Comparison of Scanline and Photogrammetry Survey for Natural Fracture Analysis, Study Case: Jatiluhur Formation and Subang Formation, Bogor

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Abstract. This research tries to compare the result of fracture measurement using the scanline as conventional method and photogrammetry method to understand the advantages of each method. This comparison is important to understand the benefit of using the photogrammetry for fracture study compared to the conventional method. The study area is located at three fractured outcrops of Jatiluhur Formation and Subang Formation at Cipamingkis river, Bogor. Two hundred fracture data from the scanline method and 215 aerial photos were collected for the analysis. The analysis found there are three main fracture sets in the study area, namely the Northwest–Southeast (NW-SE), Northeast–Southwest (NE-SW), and East-West (E-W). When measured at the same location, no significant difference in the orientation of the fracture sets can be found between both methods. However, the two different methods give a significantly different result on the fracture density calculation (P10). This difference was caused by the lithological characteristic variation, where it influences the ability to identify fracture from a distance. Additionally, the photogrammetric method enables the better identification of shear fractures and joints pattern that associated with the fold. Therefore, this study concludes that both methods are complementing each other on the natural fracture study. The scanline method is optimal for fracture density measurement, while photogrammetry is better for identification of fracture orientation and pattern in a relatively larger area.

Keywords: Geology, Photogrammetry, Scanline, Fracture, Outcrop,

1. Introduction

Photogrammetry is information gathering about physical object by recording, measuring and interpreting pattern on photo or image [1-3]. This method is widely used for industrial purposes. [4-5] use photogrammetry for open pit monitoring purpose by creating surface model with high accuracy. While [6] creates thermal imagery, aerial photos and digital elevation model with rapid, effective and safe method on Taupo volcanic zone for geothermal exploration purposes by photogrammetry survey.

Photogrammetry is an important tool in this study that be accompanied by conventional structural geology observation and measurement through scanline method. The objective of this study is to compare the orientation measurement and 1-Dimension fracture density (P10) between the photogrammetry method and the scanline method. In addition, it also tries to understand the advantages of each method. This objectives supported by field condition that has fractured outcrop extends on the river floor and photogrammetry for structural geology has not applied in the research area.
2. Research Area

Administratively, the research area is located at Cipamingkis river Jonggol and Sukamakmur sub regency, Bogor regency, West Java. This area can be reached by car within two hours from university of Indonesia, Depok. There are three stations on the southern and northern part of research area. Figure 1 show station location and satellite imagery of research area.

Research area as part of Cianjur geological map [8] is consisted of middle and late tertiary sediment from Jatiluhur formation and Subang formation. Jatiluhur formation is consisted of middle Miocene intercalated siltstone and very fine sandstone, while Subang formation includes late Miocene siltstone, limestone, with abundance occurrence of brownish very hard nodules. The primary bedding orientation is West-East with strong orientation anomaly in the research area along Cipamingkis River. The orientation anomaly show north – show trending and interpreted as a result of tectonic and structural form. The major geological structure in this area is Jatiluhur anticline with east-west orientation and plunging to the eastern side with several strike-slip fault. Figure 2 show geological map of research area modified from Sudjatmiko (1972) with several fault and fold represent as black line.
3. Data and Method

This research using primary field data through two primary methods, the scanline survey and photogrammetry survey. At the early stage of research, the desktop study is an important stage to define a specific area of interest using satellite imagery. Since the outcrop in this area is quite large, it is possible to identify using google earth pro. Based on the desktop study, the survey design developed to determine the survey planning such as the measurement station, flightpath, field condition and activity schedule. The survey design will create an effective and efficient survey activity to gain more valid data. Then the next step is the survey which could run parallelly. The last stage is the interpretation and comparison of the result of both methods which is the main research objectives. Figure 3 show research workflow.

