# STRUCTURAL CONTROL OF ALTERATION AND MINERALIZATION IN PROSPECT "X-Y", POHUWATO REGENCY, GORONTALO PROVINCE

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## ABSTRACT

The prospect "X-Y" is located in Gorontalo Province, a part of "gold district" with NW-SE arc-normal, E-W arc-parallel, and NS-NNE subsidiary lineament features and localize geological setting in the northern arm of Sulawesi. Regional geology of Sulawesi's northern arm is characterized of volcano-plutonic magmatic by typical Eocene to Recent island-arc assemblages (Hamilton, 1979). An older basement composed of granodiorite occurs in the north of the study area (Kavalieris, 1984). The study was conducted using variety of approaches, including desktop study, field mapping, and data interpretation. Desktop study are focused on lineament and fault fracture density interpretation. Field mapping include observation, measurement, and structure interpretation. Gold mineralization in the prospect "X-Y" are hosted in porphyritic dacite, lapilli tuff, and diatreme breccia unit. The type of mineralization generated epithermal low sulphidation with anomalous mineralization. It has the feature of a high fault-fracture density range of 2100-3200 m/$km^2$ value. Quartz-limonite vein, stockworking and hydrothermal crackle breccia in the central of mineralization is characterized by strongly pervasive silica-illite-pyrite and silica-illite-smectite assemblages. From outcrop, mineralization pattern had steeply inclined plane to the east. On the map, mineralization controlled by the dominant structural trends of NE-SW and NW-SE. Based on lineament and fracture, the dominating directions are NE-SW faults and NW-SE paralel fault. Then, normal-dextral fault and normal-sinistral fault structures were discovered. The occurrence of a dilatational jog, which is controlled by a normal-sinistral fault with NE-SW trending and producing fractures traversed by hydrothermal fluids.

**Keyword**: structural control, alteration, mineralization.

## INTRODUCTION

Multiple tectonic/triple junction of three plate during geologic time, involving events and materials from pre-Tertiary. These tectonic events have resulted in a complicated form of epithermal deposit, particularly in northern Sulawesi, often known as "The North Arm Sulawesi" (Hamilton, 1979). The North of Sulawesi Trench is an active subduction zone with an abundance of extensional structures that identified in the southern arc, in addition to uplift and rifting. One of the reasons for the existence and preservation of alkaline rock is likely due to extensive WNW-NW extensional structures.

Geological structures play a critical and significant role in mineralization, as a pathway for hydrothermal fluids bearing metal and ore deposition areas (Blewett, 2012; Bonson et al., 2012). Accomodation of hydrothermal fluid pathway form dilatational jogs or extentional structures. Dilatational jogs are thought to be the cause of vein zonation and clustering. Understanding the genetics and features of geological informations will lead to mineralization zone because of their relevance.

The northern arm of Sulawesi, where prospect "X-Y" is located, is one of the known 'gold districts' in Gorontalo. Regional structure setting in the research area are controlled by ESE and NNW trending in the gross fabric of structural elements and/or lineaments. Lineament and fault corridors correspond to the northern arms east-west (arc-parallel) and stripped by long-range NNW fault zones of arc-normal, as well as additional short-range NE conjugate faults of arc-normal. Epithermal prospect commonly associated with the ESE arc-parallel faults and the ENE faults (Pearson & Caira, 1999). The location of intrusive hosted and vein type mineralization appears to be influenced by correlated NNE and WNW tensional features.



E-ISSN : 2579 – 3136

## RESEARCH METHOD

The paper discusses about the structural control on gold mineralization in prospect “X-Y”, Gorontalo Province. The study was conducted using a variety of approaches, including desk study, field mapping, and data interpretation. Desktop study are focused on lineament and fault fracture density used combination of qualitative and quantitative approach to show the value of the zone with high anomalus density. Lineament and fault fracture density were conducted semi-automatically procedure, included Global Mapper 10, ArcGis 10.3, Rockwork, PCI Geomatica and Sulfer 16 software. Field study observation, core logging, and rock sampling analysis were combined with desktop study.

## RESULT AND DISCUSSION

### Geology, Alteration, and Mineralization

Geological aspect of the research area is discussed in terms of lithostratigraphic principles linked to the physical properties of rocks seen in the field, which include a lithological characteristic, lithological uniformity, and stratigraphic units. In term of rock unit is used to refer numerous component contents that deviate from lithological features. The geological units are classified into 6 unit from early to late stages, as follow: Granodiorite Unit (Qpg), Dacitic Unit (Qpd), Porphyritic Dacite Unit (Qptl), Diatreme Breccia Unit, Lapilli Tuff Unit (Qpl), and Colluvium Deposits Unit (Qk) show in Figure.1. This suggests that the research area is in a Tertiary-Quarter volcanic and hydrovolcanic environment (Marjoribank, 1998).

