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Structure Control On Alteration And Gold Mineralization At Tugurejo Area, Slahung District, Ponorogo Regency, East Java Province

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ABSTRACT
Our research was conducted in Tugurejo Village and its vicinity, Slahung District, Ponorogo Regency, East Java, Indonesia. It consists of 2 informal lithostratigraphic units, that are the Watupatok Formation lava unit and the Watupatok Formation breccia unit. The geological structures of the research site are predominantly joints filled with quartz veins and faults in the direction of NE-SW, NW-SE and E-W. The hydrothermal alterations formed in the research site were grouped into three alteration types, which are silica type (defined by Pyrite ± Quartz), argillic type (defined by Smectite ± Kaolinite ± Quartz ± Pyrite ± Albite), and propylitic (identified by Chlorite ± Albite ± Quartz ± Dolomite ± Pyrite ± Smectite ± Illite minerals). The mineralizations encountered at the research site are Pyrite (FeS2), Chalcopyrite (CuFeS2), Galena (PbS), Sphalerite (ZnS), Covellite (CuS), and Bornite (Cu5FeS4). There were abundant mineralizations found filling the joints, mainly in the shear fractures and the fault zones of breccia quartz in the Northwest-Southeast, Northeast-Southwest, and West-East direction.The research site is categorized as in the base metal horizon of the epithermal zone, and the area is the epithermal low sulfidation type. The atomic adsorption spectrometry (AAS) analysis showed the presence of Gold (Au) and metal ores, with the availability of ore elements from the most to the least amount, respectively, are copper (Cu), zinc (Zn), lead (Pb), silver (Ag) and gold (Au).
KEYWORDS: hydrothermal alteration, mineralization, ore, Tugurejo

I. INTRODUCTION

The presence of gold and its associated minerals depend on the number of main ore deposit types found in an area. The main sulfide minerals accumulation usually found on the epithermal type are Au, Cu, Ag, Pb, Zn, which probably occured in the research site. Geological research is suggested to find the mentioned deposit type or other deposit types, as the deposit mineral potentials in each area might be different.

The relation between various deposit types in an area could be identified from the continuity of its genetic process of hydrothermal-magmatic activities and the fluid dispersion. Gold mineralization zone is usually characterized by narrow-to-wide quartz vein crack apperture and dissemination on fault brecciation zone.

A comprehensive understanding is needed on the relation between different types of deposit or the characteristics of different productive stages in the evolution of hydrothermal-magmatic system.The exploration is directed to make use of the mineralization alteration to point us towards deposit types with considerable potential, and it must fully explore each occurence to determine whether it is economical. Geological structures are very important in controling the alteration and mineralization patterns in an area;therefor, this research emphasized the presence of geological structures, including the orientation of faults and joints in the study area.

The aim of this research is to determine the source, relation and path of gold mineralization and its associated minerals (Cu, Ag, Pb,Zn) with the geological structures of various deposit types, so that the results could be used to develop zoningthat could identify the presence of gold mineralization and its mostassociated minerals. The zoning of productive and non-productive area will be examined thoroughly on the hydrothermal system, both mineralized areas and non-mineralized areas, by analyzing the ore-forming environment. At the end of the research, we will define the orientation of the geological structures, particularly faults controlling the alteration and mineralizations of the research area.

II. RESEARCH LOCATION

The potential area of the research siteis administratively located in Tugurejo Village area and its surroundings, Slahung District, Ponorogo Regency, East Java Province, defined by UTM coordinates as follows:

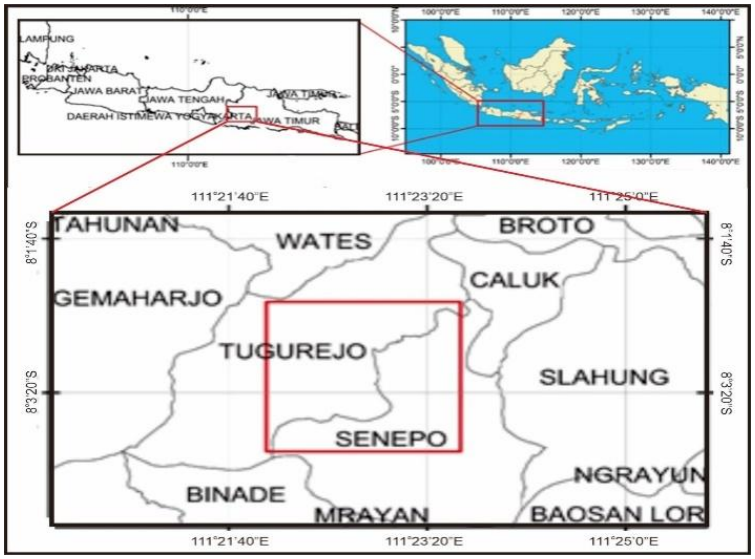

Figure 1.1. The research site is in the Tugurejo Village area and its vicinity, Slahung District, Ponorogo Regency, East Java Province.

III. METHODOLOGY

This research is a part ofresearch series on alteration and mineralization related tocontrollinggeological structure of the research site. It was conducted by geological mapping focusing on data of joints and faults in the vicinity of alteration and of which the appertures are filled with quartz veins containing minerals such as pyrite, chalcopyrite, galena, sphalerite, and other minerals which could not be seen megascopically. Furthermore, theinformation of joints and faultsorientation were recorded and analyzed, to define whether the alterations and mineralizations of the site were controlled by geological structures. Analysis was conducted on the geological structures, mineralography, alterations and minerals using X-Ray Diffraction (XRD) and Atomic Absorption Spectrophotometry (AAS).

IV. PREVIOUS RESEARCH

Arifudin Idrus (2010) who conducted research at the site, mentioned that based on alterations and mineralizations and temperatures,ore minerals were found abundantlysuch as Ag, Cu, Pb and Zn, exceptfor Au that is low. The temperature was between 150-390°C andthe fluid salinity is 0.27-0.33 wt.% NaCl. However, this research did not correlate the result with the geological structure control at the site.

Salma Difa (2019) carried out research in Blitar, which is close to our study area, concerning alterations and mineralizations. The research concluded that the study areais highsulfidation epithermal area, where there are many ore minerals and low of gold. This research did not consider the geological structure control as well.

Van Bemmelen (1949)had performed research on regional geology of Ponorogo area and its surroundings, but the research did not explain in detail regarding the structure and the direction of tectonic forces. Furthermore, there is no research found explaining the possibility of mineralization of any particular deposit types in the tectonic setting of southern mountain zone in East Java. This research will fill the gap by looking for an explanation of the relationship between the formed structures and the gold alterations and mineralizations. It is because the structure pattern plays a part in controlling mineralization process, which could be identified by the presence of quartz veins filling all the joints and fractures in the zone.

V. GEOLOGICAL SETTING OF THE STUDY AREA

According to the regional stratigraphy from the Pacitan Geological Map by Samodra et al. (1992), the site is a part of Watupatok Formation. Based on field observation and analysis results of the physical observation in lithology, geological structures and rock orientation, andgeological cross section, the stratigraphy classification of the study areais comprised of Watupatok Formation Lava Unit and Watupatok Formation Breccia Unit

The lava units in the area were found in the river valleys and roadsides, occupying an area of 57% from the total research area. Megascopic description on the andesite lithology in the field exhibited gray to blackish grayof fresh colour, light gray to brownfor weatheredcolor, a massive structure, columnar joints, and sheeting joints. Theprimary mineral compositions are hornblende, biotite, plagioclase, k-feldspar, quartz, and glass. The site underwent weak to unaltered hydrothermal alterations and there were veins filledwith pyrite,

chalcopyrite, and sphalerite mineralization found in several observation sites. This unit is in the age of Late Oligocene-Early Miocene(Samodra et al., 1992) and the stratigraphic relationship of this unit with the Watupatok Formation Breccia Unit is interfingering.

The breccia unit occupies around 43% of the research area, wherethe characteristics of this unit in the site are having gray as fresh colour and cream on weatheredcolour, having massive structures, gravel-fine sand grain size, poorly sorted, angular roundness and open packing.It has fragments of tuff, lithic, feldspar and matrices of tuff, while the cement is silica. The unit experienced strong hydrothermal alteration to unaltered and there were veins with mineralizations of galena, chalcopyrite, and sphalerite found in some observation locations. The age of this unit is around the Late Oligocene-Early Miocene (Samodra et al., 1992). The stratigraphic relationship of breccia unit with the Watupatok Formation Lava Unit is interfingering.

