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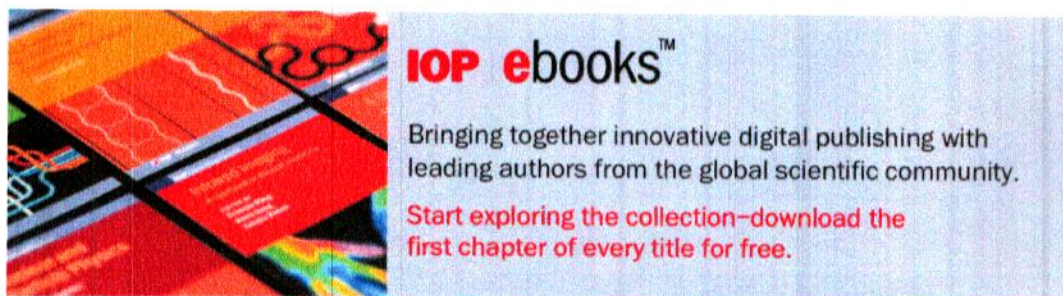
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Geochemical composition and morphology study of Major Minerals of Angus Stone from Gamalama Mountain, Ternate Island, Indonesia

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Abstract: This research is aimed to recognize the chemical composition, type, and main mineral morphology that are consisted in Batu Angus. The analytical methods used are X-ray Fluorescence (XRF), X-ray Diffraction (XRD), Fourier Transform Infra-Red (FTIR), and Scanning Electronic Microscopic (SEM). The result of the research showed that the chemical composition of Angus stone consists of silicone mineral and iron. The kind of silicone mineral is identified as mineral quartz, cristobalite, and tridymite while the iron mineral is identified as maghemite. The silicone mineral morphology has tetragonal, cubic, orthorhombic, hexagonal, and trigonal geometry shapes.

Keywords: Quartz, Cristobalite, Tridymite, Maghemite, Geometry

1. Introduction

Ternate is an island that is located in North Maluku. Within the island, there is Mount Gamalama which is an active volcano in the center of Ternate. The river flow pattern is a radial pattern where the main flow is more to the west compared to the other directions [1]. The mountain's height is around 1,715 meters above sea level, with eruption results that composed of basal to andesite [2]. The volcano has a volcanic cone shape which was formed from the sedimentation of volcanic eruption results with steep slope – slightly slanted [3].

The observation result through satellite imagery showed that Gamalama Volcano Eruption happened in the year of 1737, 1763, 1840, 1897, and 1907; with an accumulation of molten lava flow towards Kulaba beach and Angus Stone which are in the eastern part of Ternate Island [4]. The beach in the island is relatively narrow, with pebble-sized to fine sand sediment deposits. The black colored fine sand in the mentioned beach originated from volcanic material in form of lava flow [4]. One of the volcanism of Gamalama is the lava basalt flow. This kind of stone can be formed in the main lava plateau of the continent, in the bottom of the ocean, as well as in the rift valley part of the volcano [5]. This kind of stone is composed of fine-grained minerals which are commonly plagioclase calcic and mineral mafic such as clinopyroxene, but can also contain quartz, orthopyroxene, olivine, feldspathoid, Fe-Ti oxide, and apatite [6]. When the lava that forms this stone is solidified, a smooth surface (*ropy lava*) or the rough one called *scoriaceous*



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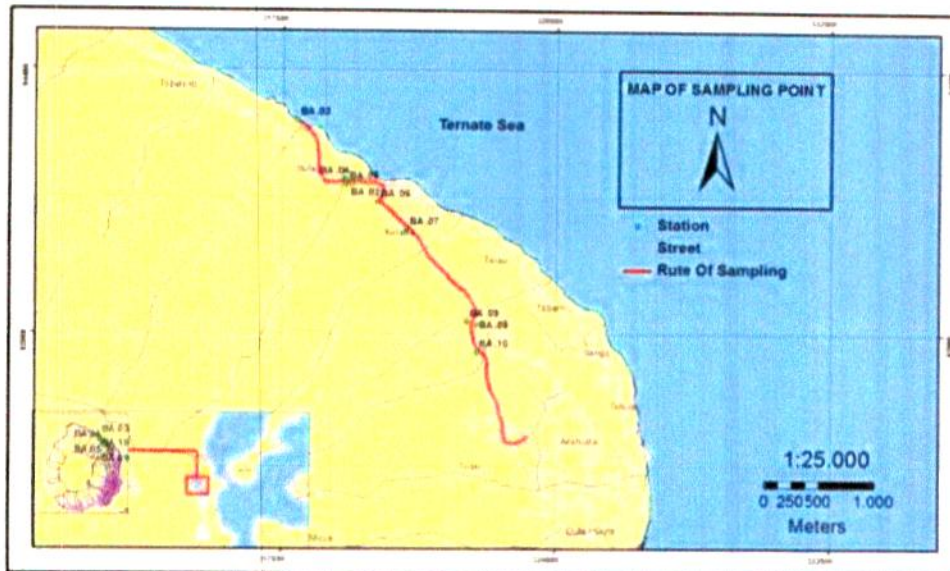
can be produced [7]. This kind of stone is called "Batu Angus (Angus Stone)" by the locals.

