Petrogenesis study of quaternary volcanic rocks based on petrography analysis in Lubuk Nipis Village, Muara Enim District, South Sumatra

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Abstract. This study aims to identify the characteristics of quartz volcanic rocks as well as their existing source and process of formation in the Lubuk Nipis area of Muara Enim Regency, South Sumatera Province. In conducting this study, field observation is required to obtain primary data directly and then petrography analysis is needed to analyze volcanic rock samples obtained during field observation. There are 3 types of rock units generated by volcanic activity during the quaternary period in the study area. The three units of rock are, among others, units of andesite intrusion (Qpva), units of andesite lava (Qhv), and units of tuff lapilli & tuff breksi (Qhv). In units of andesite intrusion visible porphyritic crystal texture with Plagioclase minerals become the most dominating minerals with the emergence of other primary minerals such as Quartz, Feldspar, Biotite, Hornblende and Pyroxene. Andesite lava comes with 2 different types of characteristics, porphyritic and microporphyritic texture. There are also seen the flow texture that shows the lava flow process during the formation of rocks in andesite lava units. While other units of rock that is unit of tuff lapilli & tuff brecci is a product of pyroclastic fall. This unit has a composition of tuff material that dominates, also present are crystalline materials such as plagioclase, quartz, feldspar, and biotite. Further assisted by the analysis of DEM (Digital Elevation Model) to see the geometry of the spread of volcanic facies, can be interpreted the order of formation of rock units in the study area.

1. Introduction
The South Sumatra Basin is a sedimentary basin that has a history of volcanism before the quartering period that was not too intensive. The volcanic activity that occurred was when the formation of the Lahat Formation and did not develop too much until the quaternary period. Only in the pleistocene the volcanic activity begin to form which formed quaternary volcanic rock formations. From this volcanic activity produces volcanic rocks in the form of intrusion, lava flow, tuff, to volcanic breccias. Meanwhile, previous studies on quaternary volcanic rocks in the South Sumatra Basin have not been widely carried out, so information on the history of rock formation, characteristics, and stratigraphic conditions in the formation of quaternary volcanic rocks in the South Sumatra Basin is still difficult to find. Therefore, it is a challenge to conduct petrogenesis studies on volcanic rocks and interpret the formation process along with the characteristics of volcanic rocks in the study area. This petrogenesis study has the aim of understanding and analyzing how the formation process, rock type, and the characteristics of volcanic rocks in the study area in Lubuk Nipis Village and its Area, Muara Enim Regency, South Sumatra, Indonesia. Based on data obtained from petrographic analysis can be seen texture and physical appearance of rock which is a reference in the interpretation of rock formation in the study area.
2. The Scope of Research Area

This research area is located in Lubuk Nipis Village and surrounding areas, Muara Enim District, South Sumatra Province, Indonesia (figure 1). The area of the study is 7 x 7 km with elevations ranging from 250 - 600 meters above sea level. Based on these elevations, the research area is included in the classification of hills to high hills (Widyatmanti, et al, 2016).

![Figure 1. Research Location](image)

The research area is in the South Sumatra basin and precisely at the edge of the basin which is bounded by the hills of Sumatra Island. According to Van Bemmelen (1949) regionally the research area entered the plain and hilly terrain physiographic zone located in the high area of Muara Enim which was surrounded by quaternary volcanic hills. Some of the hills around the research area are part of the physiographic zone of the Bukit Barisan which extends in the direction of the island of Sumatra. Stratigraphy in the study area is dominated by the Qhv Formation (Quaternary Holocene Volcanic) which is formed when the holocene and produces lava flow rocks with autobrection in several locations and pyroclastic fall materials that form tuff lapilli and tuff breccia rocks with igneous rock material. The Qhv Formation is the youngest formation in the study area. Previously also formed intrusion volcanic rocks at the time of Plistocene and formed the Qpva Formation (Quaternary Pleistocene Volcanic Andesite) which was a shallow andesite intrusion. This quaternary volcanic formations cover the sedimentary formation underneath in a non-conformity manner so that there is no firm contact between quaternary volcanic rocks with older sedimentary rocks. The sediment formation which is still revealed in the study area is the Gumai Formation with carbonated carbon fiber which has a content of foraminifera fossils and begins to form at the beginning of the miocene.

