Andesitic rock microphotograph (PPL and XPL)
Afs = K-Feldspar; Bi = biotite; Pla = plagioclase; Qz = quartz

Rys. 2. Mikrofotografia skał andezytowych (PPL i XPL)
Afs = skaleń K; Bi = biotyt; Pla = plagioklaz; Qz = kwarc

Fig. 3. Sampling location
Source: personal documentation

Rys. 3. Lokalizacja poboru próbek

2.2. SEM-EDS analysis

The results of this analysis are the sample images observed using a microscopic observer with magnifications of 1,000×, 5,000×, and 10,000× magnification in order to see the texture of the opal mineraloid-bearing rock samples in detail and detail. Scanning Electron Microscopy – Energy Dispersive X-ray spectroscopy analysis was conducted at the Muslim

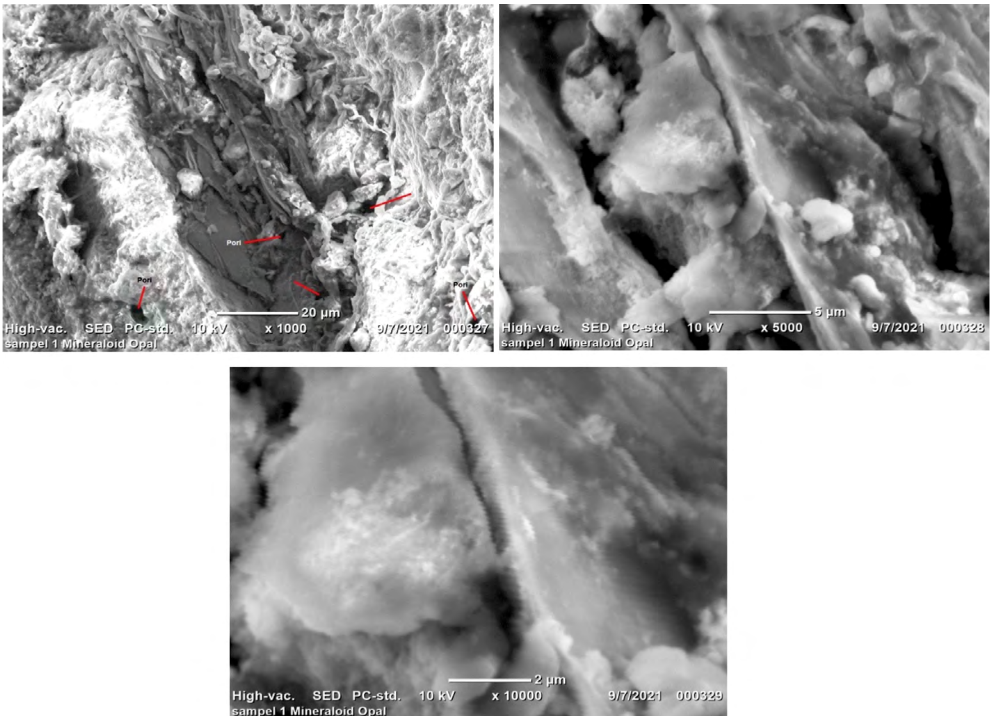

Fig. 4. Image of rock sample 1 with magnification of 1,000×, 5,000×, and 10,000×
Source: Indonesian Muslim University Laboratory

Rys. 4. Obraz próbki skały 1 w powiększeniu 1000×, 5000× i 10 000×

University of Indonesia Laboratory. Figure 4 shows a vuggy that can be filled with colloidal silica and fossilized wood.

Based on the results of observations at 1,000 times magnification, it is known that the opal mineraloid-bearing rock sample 1 consists of layers of plates with a grainy texture with non-uniform grain sizes. This is caused by forming less stable minerals, so the size distribution of minerals in opal mineraloid-bearing rocks is different and varied (Marlina et al 2015). The grain analysis in Figure 3 shows that the opal mineraloid carrier sample 1 consists of irregular plates with a thin thickness and is vuggy between the plates and the grains. With regard to size, it is still visible at a magnification of 5,000 times. The following image is a picture of the two rock samples bearing the opal mineraloid:

Energy Dispersive X-Ray Spectroscopy was characterized to determine the composition of elements and compounds found in opal mineraloid carrier rocks (Marlina et al 2015; Tutu et al. 2015; Walewangko et al. 2021). The obtained data states that most of the rock constituents of opal mineraloids are aluminum and oxide. This is the composition data of the elements Al and O, which are quite large. This could be due to the freezing and cooling of the magma during the formation of andesitic rocks, which are rich in Al and O minerals –

the biggest. The results of EDS showed that Al was 54.48%, O was 43.43%, Ca was 1.35%, and P was 0.74%. The results of the EDS analysis also provide information about the chemical composition of the rock containing the opal mineraloid as shown in Table 1 in sample 1 with the highest chemical compound composition being Al_2O_3 of 96.63%, CaO of 1.77% and P_2O_5 of 1.60%.