Geological Structure of the Study Area

Geological structure is one of the important controlling factors of mineralization and it has an important role towards the distribution pattern of copper and lead ore deposits in thestudy area. The geological structurewas recorded in the rock and causing deformation upon rocks in the study area. Fordetermination of the geological structure, we use Shuttle Radar Topography Mission (SRTM) image, by observing the valley alignment pattern.

The geological structure in the study area was clearly visible from the straight-lined river valley. As for the structures found in the field observation, they were in the form of shear joints, tension joints, and strike-slip faults. Data measurement of geological structures in the field consisted of shear joint, tension joint, plunge, rake, bearing, andfault associated joints, shear fracture and gash fracture.

Joint Structure

A joint is a fracture in rock that relatively does not undergo significant shift or displacement. Rocks that experience pressure beyond their elasticity, will crack and form some specific pattern. The development of joint pattern that intersects each other and forms a sharp angle towards the direction of force is known as shear joint and tension fracture pattern that is relatively aligned to its direction of force, will form an extension joint. Whereas a joint that is formed after the force stopped, relatively perpendicular to its direction of force, will form a release joint. Many shear joints could be found on the lava unit and are mostly filled with quartz and other minerals formed and generally have orientation relative to the north-south direction (Table 4.2).

Tabel 5.1Orientation of joints filled with mineralization veins in research sites.

Observation Location	Orientation of Veins				
LP 2	N165ºE/82º	N157ºE/84º	N169ºE/79º	N172ºE/80º	N165ºE/78º
LP 3	N185ºE/81º	N187ºE/79º	N179ºE/78º	N187ºE/82º	N190ºE/83º
LP 8	N180ºE/78º	N183ºE/80º	N250ºE/50º	N185ºE/81º	N255ºE/55º
LP 9	N178ºE/52º	N181ºE/49º	N180ºE/50º	N182ºE/59º	N175ºE/51º
LP 10	N031ºE/77º	N210ºE/78º	N028ºE/81º	N025ºE/79º	N0202ºE/83º

Fault Structures

The existing fault structures in the studyarea were well recorded in breccia and lava unitsof Watupatok Formation. Based on the stereographic analysis, there were 3 common directions of the main faults, they are West-East (W-E), Northwest-Southeast (NW-SE), and Northeast-Southwest (NE-SW). Fault structures could be the controlling factor of alteration and mineralization processes in research site, as a channel way for hydrothermal fluid to interact with the neighboring rocks. Data measurement parameters of fault in the field are fault plane, slickensides, and joints created by the movement of the fault. For regional faults whose parameters cannot necessarily be found yet, an interpretation was performed based on the contour pattern, lithological distribution, alteration distribution, and mineralization distribution.

The fault with West-East (W-E) direction was found on the main tributary in the study area, in Nepo tributary. This faultmoves horizontally to the right and is well recorded on lava rocks of Watupatok Formation Lava Unit.

The fault with Southeast-Northwest (SE-NW) direction was found on the main tributary in the study area, in Nepo tributary. This faultmoves horizontally to the right and is well recorded on lava rocks of Watupatok Formation Lava Unit. This Southeast-Northwest orientation fault is the main faultcontrolling alteration and mineralization at the research site. This fault is associated with mineralized veins at N330°E/80°

and N165°E/80°. The fault zone in Southeast-Northwest direction is the alteration zone which exhibit the gradation change from low to high temperatures, going outwardfrom the center of fault zone, started from silicification alteration in the center, to argillic and then propylitic alteration at the outmost part.

The fault oriented in Northeast – Southwest (NE-SW) direction was found on the main river in the research site, they are in Nepo River and Nepo Hill. This fault has movement horizontally to the left and was recorded in the lava rocks of Breccia and Lava Units of Watupatok Formation. This fault is also a main fault controlling alteration and mineralization in the study area.

The fault in the direction of Northeast-Southwest (NE-SW) is associated with mineralized veins at N031°E/77° and N049°E/79°. This fault zone is the alteration zone which exhibit the gradation change from low to high temperatures, going outward from the center of fault zone, started from silicification alteration in the center, to argillic and then propylitic alteration at the outmost part.