![Figure 3. Research workflow](image)

In the field survey, we use scanline method of at three observation stations from south to north of Cipamingkis river. The main objective of this survey are the measurement of orientation and dimension from fractures at fractured outcrops as shown of Figure 4. These field data will be analyzed using DIPS to identify the main orientation of fracture set by rosset diagram and named as ‘SLFRC’. Lithological characteristic is also recorded such as the colour, structure, grain size and compaction/strength using hand specimen description. While the compaction/strength determine by based on ISRM Grade [9-11]. Table 1 show ISRM grade as field strength measurement of lithological response to geological hammer.
Table 1. ISRM Grade [2,6,12]

| ISRM Grade | Term        | Field estimation of strength                                                                 |
|------------|-------------|---------------------------------------------------------------------------------------------|
| R6         | Extremely strong | Rock material only chip under repeated hammer blow, rings when struck                        |
| R5         | Very strong  | Require many blows of a geological hammer to break intact rock specimen                        |
| R4         | Strong       | Handheld specimen broken by a single blow of geological hammer                               |
| R3         | Medium strong| Firm blow with geological pick indent rock to 5 mm, knife just scrapes surface               |
| R2         | Weak         | Knife cuts material but too hard to shape into triaxial specimen                              |
| R1         | Very weak    | Material crumble under firm blow of geological pick, can be shaped with knife                |
| R0         | Extremely weak| Indented by thumbnail                                                                       |

The photogrammetry survey done by DJI Phantom 4 Pro with altitude 80 – 100 meters from surface and overlapping imagery 80%. The survey location in exactly similar with scanline survey with larger scope. This imagery will be processed through two primary stage, namely processing and analysis. The first step of processing is aligning the photo based on coordinate and altitude. After alignment, all photo will processed to create dense cloud and mesh as basis model. From dense cloud, we could create digital surface model, outcrop digital model and orthomosaic photo depends on the purpose. All the processing steps take time of processing from half hour to one day depends on aerial photo quantity. Figure 5 show photogrammetry survey activity.
The next step is lineament identification from orthomosaic photo of each station using Global Mapper. In this study, the lineament divides into two categories, 1) fracture lineament from non-scanlined (P-ALLFRC) which consist of all fractures in the survey area. and 2) fracture lineament from scanlined track (P-SLFRC) which consist of fracture that intersects with scanline survey and this data will be used for comparison of fracture orientation from scanline survey and photogrammetry survey. The lineament will be analyze using DIPS to create rosset diagram for each station and fracture categories.

The occurrence, orientation and density of fracture could be understood by fracture characteristic analysis [12]. Determination of set fracture is using mode of rosset diagram trend. Since there are several types of fracture density in Pxy Diagram [2], this research only calculate the 1-Dimension fracture density or called by P10 value. P10 value is get by number of fracture that intersect the scanline track divided scanline length. So the higher value mean more dense fracture in one meter. Figure 6 show Pxy Diagram for fracture density, intensity and porosity.

![Figure 5. Photogrammetry survey](image)

![Figure 6. Pxy Diagram [3-4]](image)
4. Result and Discussion

4.1 Result

In general, all of the three stations have moderate dip to the east with non-bed confined fractures. This fracture shown by the fracture cuts the bedding and does not stop at the bed boundary indicates post-depositional fracturing in this area as shown by figure 7. Detail result of each station will be described below.

![Non-bed confined fracture](image)

Figure 7. Non-bed confined fracture (yellow: bed boundary, black: fracture)

4.1.1 S1 Station. This station is located at the southern part of the research area with outcrop on the river floor with dipping to the east. The outcrop of light grey siltstone intercalated with very fine sandstone that has parallel bedding and moderate compaction (R3 – R4 ISRM). The fracture has no to small aperture with water erosion marker in several spots. Outcrop photo provided on figure 8

![S1 Outcrop](image)