Table 1. Description of the photo-electron kinetic energy, mass percentage, and atoms of each element, sample 1

Tabela 1. Opis energii kinetycznej fotoelektronów, procentu masy i atomów każdego pierwiastka, próbka 1

Elements	Photo-Electron Oak (Kev)	Mass %	Atom %	Compound	Mass %
C	0.277	ND	ND	–	
O	0.525	43.43	56.66	–	
Al	1.486	54.48	42.14	Al_2O_3	96.63
P	2.013	0.74	0.50	P_2O_5	1.60
S	2.307	ND	ND	–	
Ca	3.690	1.35	0.70	CaO	1.77
Total	**10.298**	**100**	**100**		

Table 2. Mass Percentage (%) of each sample element 1

Tabela 2. Procent masowy (%) każdego pierwiastka próbki 1

Elements	Mass (%)
C	ND
O	43.43
Al	54.48
P	0.74
S	ND
Ca	1.35
Total	**100**

The analysis results on measurements at a magnification of 1,000 times showed that opal mineraloid-bearing rock sample 2 had a different microstructure from sample 1. Rock sample 2 consisted of a dominant layer of slabs lacking grain texture. This is also caused by good magma cooling so that the formation of minerals is relatively stable, and the process of forming and cooling minerals makes the crystalline state perfect (Silvia et al. 2020). The results of grain analysis using large measurements are presented in Figure 5; no gran-

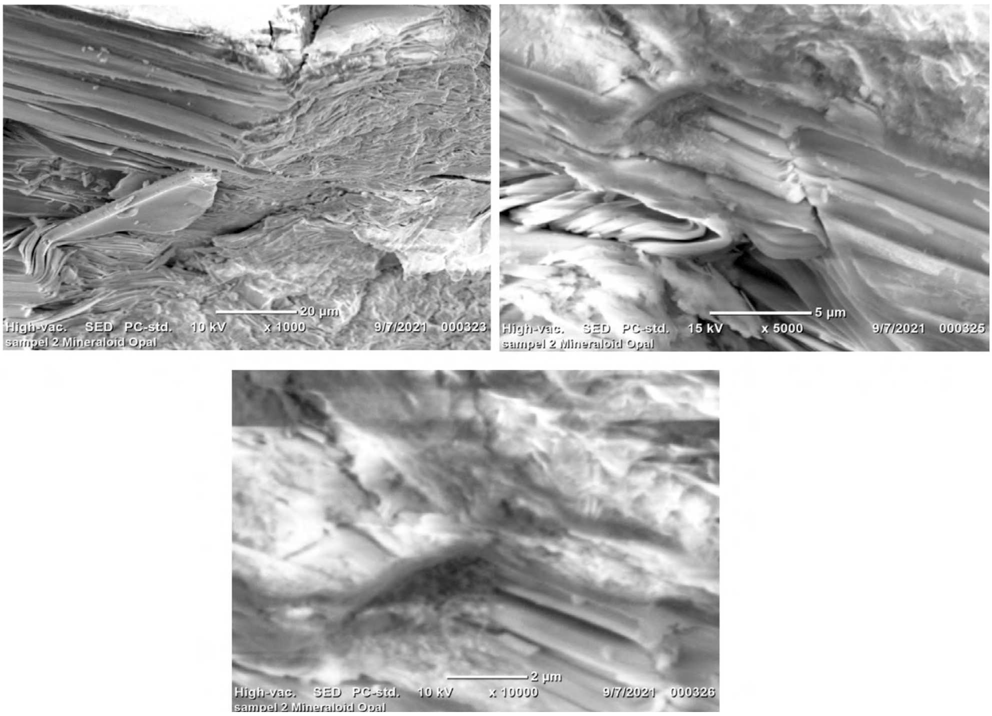

Fig. 5. Images of rock samples 2 with magnifications of 1,000×, 5,000×, and 10,000×
Source: Indonesian Muslim University Laboratory

Rys. 5. Obrazy próbek skał 2 w powiększeniach 1000×, 5000× i 10 000×

ular appearance was found. It is known that the rock containing opal mineraloid sample 2 consists of plates that are somewhat regular and thin, and there is no vuggy between the layers of the plates at 5,000 times magnification. Based on the results of SEM (Scanning Electron Microscopy) analysis, this is closely related to the type of rock that carries this opal mineraloid rock, which is a volcanic igneous rock with andesitic rock types that contain minerals such as plagioclase, biotite, k-feldspar, muscovite and quartz, which have a state of grain texture that is microscopically uneven and non-uniform.