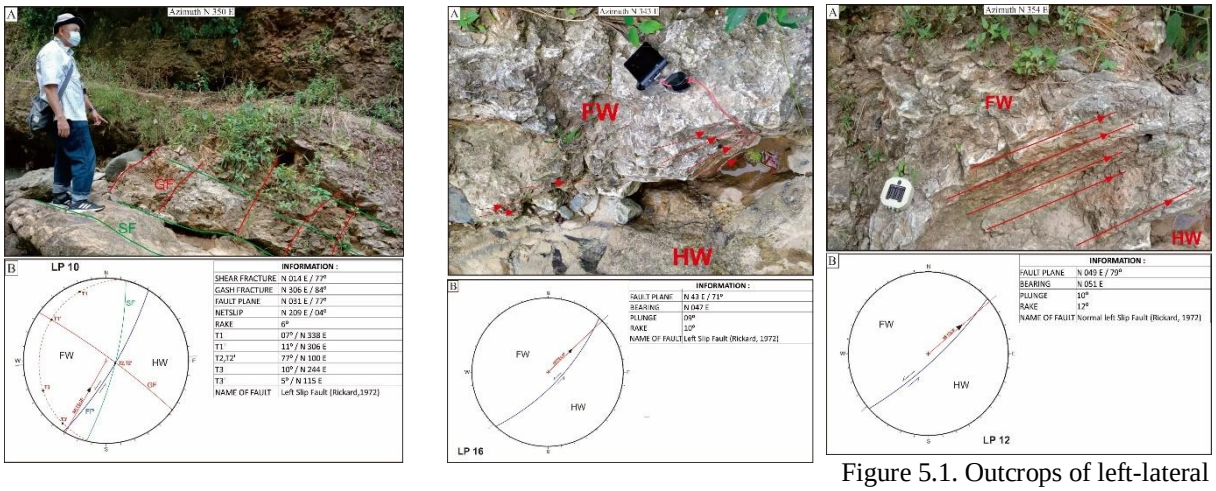

Figure 5.1. Outcrops of left-lateral fault in the direction of Northeast-Southwest (NE-SW) on Nepo River. The stereographic analysis of the left-lateral fault is Left Slip Fault (Rickard, 1972). Quartz veins with the size of 1-5 cm were found, accompanied by silicic and argillic alteration along the fault zone, and also pyrite and chalcopyrite minerals.

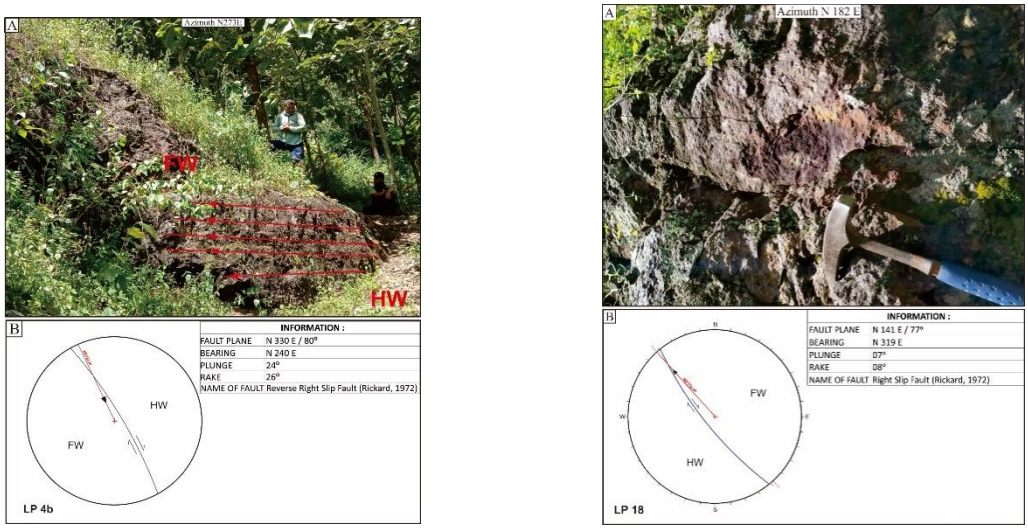

Figure5.2**.** (A) Outcrops of right-lateral fault in the direction of Southeast-Northwest (SE-NW) on the Nepo Tributary. (B) The stereographic analysis of the right lateral fault is Reverse Right Slip Fault (Rickard, 1972). Quartz veins with the size of 1-5 cm were foundaccompanied by silicic and argillic alteration along the fault zone, pyrite and chalcopyrite minerals.

