The Genesis of Gemstone based on Pillow Lava Primary Structure: A Case Study from Kumbang Formation, Limbasari

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Abstract. Gemstone/Jasper is an ornamental rock included in the quartz (SiO2) microcrystalline chalcedony variety. Jasper is translucent, has a microcrystal structure, and consists of several mixes of other minerals resulting in appealing color and patterns. In general, Jasper forms as a result of hydrothermal activity controlled by geological structure (secondary structure). On the other hand, Jasper is formed in Limbasari, controlled by a primary structure on pillow lava. The methods used are field data collection, petrography, and XRF (X-Ray Fluorescence). From the data collected in the field and results from petrography analysis and genesis geochemistry. We can infer that the Jasper found in the research site can be called Peperite. The jasper there is a result of unconsolidated tuff deposits still in the form of wet deposits rolled up by the movement of pillow lava and sealed in the gaps of the pillow lava primary structure, starting a partial melting process, and then cooled swiftly, resulting in glassy texture.

1. Introduction

The term 'peperino' is used by [1] to describe clastic rocks from central France which consisted of a mixture of limestone and basalt lacustrine. [2] interpreted the rocks as having originated by a 'violent and intimate union of volcanic fragmentary matter with limestone while yet in a soft state'. Gemstone or commonly known as Jasper lately become one of the highly sought-after gemstones. As one of the industrial minerals for determining the prospect area, the geological research is required because of the genesis controlled by geological processes. The initial outcrop evidence such as fractures, tensions, and breccias, indicate the structural geology involvement [3], [4] research revealed the genesis of gemstones on the mountain range on the southern part of java in Pacitan is the result of a hydrothermal process, supergent enrichment, and being an ancient river deposit. Typically gemstone can be found spread out at the tertiary volcanic area, an area with complex geological structures, and alteration, especially at the Serayu Utara mountain range. Magmatic activity occurred along the volcanic arc and parallel to the tertiary subduction zone of the island of Java. Magmatic activity that occurred along the volcanic arc and parallel to the tertiary subduction zone of the island of Java is a potential area for the formation of ore or non-ore mineral deposits. The formation of gemstone in this zone has a high possibility of controlled by tertiary magmatic activity. Tectonism that happened as a result of a
collision between oceanic crust and Jawa island arc on Oligo-Miocene resulted in magmatism and volcanic activities in this arc with the marine-land environment. This research aims to gain clarity about the genesis of gemstone in Kumbang formation, Limbasari. (Fig. 1)

![Research Location](image)

**Figure 1. Research Location [5]**

Stratigraphy of the area based upon [6] composed of Tertiary-Quaternary rock, which consists of Pemali Formation, Rambatan Formation, Halang Formation, Rock Intrusion, Kumbang Formation, Tapak Formation, Kalibiuk Formation, Ligung Formation, Mengger Formation, Gintung Formation, Linggopodo Formation, terrace deposit, Quaternary Volcanic Sediment, Andesitic Lava dan and the youngest are Slamet mountain laharic deposit and alluvial deposits. The research conducted in this area is focused only on Kumbang formation Gemstone/Jasper. The lower part of the formation consists of breccias with an angular fragment and an andesitic lava deposit. The upper part consists of alternating layers between tuff and breccias and tuff sandstone. This formation is middle-late Miocene in age [7] and has a thickness of 2000 m with a good outcrop at Mount Kumbang.

2. **Methods**

This research is conducted with field observation and laboratory/studio approach. The approach in the field is carried out to retrieve geologic information of the field (location, lithology, stratigraphy, structure, and rock structures). Afterward, petrography analysis is carried out in Geological Engineering UNSOED, and X-RD analysis.
3. Result and Interpretation
The spreading of gemstones or jasper in the research site, in general, is highly related to the geologic process happening in the past/present in the area. It is showed that the jasper reserve in the area is an in-situ rock that associates with pillow lava (Fig. 2).

Figure 2. Reserve of gemstones/jasper as an in-situ rock on the gaps of pillow lava primary structure.

3.1 Characteristic of gemstones or jasper
Gemstone or green jasper inside of pillow lava can be found in the field as an insertion between gaps in spheres of pillow lava. In general, it takes a form as an irregular pattern following the gaps between the spheres of pillow lava (Fig. 2). A few meters from the location of the gemstone/jasper reserve found an outcrop resembling a breccia with basalt igneous rock fragment and a matrix of whitish mudrock, with a hardness level comparable to the gemstone/jasper, described as peperite (Fig. 3). Pepperite is a rock naming determination according to the genesis of the rock, which is the process of mixing between a magma intrusion or a lava flow with an unconsolidated deposit or weakly consolidated deposit [8].

Figure 3. Pepperite outcrop as an association for the gemstones/jasper in the research site.