3. Methods

There are several stages and methods in carrying out this study to get the expected results.

- Literature study
- Field Observation
- Petrographic analysis
- DEM Analysis

4. Results and Discussion

4.1. Field Observation Results.

Based on field observations there are rock outcrops that are divided into 3 types of volcanic rock units. 3 types of rock units are distinguished based on physical characteristics according to field
observations and the processes and materials of their formation. After obtaining rock outcrop data from the research location, a rock distribution map was build which produced a geological map of the rock unit (Figure 2).

![Figure 2. Rock units geological map of study area](image)

The first type of volcanic rock unit is the andesite intrusion rock unit which is a product of the Qpva Formation (Quaternary Plistosen Volcanic Andesite) which is present in the form of intrusion hills (Figure 3). Intrusion can occur in shallow intrusion with a relatively narrow spread. Samples taken from the foot of this intrusion hill have a high degree of weathering where the vegetation intensity grows quite high around the intrusion hill. This rock has the characteristics of a physical color of bright gray with blackish weathering colors. Megascopically this rock has a massive structure with porphyritic to porphyroanitic textures. The minerals that are seen as phenocyes are Plagioclase, Biotite, and Hornblende, there are also other minerals that are not seen megascopically and are only seen through microscopic observation.
The second type of rock unit is a unit of andesite lava rock (Figure 4) which is an effusive eruption product from the Qhv Formation (Quaternary Holocene Volcanic) which is a product of lava flows formed during the holocene. These rocks are scattered in research areas with thick enough thickness and become the main morphology forming in the study area. Andesite lava rocks form steep slopes to steep locations in several large rivers in the study area. In some observation locations, there is also an autobrection phenomenon on the outside of andesite lava rock. Autobrection occurs as a result of freezing of lava that is not yet fully solid but has broken into fragments and then rejoined into the stream and froze along with the remaining lava flow (Roverato, et al, 2015). In general, these andesite lava rock units have characteristics of fresh gray with brownish or blackish weathering colors. The intensity that is present at each observation location varies depending on the intensity of the vegetation and the influence of the river flow. Based on the observation of megaskopis, this andesite lava rock unit has a massive and amygdaloidal structure in several locations with porphyritic to afanitic crystal textures. The constituent minerals are dominated by phenocrysts of plagioclase along with other minerals that act as phenocrysts and mass.

**Figure 4.** [A] Lava flow outcrops in Endilau Besar River. [B] steep hils formed by lava flows. [C] Auto breccia phenomenon on andesite lava.
The third type of rock unit is tuff lapilli and tuff breccia units (Figure 5) which are falling pyroclastic rocks derived from explosive eruption products in the Qhv Formation (Quaternary Holocene Volcanic) during the holocene period. These rocks are spread irregularly in the study area and most of them cover the units of previously formed andesite lava rock. The existence of this rock unit also changes the morphology to be more gentle on the upper part of the lava flow because it has a lower resistance level compared to andesite lava rock below it. Tuff lapilli and tuff breccias can be distinguished based on grain size but the distribution is uneven and irregular so it is difficult to distinguish the unit boundary of the rock. In general, this rock unit has a white to beige color with brownish weathering color. Pyroclastic materials fill this rock starting from the size of ash, lapilli, to blocks / bombs (Fisher, 1966). Block / bomb material (> 64 mm) is dominated by fragments of andesite rock that participate in the phase of falling pyroclastic formation. Besides that because it is formed through the falling pyroclastic type, the outcrops found at the observation location have relatively good sorting and have a graded bedding texture on vertical outcrops.

4.2. Petrography Analysis

By petrographic observation, the first type of rock unit namely andesite intrusion rock shows porphyritic texture, in the presence of a glass mass so that it can have a degree of hypocrystalline crystallization (Figure 6). Porphyritic texture shows that this rock was made by two different phase of cooling. The first phase is slow cooling that produced big crystal phenocrysts, and as time goes by, the cooling was change to be faster and produced the small groundmass. The crystal size is based on the Williams scale, et al. (1945) ranging from fine (<1 mm) to medium (1-5 mm) and has a level of uniformity of crystals that are not uniform or inequigranular. The dominant mineral composition is Plagioclase with 61% mineral percentage. Plagioclase in these rocks is present as phenocrysts and also the mass in the form of plagioclase microlites. In addition to plagioclase, the primary minerals present in phenocryst or mass forms include Quartz, Feldspar, Biotite, Hornblende, and Pyroxene. In addition
to these primary minerals, secondary minerals such as Opaque Minerals, Chlorite, Clay minerals, and Glass mass were also present. Also we can see the special texture of intergrowth in this rock between plagioclase crystal and mafic crystals that can be evidence of concurrent formation between the two types of crystals.