Hydrothermal alteration is influenced by lithological features, geological structures, and fluid characteristics by the existence of secondary minerals, which can impact any lithology in the research area. From proximal to distal, the alteration is separated into five groups of alteration minerals: silica-illite, silica-illite-smectite, silica-smectite, silica-smectite-chlorite, and chlorite-carbonate-pyrite (Figure.2). Both physically and conceptually, quartz vein stockworking to the silica-illite and silica-illite-smectite alteration zone proves the significance of boiling, mixing and rapid cooling in the precipitation of ore minerals.

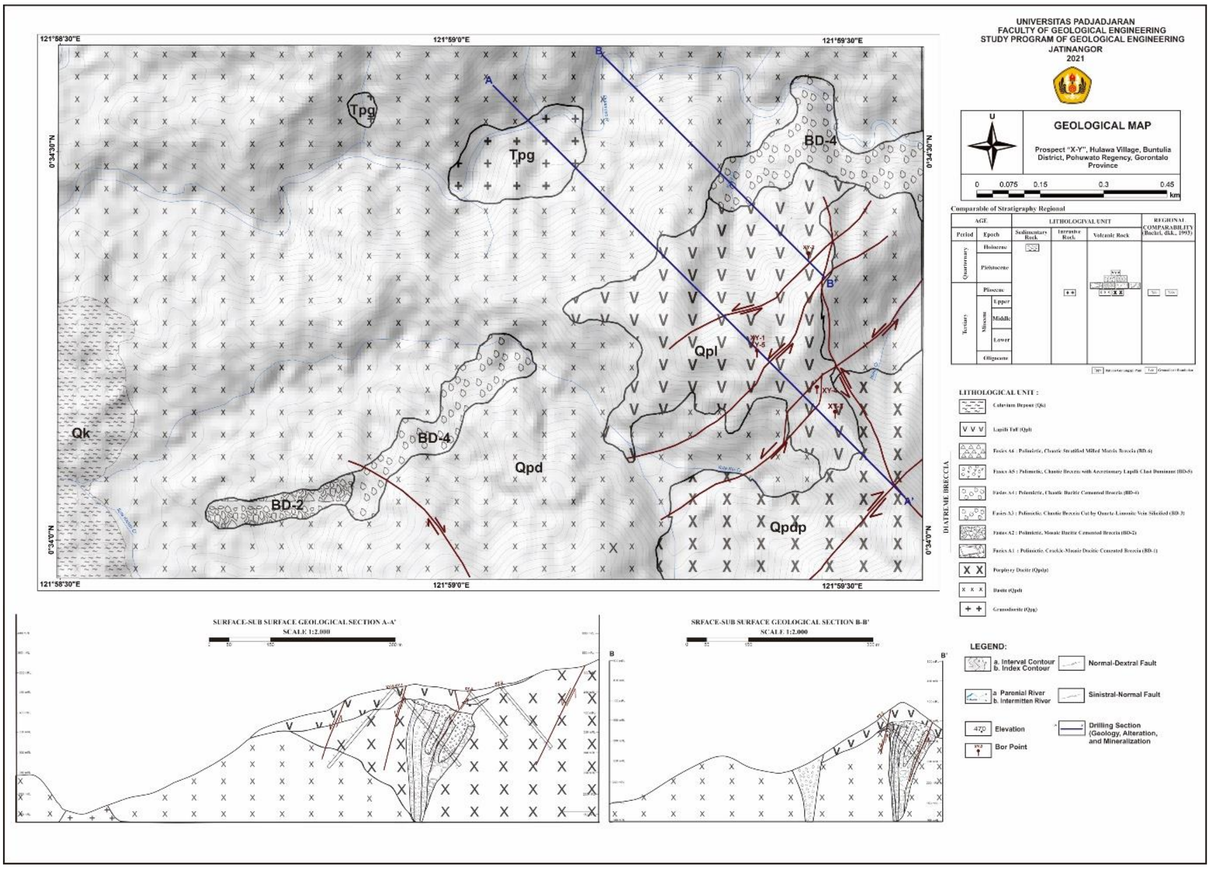


**Figure 1.** Geological map in the research area



E-ISSN : 2579 – 3136

Mineralized rock in the research area associated with hydrothermal crackle breccia, quartz veining and stockwork. The mineralization appears as a broad zone with steeply dipping inclined. The existance of mineralization generated by an open space filling structure. Based on outcrop mapping and core logging observation, the mineralization are hosted in strongly pervasive silica-illite-pyrite and silica-illite-smectite altered porphyritic dacite and lapilli tuff. Veining zone are seen in the proximal of zone of low sulphidation epithermal deposit system.