3.2 Petrography Characteristic
Petrography analysis is done to discern the mineralogy characteristic of the research site gemstone/jasper. Petrography observation result of the gemstone/jasper (Fig. 4). Thin section SM-04 consists of 5% white-colored or transparent quartz with low relief and 3% black opaque minerals. Embed on 77% brownish glass fragment matrix, transformed into chlorite. In petrography known as vitric tuff [9]. Thin section SPT 09 consists of 2% of black opaque minerals and 2% of low relief quartz. Embed on 94% of fine glass fragment matrix transformed into chlorite clay minerals. In petrography known as vitric tuff [10].
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Figure 4. Thin section of the petrography samples. In the sample SM04 the chlorite, quartz, Opaque, Glass are seen. While in the SPT9 sample there are Opaque, quartz, and chlorite.

3.3 Geochemistry Analysis
Geochemistry analysis was done through the XRF method to comprehend the chemical element content of gemstone/jasper as an altered rock. Pillow lava acts as the alteration medium and tuff has not been altered into becoming a gemstone/jasper.

Table 1. XRF analysis result of gemstone/jasper (SYJ01), basalt (SYB02), and tuff (SYL03)

| No | Sample code | SYJ01 | SYB02 | SYL03 |
|----|-------------|-------|-------|-------|
| 1  | SiO₂        | 83    | 50.1  | 72.4  |
| 2  | TiO₂        | 0.21  | 1.41  | 0.43  |
| 3  | Al₂O₃       | 5.44  | 17.9  | 9.86  |
| 4  | Fe₃O₂       | 5.56  | 13.9  | 5.19  |
| 5  | MgO         | 1.19  | 3.11  | 0.95  |
| 6  | MnO         | 0.02  | 0.25  | 0.05  |
| 7  | CaO         | 1.19  | 11.5  | 4.69  |
| 8  | K₂O         | 3.32  | 1.27  | 6.09  |
| 9  | P₂O₅        | 0     | 0.22  | 0     |
| 10 | TOTAL       | 99.93 | 99.66 | 99.63 |
The result of the analysis showed a difference in silica compound (SiO2) content on the unaltered to become jasper tuff (SYL03) and gemstone/jasper (SYJ01). It indicates a silicification process as a result of the interaction between tuff and pillow lava (SYB02). The green color found in gemstone/jasper is because of the dominant existence of chlorite minerals [11].

4. Discussion

Gemstone/jasper genesis and primary structure as the controller

In megascopic, gemstone/jasper on the research site has a dark green color but in some places, a gradation from the inside to the outside respectively showed the dark green color to the yellowish-green. (Fig. 5)

[10] mentioned that Jasper is the metamorphic process within the lower degree, and its explained as the product of greenschist metamorphism from metasomatism and contact metamorphism. We concur with [11], that the term peperite is best used in a genetic sense. [12] defined the term as follows: Peperite (n): a genetic term applied to a rock formed essentially in situ by the disintegration of magma intruding and mingling with unconsolidated or poorly consolidated, typically wet sediments. The term also refers to similar mixtures generated by the same processes operating at the contacts of lavas and other hot volcaniclastic deposits with such sediments. Evidence of unconsolidated tuff still wet deposit contact with basaltic lava, shown in the field on peperite breccias outcrop as an unaltered deposit located in the gaps and joints igneous rock. (Fig. 6).
Figure 6. Shown evidence in the field of unconsolidated or weakly consolidated deposit upon contact with lava, (A) tuff deposit turning into igneous rock fragment. (B) tuff deposit in the gaps of igneous rock [8].

According to the appearance data and gemstone/jasper association in the field backed by data from petrology, petrography, structural geology, and geochemistry analysis aspects, it is concluded that genesis process of gemstone/jasper in the research site is highly related to volcanism at that time, as described in peperite formation terminology. As a result, gemstone/jasper in the site as seen from the genesis itself can be called peperite. The original characteristic of it is unconsolidated tuff deposits still in the form of wet deposits, contact with lava, rolled up and sealed in the gaps of the pillow lava primary structure, starting a partial melting process, and then cooled swiftly, resulting in glassy texture (Fig. 7). The role of structural geology in this is the primary structure on pillow lava as a medium for the formation of peperite in the Kumbang Formation in Limbasari.
Figure 7. Formation of peperite controlled by primary structure modeling, (A) wet deposits rolled up by the movement of pillow lava and sealed in the gaps of the pillow lava primary structure, starting a partial melting process, (B) peperite formed by fragmentation of pillow lava as a result of some processes one of them is fragmentation because of cooling and autobreccia by a mechanical process [8].

5. Conclusion
Pillow lava's primary structure becomes one of the controlling factors in the formation process in the research site. Kumbang formation gemstones/jasper found in Limbasari can be called as peperite, as a result of unconsolidated tuff deposits still in the form of wet deposits rolled up by the movement of pillow lava and sealed in the gaps of the pillow lava primary structure, starting a partial melting process, and then cooled swiftly, resulting in glassy texture.

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