![Figure 6. Petrography appearance of Andesit Intrusion rocks](image)

There are 2 types of characteristic in the second rock type, namely andesite lava. There are Porphyritic andesite lava and aphanitic andesite lava. In the 18.2 sample the andesite lava showed a general white color (PPL). The texture of this rock is porphyritic with the flow texture on several sides of the sample (Figure 7). The special texture of zoning was also seen in several plagioclase crystals present in the sample. The presence of glass masses in these rocks shows the degree of cratization of hypocrystalline rocks. The mineral composition present in this sample is dominated by Plagioclase minerals (66%) either in phenocryst or in the form of mass. Other minerals that fill this rock include Quartz, Biotite, Hornblende, Opa Mineral, Chlorite, Mineral Carbonate, Clay Minerals, and Glass mass. There is intergranular texture which shows an intergrowth between plagioclase crystals and mafic mineral crystals. Intergranular texture shows a joint growth between plagioclase minerals as the main constituent of the surrounding mafic minerals. In addition there is also a sub-ophitic inclusion texture where the pyroxene minerals are included by plagioclase minerals. This is because pyroxene is formed at a higher temperature than plagioclase, so the pyroxene crystals formed earlier can be included by the plagioclase crystals formed afterwards. The presence of this inclusion texture shows differences in the order of formation of crystals between the main minerals formed earlier with minerals formed afterwards.

While in the sample 19.4, andesite lava showed a general felsic colour and has a aphanitic texture that show the small crystal all over the rocks. The existence of this texture shows a rapid cooling of this rock from lava flows. The flow texture of trachytic is also can be seen clearly in this rock and can be the evidence of flow activity during the forming of this rock. The presence of glass masses in these rocks shows the degree of cratization of hypocrystalline rocks and also be the evidence of the high speed cooling that occur in this rock.
While the third type of rock, namely tuff lapilli and tuff breccia with code 15.6 has a brownish (PPL) cream and blackish gray (XPL). Based on petrographic observations, this rock has a porphyritic texture. What distinguishes tuff breccias and tuff lapilli besides their grain size is the presence of abundant lytic fragments in rock tuff breccias. Block / bomb-sized material in the breccia tuff is dominated by lytic fragment material. The percentage of the presence of lytic fragments was 25% with the indicated source of andesite rock because it was dominated by plagioclase minerals and saw the previous Qhv product which was andesite lava. In addition to the lytic fragments there is also a crystal material (8%) consisting of Plagioclase, Quartz, and Feldspar minerals. Glass material is also present in rocks with a percentage of 5%. Based on plotting on the grain size diagram of pyroclastic ash, lapilli, and block / bomb (Fisher, 1984) the Tuff Breccia rock naming was found. Petrography appearance of Tuff lapilli and tuff breccia can be seen in Figure 8.

**Figure 7.** Petrography appearance of Andesite Lava rocks

4.3. Discussion

Volcanic rocks in the study area originate from volcanic activity that took place during the quarterly period from plistocene to holocene. Based on field observations, there were 3 units of volcanic rocks namely andesite intrusion, andesite lava, and tuff lapilli & tuff breccia. Petrographic analysis is then carried out to see the characteristics of each rock unit in more detail and can be a reference in seeing
the process of rock formation. In addition, based on the DEM (Digital Elevation Model) analysis, it can be interpreted that the source of volcanic rocks in the study area comes from Isau-Isau Hill which is in the northwest of the study area by looking at the geometry of the ridges and the direction of the spread of volcanic material coming from Isau-Isau Hill (Figure 9). Material that dominates in the study area namely lava flow and pyroclastic fall, can also be interpreted that the study area is included in the proximal volcanic facies (Boogie & Mckenzie, 1998).