Hydrothermal crackle breccia hosted in porphyritic dacite and lapilli tuff (Figured 2.A). Megascopically, hydrothermal crackle breccia has monomictic, crackle-mosaic texture, angular-subangular clast shape, clast supported, altered by silica-illite to silica-illite-smectite with strongly pervasive alteration, quartz-limonite-pyrite matrix cemented breccia. Comb/drussy and dogteeth quartz as the texture of vein in hydrothermal crackle breccia.The existance of sulfide minerals as a pyrite, and minor base metals such as galena and sphalerite in vein or hydrothermal crackle breccia. Alteration minerals feature are indicated by whitenish brown color because feldspar minerals is altered into clay minerals (Figured 2.B).

Different geological features show in the north of research area that characterized by crystalline quartz-chalcedony veins, are seen in the distal facies zone. Crystalline quartz-chalcedony veins are hosted in dacitic rock units and porphyritic dacite in the SW-SE of the research area (Figured 2.C). Quartz-chalcedony vein have a crystalline texture, a vein density of 6 vein/m, and 4 cm of wide. There was no oxidation process that altered sulfide minerals.

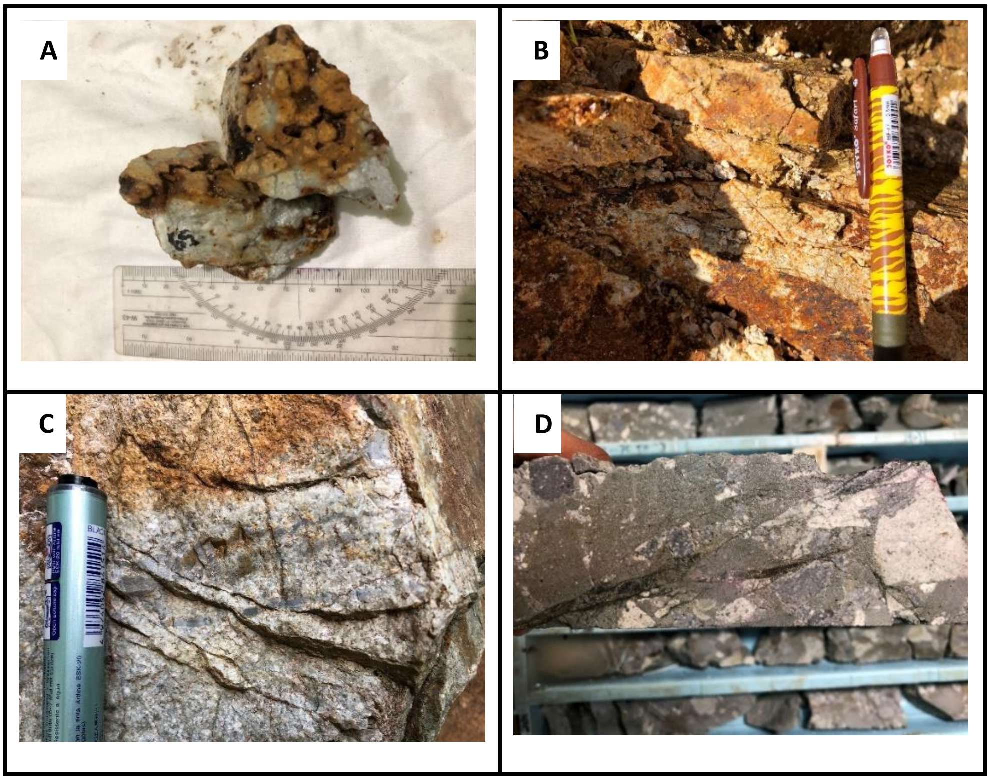


**Figure 2.** Hand speciment sample : (A) hydrothermal crackle breccia (B) quartz-limonite vein and stockworking (C) crystalline quartz-chalcedony-pyrite veins (D) Massive chlorite-carbonate-limonite veins