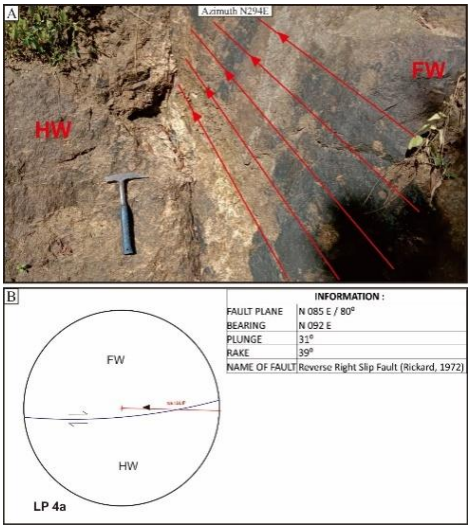

Figure 5.3.(A) The plane of right lateral fault in West-East (W-E) direction on LP 4. (B) The stereographic analysis of right lateral fault onLP 4b is Reverse Right Slip Fault (Rickard, 1972).Quartz veins werefound with the size of 1cm-3cm, there are also argillic alteration along this zone and pyrite minerals.

VI. ALTERATION IN THE STUDY AREA

Hydrothermal alteration is a complex process involvingchanges in mineralogy, texture, and rock chemical composition. The process is the result of interaction between hydrothermal solution with the rocks it passes in specific physical and chemical conditions (Pirajno, 1992). Alteration zoning has unique characteristics and patterns, butit could be identified based on minerals that change with temperature. This zone generally follows the geological structure patterns that were formed, predominantly to the NE-SW direction and some to the NW-SE direction.

The observation results of megascopic and petrographic, and XRD analysis results of some altered rock samples from the field introduced three alteration zones, they are: Silicic type (defined by Quartz ± Pyrite minerals), Argillic type (identified from Smectite ± Kaolinite ± Quartz ± Pyrite ± Albite minerals) and Propylitic type (defined by Chlorite ± Albite ± Quartz ± Dolomite ± Pyrite ± Smectite ± Illite minerals.).

Silicic type (Quartz ± Pyrite)

The silicictype of alteration is identifiedby a group of Quartz ± Pyrite minerals. This zone underwent pervasive alteration with strong to very strong intensity (61-85% secondary minerals), characterized with the presence of secondary quartz. It was formed in volatile rich conditions then after fluid rich phase,this alteration underwent leaching and became vuggy textured. It could even get brecciated, opening spaces for the prepcipitation of metals brought by the hydrothermal solution. Silicific alterationis formed in the low pH fluid condition ofhydrothermal solutionand in relatively low temperature. The distribution of this alteration resides a small area of 1% from the research site, and commonly found in epithermal mineralization systems. The silicic alteration found in the research area has undergone strong alteration and could be found in the andesitic lava lithology. The distribution pattern ofalteration was affected by the existence of structures developing in the research sites.

Argillic type (Smectite ± Kaolinite ± Quartz ± Pyrite ± Albite)

This zone is characterized by a group of main minerals such as Smectite ± Kaolinite ± Quartz ± Pyrite ± Albite. This zone underwent pervasive alteration and strong intensity (61% secondary minerals), characterized with the appearance of white and reddish white colours, dominated by Smectite-Kaolinite clay minerals. The zone affected the Watupatok andesite lava unit and the Watupatok volcanic breccia unit. This alteration zone occupied 8% area of the research site, spreaded around the silicic zone. The distribution of this alteration zone was interpreted as vertically controlled by the geological structures of faults. Argillic alteration was formed in the inetrmediate phase when the volatile rich hydrothermal fluid came out through fractures with pH of 4-5 and in relatively intermediate temperature. Generally,the argillic alteration zonelocated near a heat source would be surrounding the silicic alteration zone because the temperature would decrease as it gets farther from the fault line where the hydrothermal fluid comes out.