Figure 9. Volcanic distribution analysis from DEM data

The first type of rock unit namely andesite intrusion from the Qpva Formation is the first volcanic rock in the study area. This rock interferes with the Gumai Formation plant to form an intrusion hill. This andesitic intrusion has evidence with the presence of shalestone outcrops that have contact metamorphism due to the influence of andesite intrusion. The presence of pyroxene minerals shows that this rock freezing process starts at a fairly high temperature which is around 1000°C - 1200°C. However, the presence of Biotit and Hornblende minerals that coexist with Pyroxene minerals indicate that there is a fairly rapid temperature change in this rock formation. This is reinforced by the special texture appearance of zoning in some of the plagioclase crystals present. Zoning texture itself shows a significant temperature change when the rock freezing process so that the plagioclase crystal has a slightly different twin texture and is called the zoning texture. In addition, petrographic observations found no flow texture or mineral alignment in these rock samples, thus indicating that when forming, these rocks were formed not from lava flows but intrusion processes.

The volcanic rock that is formed is the second type of rock unit, the andesite lava Qhv Formation which is a product of the effusive eruption from the indicated source is Isau-Isau Hill. It can be seen from the ridges from the Isau-Isau Hill to the research area. The existence of this rock unit is not aligned (Non-Conformity) with sedimentary rocks below it. Based on petrographic observations, samples of andesite lava rock from the study area generally have a flow texture which shows the alignment of plagioclase minerals and becomes a reference in telling the existence of lava flow processes when rock formation. The presence of autobrection phenomena in several observation locations shows the presence of a defrosting process on the outside when the lava freezing is not completely perfect. However, the broken fragments were mixed again with the residual lava flow and froze together into a breccia texture on the outermost part of the lava flow. This rock begins to form at
a temperature of around 1000˚C with the discovery of pyroxene minerals although the amount does not dominate. Also present is a special zoning texture which shows a relatively fast freezing process coupled with the presence of a glass mass in each sample which shows direct contact with lava with water or air. The presence of alteration minerals also influences the ongoing formation of rock. Chlorite and sericite minerals become the most widely occurring alteration minerals coupled with the presence of carbonate minerals in some samples indicating the presence of phyllic to propylitic alteration (Corbett & Leach, 1996).

The last volcanic rock formed in the study area is the third type of rock unit, namely tuff lapilli and tuff breksi. It is a product of Qhv Formation originating from the explosive eruption of Isau-Isau Hill which releases falling pyroclastic material and its deposition position covers andesite lava rock which has been formed earlier in the study area. Contact of tuff lapilli and tuff breccias with underneath rocks is non-conformity as evidenced in several observation locations which indicate an inconsistent contact between andesite lava and tuff lapilli. The existence of vertical outcrops that have a good sorting with graded bedding texture indicates the process of its formation which comes from falling pyroclastic. Deposition of pyroclastic material follows the morphological formation that has been formed by andesite lava flow. The presence of pyroclastic material at the upper part of andesite lava also changes the morphological pattern because of the lower level of resistance so that it is more easily eroded. Based on a series of research methods that have been carried out, petrogenesis can be illustrated and the formation sequence of the three volcanic rock units in the study area (Figure 10).

![Figure 10. volcanic rocks petrogenesis illustration of study area](image)

5. Conclusion
Based on a series of research methods that have been carried out to complete this study, there were 3 units of volcanic rocks in the study area, namely andesite intrusion, andesite lava, and tuff lapilli & tuff breccia. Stratigraphically, andesite intrusion rocks are formed first by intruding on the Gumai Formation and forming an intrusion hill at the time of Plistocene. Then formed andesite lava which is a product of the Qhv Formation which was formed during the holocene period with special texture.
characteristics of flow seen through petrographic observations. In addition, the Qhv Formation also produces falling pyroclastic products whose spread is above the previously formed andesite lava by forming tuff lapilli and tuff breccia rocks. Based on DEM analysis, lava flow and falling pyroclastic are indicated from the same source but with different types of eruptions, namely effusive and explosive eruptions. The source of the falling lava and pyroclastic material comes from Isau-Isau Hill in the northwest of the study area. Based on the type of rock in the study area it can be concluded that the study area is a zone of proximal volcanic facies (Bogie & Mackenzie, 1998).

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