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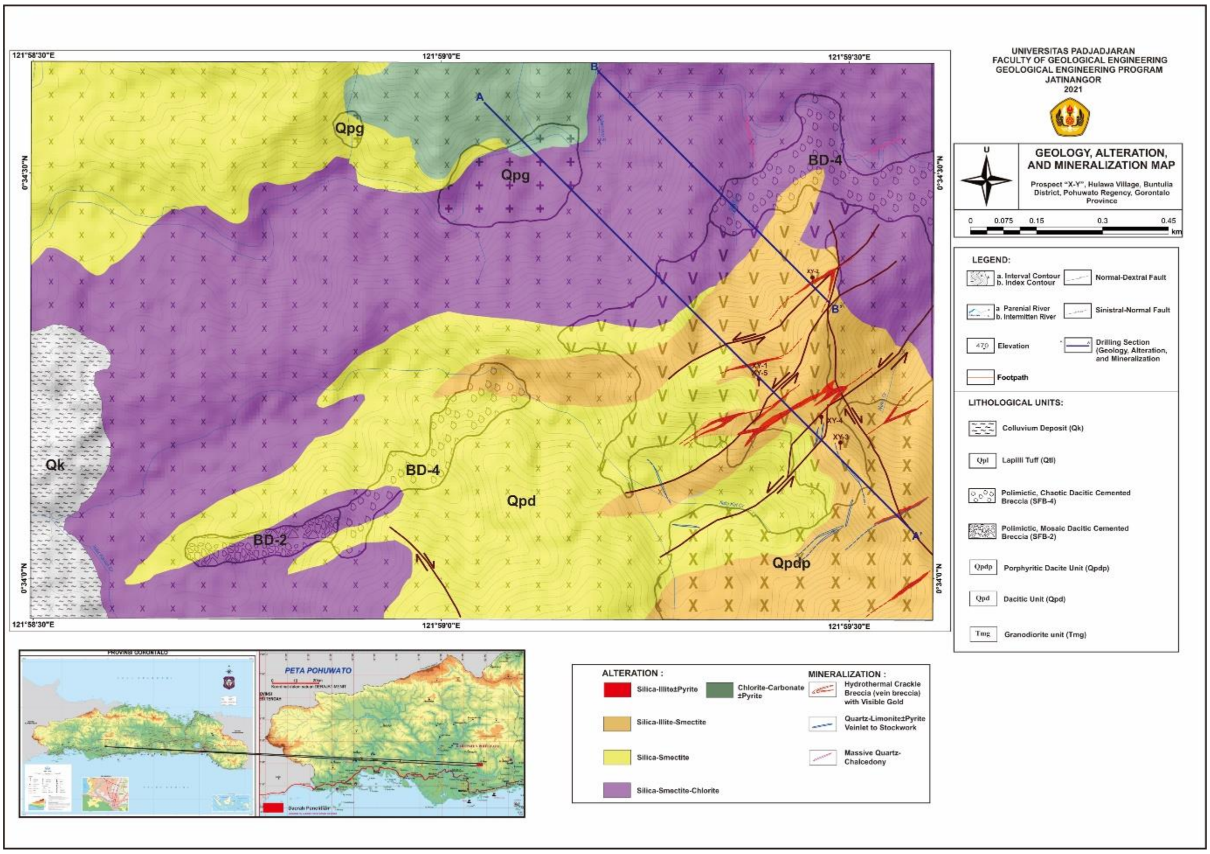


**Figure 3.** Alteration and mineralization map in the research area

**Structural Control on Alteration and Mineralization**

**A. Lineament Pattern**

Structural control of the research area refers to the field data in the form of joint and fault measurements which are correlated with lineament analysis and a study of geological structures according to Marjoribank (1998). The lineament pattern analysis can show the appearance of the lineament direction are obtained from citra DEMNAS imagery. Based on the lineament analysis of the DEMNAS image, the research area has a dominant of NNE-SSW, and locally NE-SW to NW-SE trending. In addition, there are indications of ring faults in the SW and NE parts of the research area which are controlled by a NE-SW trending lineament.



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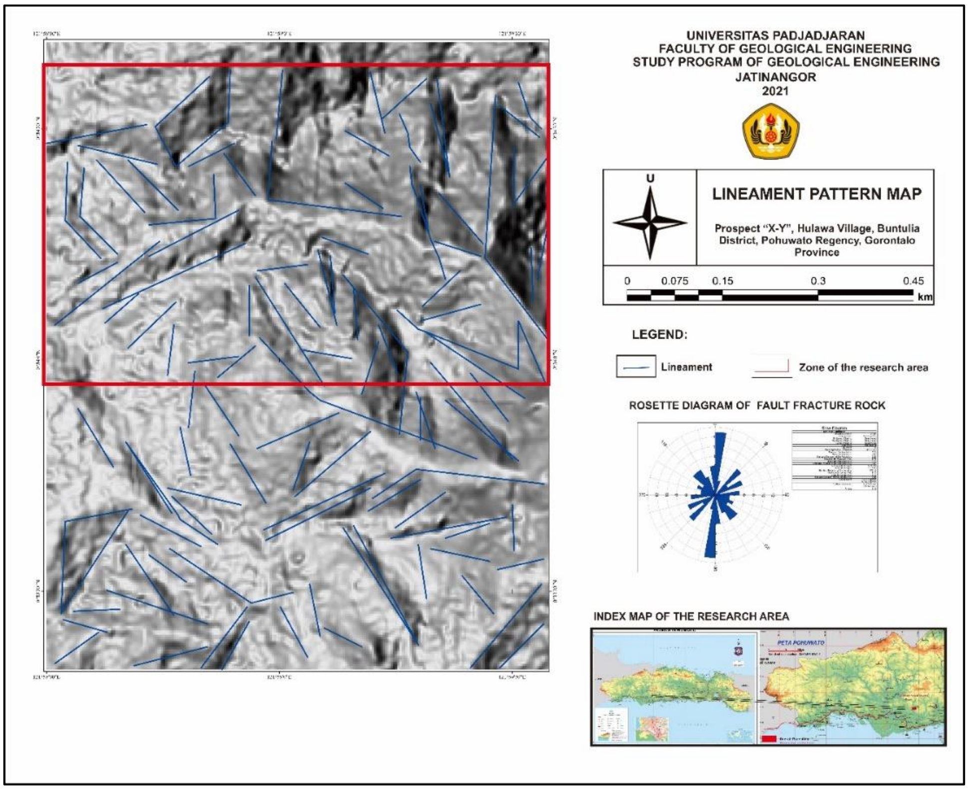