Propylitic type (Chlorite ± Albit ± Quartz ± Dolomite ± Pyrite ± Smectite ± Illite)

Propylitic alteration is characterized by the presence of Chlorite ± Albite ± Quartz ± Dolomite ± Pyrite ± Smectite ± Illite minerals. This propylitic zone underwent alteration of nonpervasive-pervasive pattern from weak to very strong intensity (24-78% secondary minerals). The field manifestation of this alteration generally still exhibits its original rock texture, but green coloured chlorite mineral started to emerge locally and some of it were strongly altered so they became strong green coloured. Propylitic alteration was formed in the early phase when the volatile rich hydrothermal fluid came out through fractures on high temperature.

The pattern of the propylitic alteration in the research site was controlled by the geological structures developed in the study area. The propylitic alteration distribution was around 34% of the overall research site area. This alteration acts as a closure to other alterations and it was found in several places in the study area.

Mineralization of the Study Area

The presence of minerals that could be seen megascopically in outcrops are pyrite, chalcopyrite, couvelite, bornite in quartz veins filling the fractures. Based on the AAS analysis results of several samples, it was obtained that the content of Au, Ag, Cu, Pb and Zn elements are as follows:

O	NO SAMPLES	Au (ppm)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)
	LP - 3	0.01	1.3	502	35	305
	LP - 6	0.03	27.2	18203	1154	3506
	LP - 8	0.02	2.1	748	1093	249
	LP – 9	0.08	1.5	295	268	50
	LP - 10	0.10	2.4	598	855	88
	GLG908-5	0.05				
	LP - 11	<0.01	<0.5	24	6	44

Based on the AAS analysis results, there was a small amount of gold whereas elements of Cu, Pb and Zn were relatively high, therefore a further, more detailed research is needed to be followed.

VII. DISCUSSION

The presence of mineralizations in thestudy area were found in silicic alteration zone, and mostly in argillic and propylitic alterations. The mineralizations are relatively associated with quartz veins (vein, veinlets, and stockwork system) with a width of 3cm-1m. The ore mineral precipitation pattern which is generally found in research site tends to fill the quartz veins in joints and fault zones or in "quartz breccia".

Based on those data, we interpreted that alterations and mineralizations in the research site occureddue to of the hydrothermal fluid coming out through fractures, whether it be joints or faults occurred in the research site. Generally, minerals were found in quartz veins filling the fault zones or on "quartz breccia" that has a certain orientation in the fault line.

The fault zonesaregenerally at N30°-45°E/70°-80°, N300°-345°E/70°-80° and some are at N80°E/70°. However, the ones with high content of ore minerals or Cu, Pb and Zn elements are quartz veins following the direction of NE-SW or N 30°-45°E/70°-80°. Therefore, the alterations and mineralizations in the research site were controlled by the geological structures that occurred in the study area.