In sample 2, there were differences in the EDS results on the effects of the elements and compounds present in the opal mineraloid carrier rock. The results of the EDS analysis of samples of two opal mineraloid-bearing rocks show that most of the opal mineraloid-bearing rock constituents are in the form of aluminum and oxide. This can be seen from the results of the content of Al and O, which is quite large. The largest peroxide compounds are alumina, phosphorus, and other impurities such as calcium and sulphur because the content of Al, P, Ca, and sulphur is the largest. The results of EDS show that the Al content is 45.17%, and O is 47.34%, P is 4.32%, S is 0.29%, and Ca is 2.88%. The results of the EDS analysis also provide information about the chemical composition of the opal mineraloid-bearing rock as

Table 3. Description of the photo-electron kinetic energy, mass percentage, and atoms of each element, sample 2

Tabela 3. Opis energii kinetycznej fotoelektronów, procentu masy i atomów każdego pierwiastka, próbka 2

Elements	Photo-Electron Oak (Kev)	Mass %	Atom %	Compound	Mass %
C	0.277	ND	ND	–	
O	0.525	60.86	72.98	–	
Al	1.486	33.57	23.87	Al_2O_3	85.34
P	2.013	3.21	1.99	P_2O_5	9.90
S	2.307	0.22	0.13	SO_3	0.73
Ca	3.690	2.14	1.02	CaO	4.02
Total	**10.298**	**100**	**100**		

Table 4. Mass Percentage (%) of each sample element 2

Tabela 4. Udział masowy (%) każdego pierwiastka próbki 2

Elements	Mass (%)
C	ND
O	60.86
Al	33.57
P	3.21
S	0.22
Ca	2.14
Total	**100**

shown in Table 2. In sample 2, the highest composition of chemical compounds was Al_2O_3 of 85.34%, P_2O_5 of 9.90%, CaO of 4.02% and SO_3 of 0.73%.

2.3. XRF analysis (X-Ray fluorescence)

Based on the opal mineraloid processing and analysis performed in the laboratory, the XRF analysis results were obtained for Rongkong Opal mineraloid samples. Determination of the chemical composition or major oxides was conducted using the XRF method with a detection limit of 0.001%. This analysis results in the percentage of elements in the form of oxide compounds. The following are the results of opal mineraloid samples:

Table 5. XRF analysis results

Tabela 5. Wyniki analizy XRF (fluorescencja rentgenowska)

Quantitative Result	
Analyte	Result
SiO_2	62.196%
Al_2O_3	27.057%
K_2O	5.132%
Fe_2O_3	2.399%
CaO	2.258%
TiO_2	0.506%
RuO_2	0.234%
SrO	0.071%
MnO	0.037%
V_2O_5	0.036%
Rb_2O	0.034%
Ag_2O	0.021%
CuO	0.019%

Based on the results of chemical analysis using the XRF method, the mineraloid opal gullet sample has a fairly high SiO_2 level of 62.196%. The percentage of chemical composition Al_2O_3 is 27.057%, and the chemical composition is K_2O with a percentage of 5.132%. Chemical composition of Fe_2O_3 with a percentage of 2.399%, the composition of CaO with a percentage of 2.258% and several other compounds for which the percentage is below 1%, such as TiO_2, RuO_2, SrO, MnO, V_2O_5, Rb_2O, Ag_2O and CuO. The chemical composition of Opal is silica which contains water and does not have crystals or is amorphous. This is why opal is categorized as a mineraloid.

Conclusions

The results of the characteristic SEM (Energy Dispersive X-Ray Spectroscopy) test analysis on samples 1 and 2 on opal mineraloid-bearing rocks showed that the microstructure of opal mineraloid-bearing rocks consists of plates that are arranged unevenly, and the grain size is not uniform and is varied.

The results of the SEM-EDS test analysis showed that the mineraloid carrier rock composed of opal is in the form of aluminum and oxide. This can be seen from the results of the content of Al and O, which is quite large. In sample 1, the Al content was 54.48%, O was 43.43%, Ca was 1.35%, and P was 0.74%, with the highest chemical composition of 96.63% Al_2O_3, 1.77% CaO and 1.60% P_2O_5. In sample 2 the content of Al was 33.57%, O was 60.86%, P was 3.21%, Ca was 2.14% and S was 0.22%, with the highest chemical compound composition being Al_2O_3 of 85.34%, P_2O_5 was 9.90%, CaO was 4.02% and SO_3 was 0.73 %.