**Figure 4.** Lineament pattern map from DEM image

### B. Fault Fracture Density

Fault fracture density (FFD) analysis was conducted to determine the density value of the general lineament pattern formed by presence of fracture and fault structure. The existence of geological structures is important to generate the hydrothermal fluid pathway on secondary permeability of rocks. The value of lineament that range from 883,223 to 2600,4676 m/km². Based on multidirectional calculation, the length value of 20 lineament density that made into the form of density value from the level of the permeability zone.

1. Low density zone in the center of the research area, indicated by dark green-light green contour color with 0 – 1000 m/km² of density value. Lithological unit in low density zone includes dacitic and granodiorite unit.
2. Medium density zone, in the north of the research area, indicated by light yellow-yellowish red contour color with 1000-2100 m/km² of density value. Lithological unit in medium density zone includes dacitic and diatreme breccia unit.
3. High density zone, in the east of the research area, indicated by light red-dark red contour color with 2100-3200 m/km² of density value. Lithological unit in high density zone includes porphyritic dacite and lapilli tuff unit.

Fracture density anomalies are found in contouring clusters of high density zone with maximum density of 2100-3200 m/km². Mostly, the volcanic landscape made up coheret rock, such as porphyritic dacite, lapilli tuff, and diatreme breccia belonging the pani volcanic complex. As a result, it possible that the type of mineralization generated epithermal sulphidation with anomalous mineralization. It has the feature of a high fault-fracture density zone in cluster. High density zone that increased of fault to accumulate significant fluids flow. When deformation increases, the density of fracture create secondary permeability for hydrothermal fluids flow, resulting in extensive zones of alteration and gold precipitation. In the south and west, small to moderate gold occurrence in a low fracture density.



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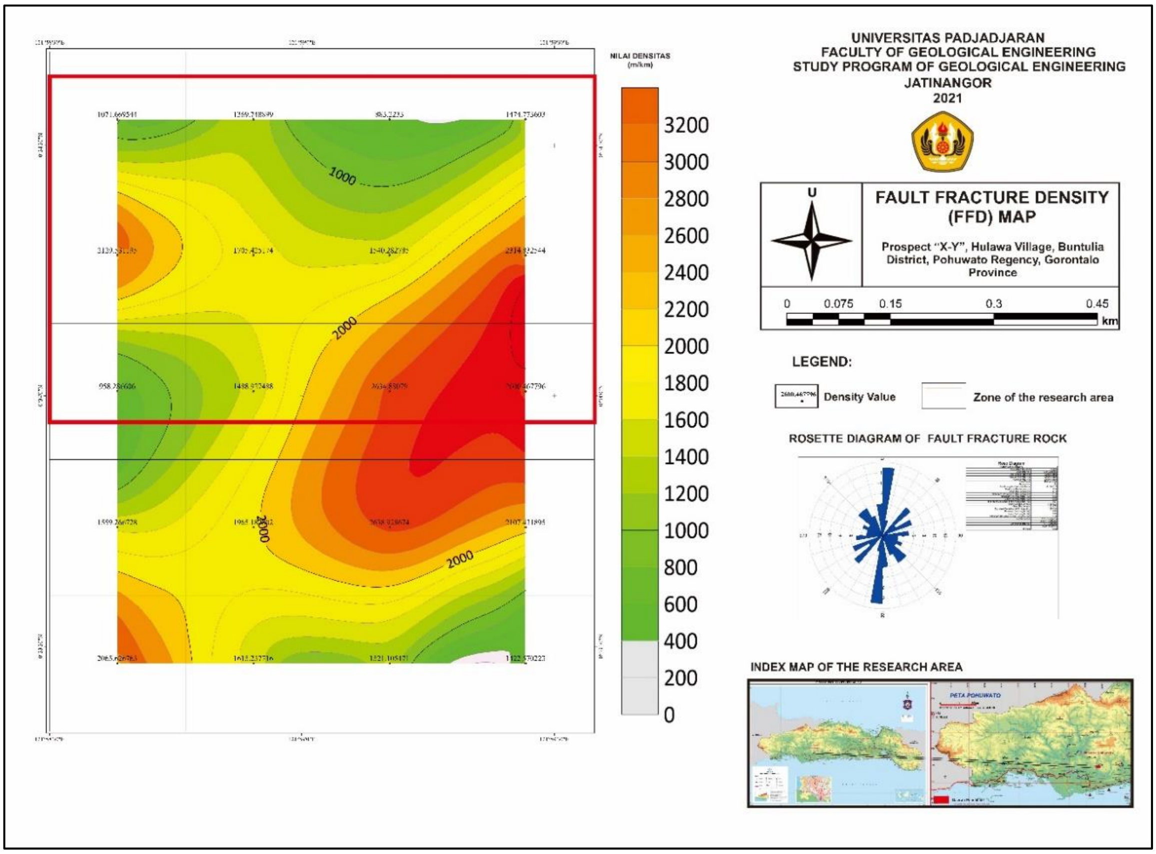