A number of research proved that the main content of basal stone or Angus stone obtained in Ternate island is consisted of steel (Fe) with the amount of 35% [8]. The high Fe content comes from olivine minerals $(Mg,Fe)_2SiO_4$ and pyroxene $((Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6)$ [9]. Other than the magnetic phase that consists of 20%, there is also domination from a non-magnetic phase (silicate phase) in Angus stone with element combination of Si-Al-K-Ca-O [8]. The characteristic of Angus stone magma is classified in andesite basaltic type with medium K magma affinity and the depth of stone formation is around 106 km [10].

Based on the elemental content of Angus stone, there is economic potential that can be used continuously [11]. An ordinary basal stone can be used as mineral fiber, insulation materials for derivative heat, for concrete stone, as well as raw material for road and building constructions [12, 13, 14]. The utilization of this stone is related to the physical and chemical characteristics of the stone itself. The existence of high iron content up to 35% as mentioned before [8] is a factor that underlies the importance of conducting a detailed research about geochemical and mineral characteristic. The insufficiency in information about characteristics and quality of Angus stone is a reason why this research needs to be conducted. The aim of this research is (i) to find out the chemical composition and kind of mineral consisted in Angus stone, (ii) and to know the mineral morphology contained in Angus stone.

2. Methodology

Angus stone sample is obtained from the lava flow area in the foot of mount Gamalama in sampling point location AB.03, AB.05, and AB.10 (Picture 1). That stone sample is then ground and filtered using mesh 400 filter. Next, the filtered sample is partially taken and put into mortar cup before crushed until it becomes as smooth as clay. From there, that part of sample is taken and put into disk mold for pellet manufacturing and pressed using hydraulic pump; where the scale on the lever is set for the thickness and then pressed. After that, the sample is used for analyzing using X-Ray Fluorescence (XRF), X-Ray Diffractometry (XRD), Fourier transform infra-red (FTIR) instruments that is carried out in the Science Building at Faculty of Mathematics and Natural Sciences University of Hassanudin (UNHAS), and the Scanning Electron Microscopic (SEM) analyzing is conducted in Chemical Engineering of Sepuluh Nopember Institute of Technology (ITS).



Picture 1. Location map of the sampling

3. Discussion

Angus Stone of Mount Gamalama is created from solidification of basaltic lava with mineral *mafic* as the dominant composition of the stone. Main chemical composition contained in Angus stone is characterized using X-Ray Fluorescence (XRF). The fine-crushed Angus stone has its chemical content analyzed using XRF. The analyzed result is shown in Table 1.



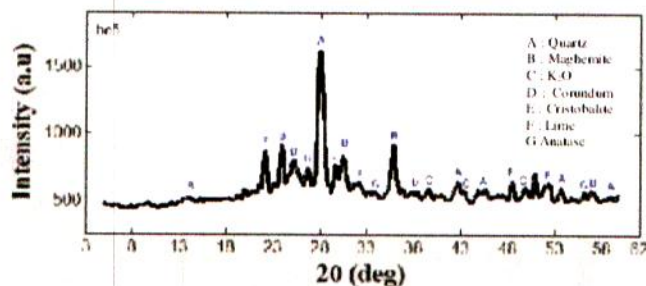
Picture 2. Angus stone mount Gamalama, Ternate Island

Table 1. Chemical element content and oxidation compound of Angus stone

Unsur	Persentase (%)	Senyawa	Persentase (%)
Si	28.94	SiO ₂	61.91
Fe	9.49	Fe ₂ O ₃	13.57
Ca	7.67	CaO	10.73
Al	5.68	Al ₂ O ₃	10.73
K	0.99	K ₂ O	1.19
Mn	0.25	MnO	0.32

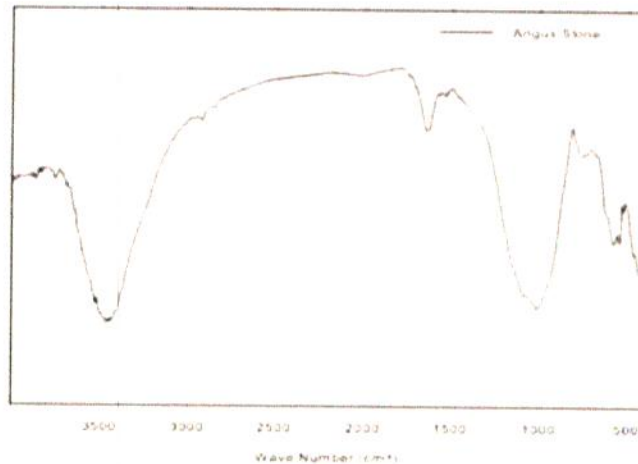
Based on the XRF analysis result, table 1 shows that a number of composing elements of Angus stone is recognized as silicon (29.98%), iron (9.49%), calcium (7.67%), aluminum (5.68%), potassium (0.99%), and manganese (0.25%). Other than that, the XRF analysis result shows that the main oxide element contained in Angus stone is silicon oxide (SiO₂) with percentage of 61.91%. Other contents of mineral oxide are Fe₂O₃ (13.57%), CaO (10.73%) and Al₂O₃ (10.73%). This result is different with the report before [8] which stated that the main substance of basal stone or Angus stone is 35% iron.