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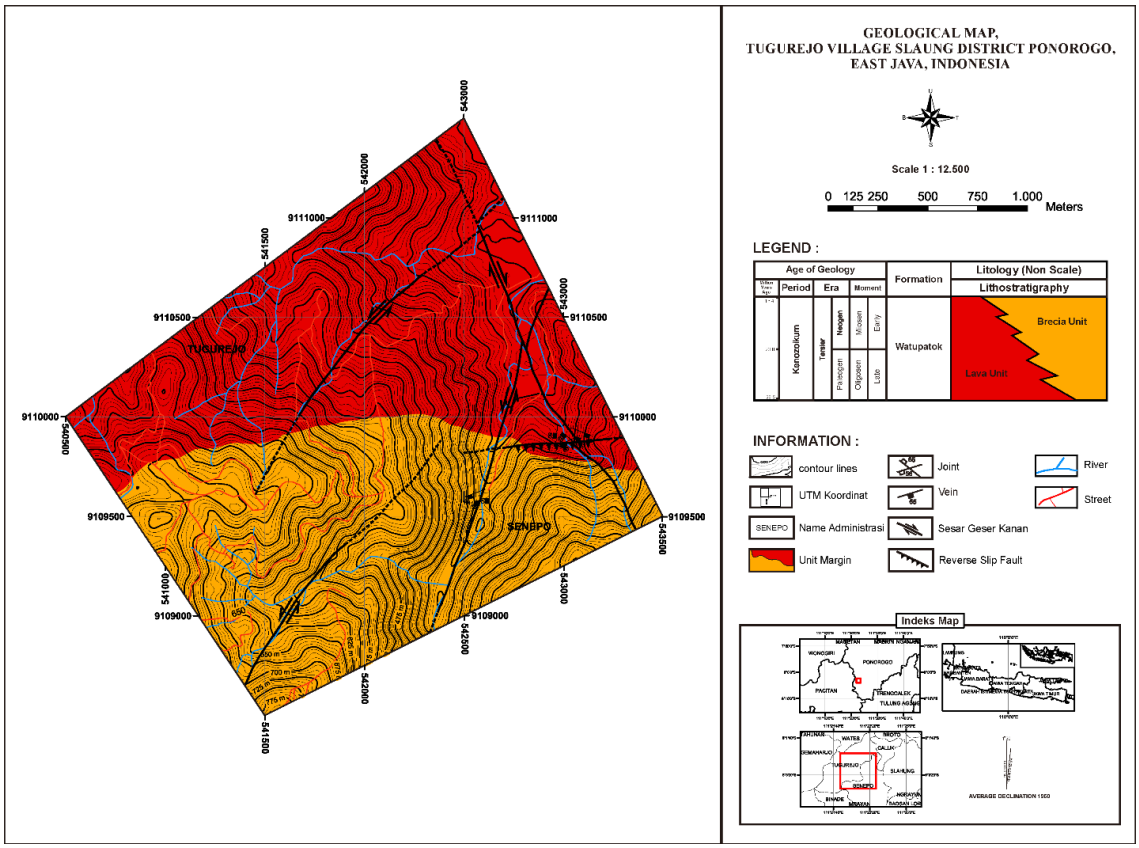

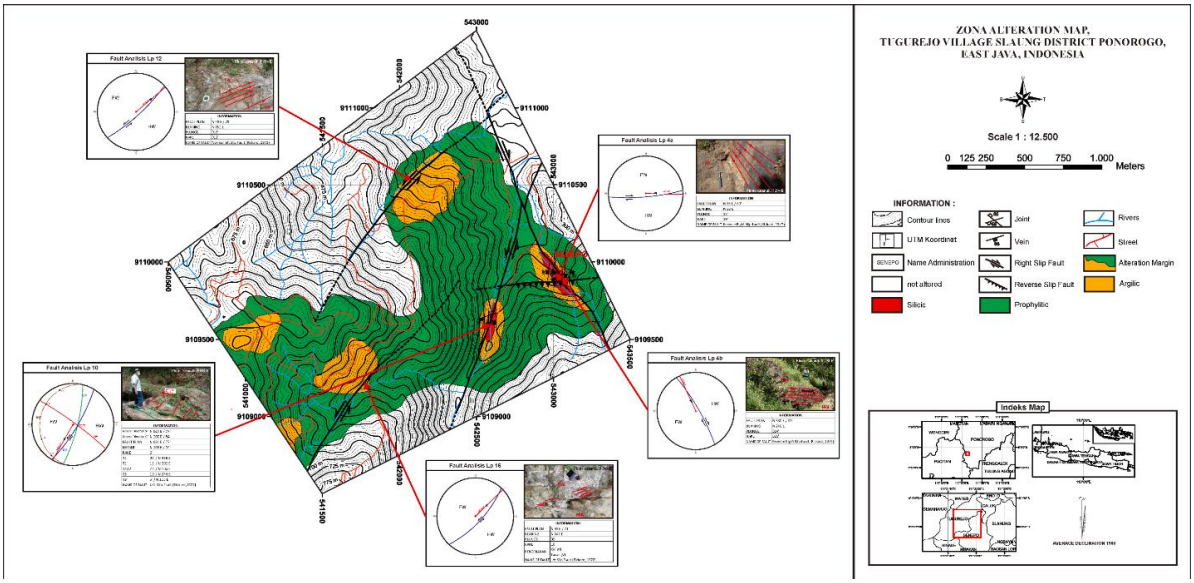

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