**Figure 5.** Fault fracture density (FFD) map generate from multidirectional hillshade

**C. Joint and Fault Analysis**

The implication of direct structural control is important role in hydrothermal fluid pathways. The main structures formed in the research area are dextral-normal faults in a NW-SE fault trending and sinistral-normal faults in a NE-SW subsidiary trending. (Figure 7).

Normal-dextral fault structure controlled by NW-SE trending as a structure formed in pre-mineralization. It generates a synthetic fault of strike-slip with dextral displacement (Figured 9) that association with silica-illite-chlorite and chlorite-carbonate-pyrite alteration. The evidence of structure represented in the south of research area with stike N340˚E/62˚E dipping to NE. According to Marjoribanks (1998), this structure interpreted to be the first structure configuration as transtensional (strike-slip and extensional) structural regime resulting normal fault.

Beside of that, the presence of NE-SW crosscut to NW-SE trends generated an anthitetic structure and shear fracture. This structure controlled normal-sinistral strike-slip fault and displacement trending to NNE-SSW dipping to SE. Dispacement configuration formed by reactivation of NW-SE trending structure elongated resulted in oblique movement associated with silica-illite-smectite and silica-illite-pyrite alteration. The evidence of this structure was found in the east and south of research area with 48˚N*E of* pitch with strike N251˚E/60˚E dipping to NW. According to Rickard (1972), this structure interpreted as a left normal slip fault. Clay gouge, as evidence of the fault existence formed by grinding process with silica-smectite and silica-illite-smectite alteration.

NE-SW the normal-sinistral fault as a structure that directly controls in syn-mineralization. Syn-mineralzation structure that controls the mineralization in the hypogene phase, forms hydrothermal crackle breccia, vein and stockworks. The normal-sinistral fault is formed by compression stress to produces an extensional zone which is the potential for hydrothermal fluid pathway. These hydrothermal veins are formed through extensional fractures which are commonly