Main mineral substance composing the Angus stone is characterized using X-Ray Diffraction (XRD) on value range 2 θ from 5 $^{\circ}$ to 60 $^{\circ}$. Result analysis XRD of Angus stone diffractogram is shown in Picture 3. 2 θ value XRD diffractogram (Picture 3) shows that the main mineral content consists of quartz, maghemite, aluminum, oxide corundum, cristobalite, tridymite, lime, and titanium oxide anatase [15,16,17,18,19,20].

**Picture 3.** Diffractogram of X-Ray Diffraction on Angus stone sample

Through the diffractogram analysis result it is known that the main mineral composing Angus stone is silica mineral. To ensure the existence of several kinds of silica mineral contained in Angus stone, infrared identification by observing the bond and interaction of

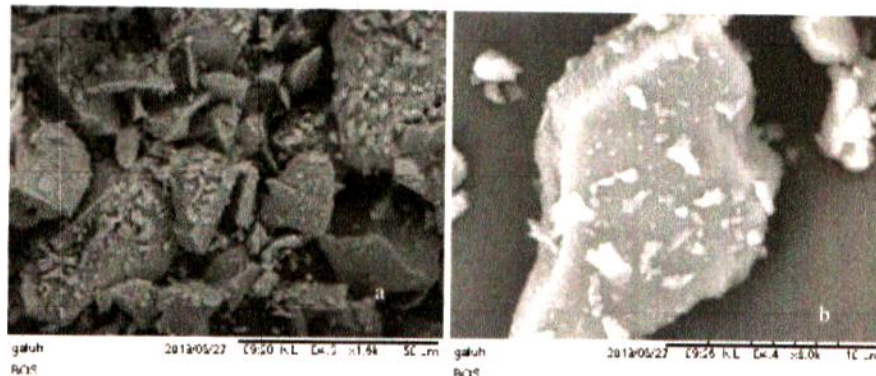
silica with other elements can be done. Infrared spectrum of Angus stone is shown picture 4.



Picture 4. Infrared spectrum of Angus stone

Characterization of silica mineral using infrared was done in a wave value range of 4000 to 400 cm^{-1} . According to Hanna [21] the silica infrared spectrum was observed on the wave value range of 2600 to 50 cm^{-1} . According to Picture 3, the silica infrared that is commonly found as siloxane function cluster (Si-O-Si), siloxile (Si-O-), and silanol (Si-OH) was visible. The siloxane function cluster could be observed on wave value 460 – 550 cm^{-1} and could be magnified on wave value 1600 – 1700 cm^{-1} . The wave value that showed siloxile function cluster was visible on the range of 1050 – 1100 cm^{-1} , while silanol function cluster was visible on wave value 3400 – 3500 cm^{-1} and can be clearer on 1600 – 1700 cm^{-1} .

Morphology characterization of main mineral composing Angus stone was done by using **scanning electron microscopic (SEM) to find out the** geometrical shape of each mineral. The SEM analysis result on mineral content of Angus stone is shown in Picture 5. According to that, it is known that a number of geometrical shapes of silica and iron are tetragonal, cubical, tridymite hexagonal, orthorhombic, and trigonal. The result of this research has compatibility with the geometrical shapes on other parties' research [15, 16, and 18]. Geometrical changes of the silica crystal were affected by temperature that causes phase change, crystal size and grid parameter. Silica crystal shape as quartz was created in room temperature (26°). Cristobalite was started to form in temperature of 800° – 1000° C, and in temperature of 1100° it became tridymite [22]



Picture 5. The *Scanning Electron Microscopic* with (a) with 1500 times of magnification and (b) 8000 times of magnification.

4. Conclusion

The main mineral contents composing Angus stone from mount Gamalama Ternate island are known as quartz, maghemite, aluminum oxide corundum, cristobalite, tridymite, lime, and titanium oxide anatase with geometrical shapes of tetragonal, cubical, hexagonal, orthorhombic, and trigonal. According to XRF analysis, the percentage of contents shown are SiO_2 (61.91%), Fe_2O_3 (13.57%), CaO (10.73 %), Al_2O_3 (10.73 %), K_2O (1.19%) and MnO (0.32%). From these results it can be seen that the composition Fe_2O_3 is not big as has been reported.

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