The Rongkong opal mineraloid from Limbong Village, Rongkong District, North Luwu Regency, South Sulawesi based on the results of XRF (X-Ray Fluorescence) analysis, found that it contains 62.196% SiO_2, 27.057% Al_2O_3, 5.132% K_2O, 2.399% Fe_2O_3, 2.258% CaO, 0.506T% TiO_2, 0.234% RuO_2, 0.071% SrO, 0.037% MnO, 0.036% V_2O_5, 0.034% Rb_2O, 0.021% Ag_2O and 0.019% CuO. The dominant compound content in opal mineraloids is SiO_2, this is due to the enrichment of silicates in the process of forming opal mineraloids.

It is hoped that future research will conduct tracer element geochemistry by conducting ICP-MS (inductively coupled plasma mass spectrometry) analysis. This is performed to determine the overall geochemical characteristics of the opal mineraloids found in the study area.

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HOST-ROCK CHARACTERISTICS AND GEOCHEMISTRY OF THE RONGKONG OPAL-C MINERALOID, NORTH LUWU REGENCY, SOUTH SULAWESI PROVINCE, INDONESIA

Keywords

Opal-C, mineraloids, X-Ray fluorescence, Rongkong District

Abstract

Opal can be found in several locations, including America, Tanzania, Brazil, Mexico, East Africa, Indonesia and Australia, which is now the world's top producer of black opal. One of the most economically valuable gems in the world is the mineraloid opal. In the Rongkong area, opal is found in the host rock of volcanic igneous rock, namely andesite. This study aims to determine the opal mineraloid host-rock's microstructural characteristics and the elemental and compound content of the opal mineraloid host-rock's geochemistry in the Rongkong area, Indonesia. The research took three samples in the field as large as hand specimens. The three samples were one host-rock sample and two opal mineraloid samples; the samples were then prepared and analyzed in the laboratory. Laboratory analysis was performed using SEM-EDS, XRF and petrographic analyses. The results of the SEM-EDS test analysis showed that most opal mineraloid carrier rock constituents are aluminum and oxide. This can be seen from the substantial Al and O content. In samples 1 and 2, Al, O, Ca and P with the highest composition of chemical compounds are Al_2O_3, CaO, and P_2O_5. The Rongkong opal mineraloid from Limbong Village, Rongkong District, North Luwu Regency, South Sulawesi, based on the results of XRF analysis, contains the chemical compounds SiO_2, Al_2O_3, K_2O, Fe_2O_3, CaO, TiO_2, RuO_2, SrO, MnO, V_2O_5, Rb_2O, Ag_2O and CuO. The content compound that is more dominant in opal mineraloids is SiO_2 due to silicate enrichment in the forming of opal mineraloids.

CHARAKTERYSTYKA SKAŁY MACIERZYSTEJ I GEOCHEMIA MINERAŁOIDU RONGKONG OPAL-C, REGION PÓŁNOCNEGO LUWU, PROWINCJA POŁUDNIOWE SULAWESI, INDONEZJA

Słowa kluczowe

opal-C, mineraloidy, fluorescencja rentgenowska, okręg Rongkong

Streszczenie

Opal można znaleźć w kilku miejscach, w tym w Ameryce, Tanzanii, Brazylii, Meksyku, Afryce Wschodniej, Indonezji i Australii, która jest obecnie największym na świecie producentem czarnego opalu. Jednym z najcenniejszych ekonomicznie klejnotów na świecie jest opal mineraloidalny. W obszarze Rongkong opal znajduje się w skale macierzystej wulkanicznej skały magmowej, a mianowicie w andezycie. Niniejsze badanie ma na celu określenie charakterystyki mikrostrukturalnej skały macierzystej opalu oraz zawartości pierwiastków i związków w geochemii skały macierzystej opalu w obszarze Rongkong w Indonezji. W ramach badań pobrano w terenie trzy próbki wielkości próbek ręcznych. Trzy próbki stanowiły jedną próbkę skały macierzystej i dwie próbki mineraloidu opalu; próbki zostały następnie przygotowane i przeanalizowane w laboratorium. Analiza laboratoryjna została przeprowadzona przy użyciu SEM-EDS, XRF i analiz petrograficznych. Wyniki analizy testowej SEM-EDS wykazały, że większość składników skały nośnej opalu to aluminium i tlenek. Widać to po znacznej zawartości Al i O. W próbkach 1 i 2 Al, O, Ca i P o najwyższym składzie związków chemicznych to Al_2O_3, CaO i P_2O_5. Minerał opalowy Rongkong z Limbong Village, Rongkong District, North Luwu Regency, South Sulawesi, w oparciu o wyniki analizy XRF, zawiera związki chemiczne SiO_2, Al_2O_3, K_2O, Fe_2O_3, CaO, TiO_2, RuO_2, SrO, MnO, V_2O_5, Rb_2O, Ag_2O i CuO. Składnikiem, który jest bardziej dominujący w mineraloidach opalowych, jest SiO_2 ze względu na wzbogacenie krzemianów w tworzeniu mineraloidów opalowych.