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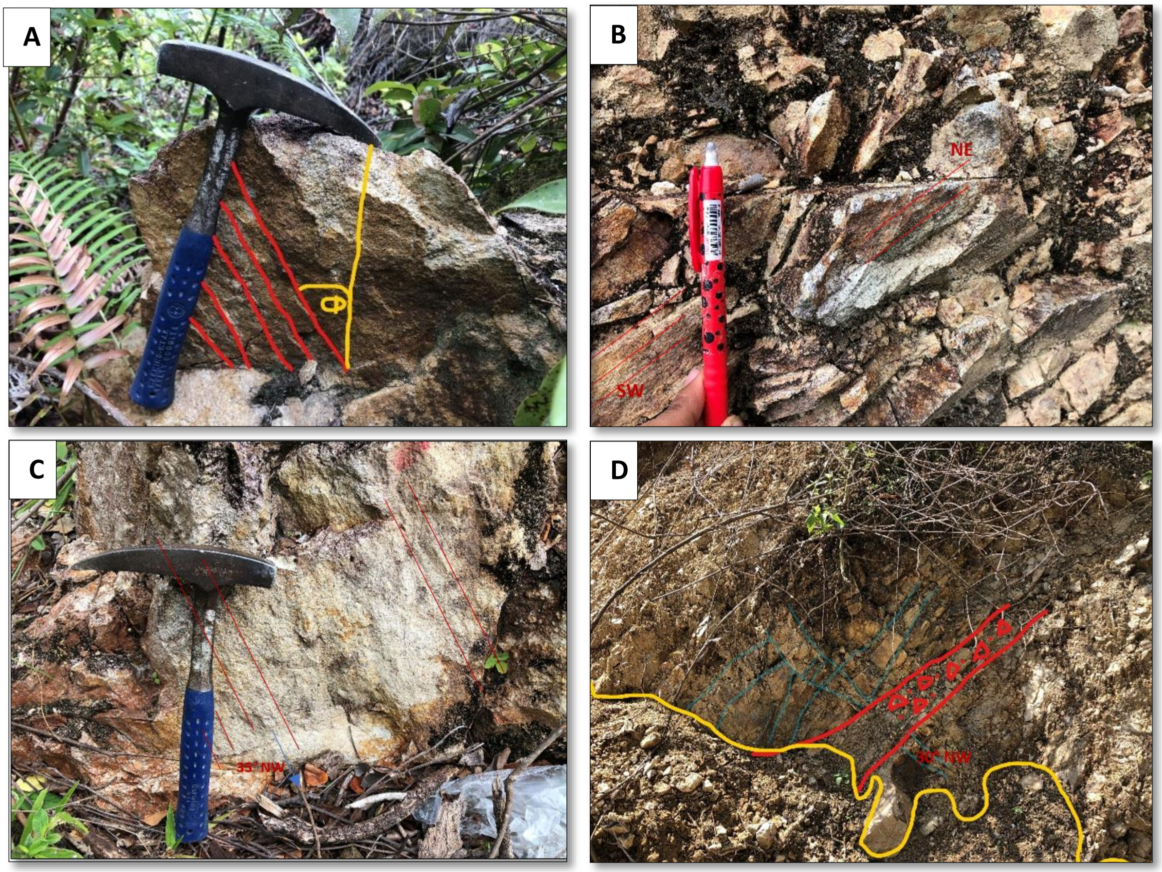
referred as dilatational jog zone (Corbett and Leach, 1997). Dilatational jog has a NE-SW trending from a transpressional process produced by the presence of a tectonic setting from olbique convergent, where en-enchelon sets that develop strike-slip fault in terms of of alteration and mineralization. Strike-slip duplex produces a fluid-filled joint by continuous compressional and extensional processes. Dilatational jog portion may indicate of increased fluid movement development of oreshoot in low sulphidation epithermal (Corbett, 2002). The complexity of the structure to the formation of mineralization not only controls of hypogene phase, but also controls the mineralization that occurs in the supergene phase.

In the field, fracture also formed in the hypogenous phase, then undergoes an oxidation process that involves the circulation of surface water. This is evidenced by the presence of oxide minerals formed in hydrothermal crackle breccias, vein and stockworks. The existence of these fractures is a pathway for meteoric water to to supergene enrichment of metal elements. In the current condition, hydrothermal fluid that filling fracture are found as quartz-limonite veins (resulting from the oxidation of sulfide minerals).




**Figured 6.** Fault slickenside in the outcrop (A),(B). Normal-sinistral fault with NE-SW trends, and (C),(D). Normal-dextral fault with NW-SE trend



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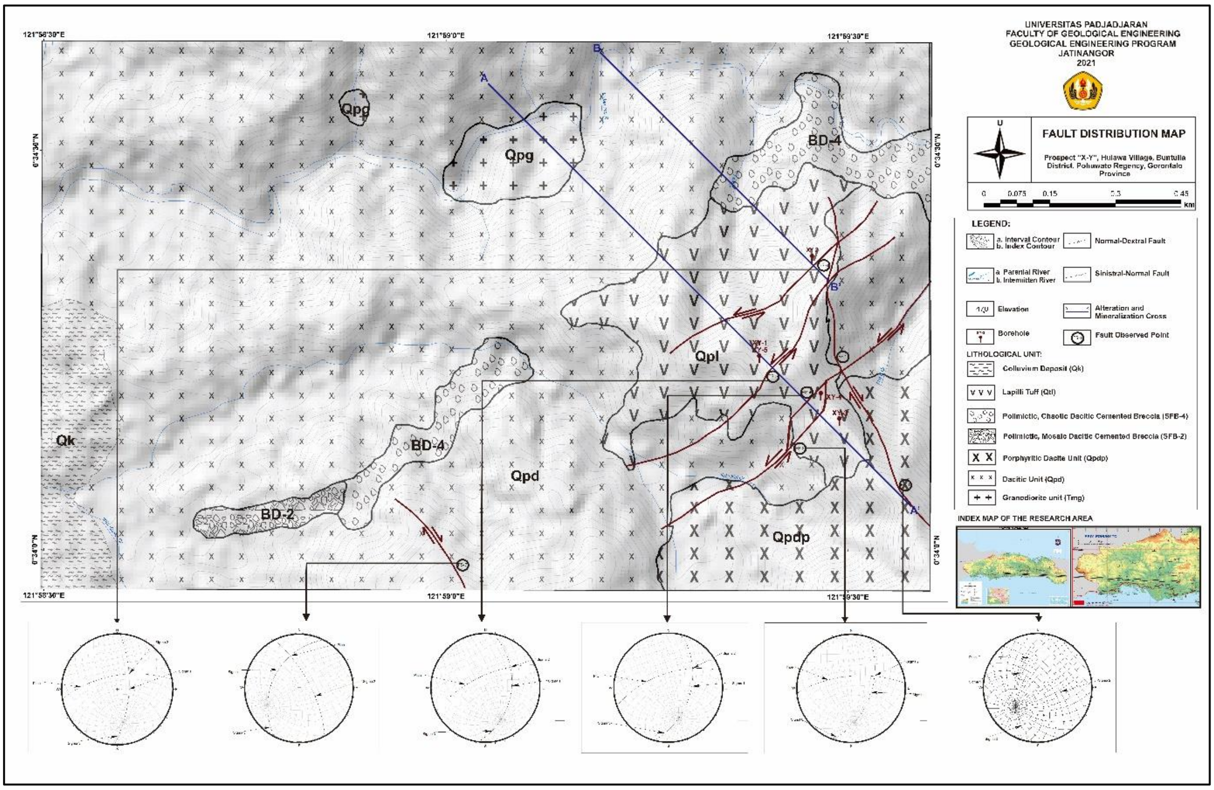
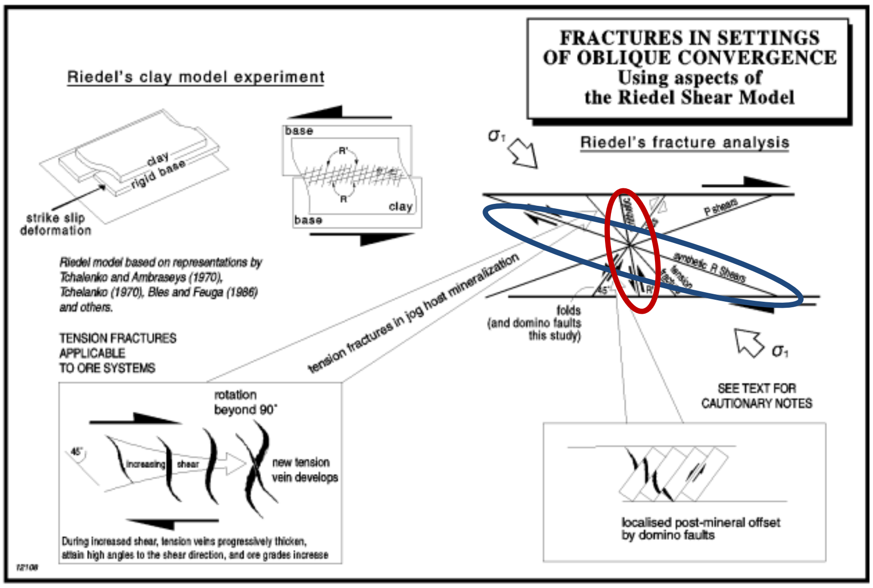



**Figure 7.** Fault structure map that distributed in the research area




**Figured 9.** Riedel shear models show the normal-sinistral fault (synthetic fault) and the normal-dextral fault (anthitetic) (Corbett & Leach, 1997)

## CONCLUSION

Implication of direct structural control in prospect "X-Y" generated an important role in hydrothermal fluid pathways. The type of mineralization generated epithermal sulphidation with anomalous mineralization. It has the feature of a high fault-fracture density zone in cluster with 2100-3200 m/km². The primary control of mineralization in the research area are dextral-normal faults in a NW-SE paralel trends and sinistral-normal faults in a NE-SW trends. NW-SW trend mineralization interpret to be the first structure, and NE-SW trend mineralization also reactivate NW-SE tren mineralization elongate resulted in oblique movement. Gold mineralization in prospect "X-Y" are hosted in porphyritic dacite, lapilli tuff, and diatreme



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breccia unit with NE-SW trend mineralization. Several evidences of structure (fault, joint, vein, hydrothermal crackle breccia, and veinlet) has been outcropped and being analyzed the type of related structure. Hopefully, the analysis can be shown the other oreshoot/dilatational pattern to explore the other anomalous of mineralization zone, with detail mapping of vein distribution, geophysic pattern and geochemical exploration. Futhure research can give any perspective and involved valuation in gold mineralization.

**ACKNOWLEDGEMENT**

The authors would like to thank for all support from PT. Gorontalo Sejahtera Mining and Universitas Padjadjaran for permitt this research. Also thanks to all parties that could not mentioned who has helped the completion of this research.

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E-ISSN : 2579 – 3136