Figure 8. S1 Outcrop

The fracture orientation of this station based on the scanline survey (SLFRC) is north-south, northwest-southeast and east-west. Meanwhile, based on fracture identification through photogrammetry at the scanline track (P-SLFRC) shows the main orientation is north-south, northwest-southeast. The west-east orientation cannot be identified, due to the limited resolution and observations through photogrammetry so it is hard to distinguish between fracture lineament and erosion of the water flow line. Then based on the photogrammetry survey in the entire area (P-ALLFRC) of the S1 station, the main orientation of the fracture is similar to the scanline survey. Figure 9 show result and interpretation of S1 photogrammetry survey.
The fracture density value at this station has a significant difference between the scanline survey and the photogrammetry survey on the scanline path. In the scanline survey, the fracture density value (P10) is 0.98 per meter, while the photogrammetry survey shows a lower value, 0.58 per meter. This difference in density value indicates a better ability of scanline to identify fractures in detail than photogrammetry. This caused by the limited resolution of the photogrammetry results in identifying small fractures.

4.1.2 U1 Station. This station is located at northern part of research area with outcrop in the middle of river with dipping to the east. The outcrop is consisted of light grey siltstone intercalated with very fine sandstone that has parallel bedding and abundance brownish very hard nodule with high compaction (R5 ISRM). Then the fracture consist of shear and joint has moderate aperture with solid lineament of fracture on the nodules part. Figure 10 show outcrop condition with nodules marked by redline and scanline marked by yellow line.
through the aerial photo in this location is easier since the fracture does not influence by water flow erosion. Result and interpretation of photogrammetry survey shown by figure 11.

Figure 11. U1 interpreted aerial photo (yellow: scanline track, red : fracture lineaments)

Fracture pattern in this station is well identified by photogrammetry survey which shows the conjugate fracture and joint That match to fold model by Fossen (2016) as shown by figure 12. Fracture developed on the folding limb due to the compression on early-stage then followed by extension on the last stage of folding. This fracture pattern support the interpretation that the area is part of Jatiluhur anticline on regional geology map [7]

Figure 12. Fracture pattern associate with fold (left : interpreted lineaments, right : fracture fold pattern by Fossen,2016)

The fracture density value(P10) at this station has similar value between both methods, which is 0.83 per meter. This similarity indicates the ability of photogrammetry is as good as scanline in identifying fractures influenced by the characteristics of the lithology with high compaction makes fracture can be identified properly through photogrammetry.
4.1.3 U2 Station. The U2 Station is located at the northern side of research area near of U1 station. The outcrop consists of light grey siltstone intercalated with very fine sandstone that has moderate compaction (R3 – R4) with few of brownish nodules. Then the fractures has similar characteristic with S1 since the lithological also similar with shear and joint part could not separate clearly.

The fracture orientation based on scaline survey (SLFRC) has northwest – southeast, east – west, and northeast – southwest. While fracture set from photogrammetry at the scanline track(P-SLFRC) is northwest – southeast and northeast – southwest. The east – west can not identified due to the water flow erosion line like in S1 station. The photogrammetry survey of entire area show similar set with scanline survey as shown by figure 13.

![Image](image.png)

Figure 13. U2 interpreted aerial photo (yellow: scanline track, red : fracture lineaments)

The fracture density (P10) from scanline is 1.41 per meter while from photogrammetry survey has significance different with value is 0.94 per meter. The lower value from photogrammetry indicates the fracture that could be identified by this method on one meter is less then the scanline method. The difference also influenced by small fracture that hard to identify using aerial photo.

4.2 Discussion
4.2.1 Fracture orientation. As the result from rosset diagram analysis based on strike orientation, we found that the scanline and photogrammetry does not show significance difference of fracture orientation such as northeast – southwest, northwest – southeast, east – west. Than fracture pattern could be determinen easier by photogrammetry since we had the visualization of the fracture. The photogrammetry uses less time to get more fracture data in larger area, and has advantages for this purpose than scanline survey. The complete comparison of strike and dip data will be conduct in future research. Table 2 show rosset diagram and fracture set interpretaion from scanline and photogrammetry survey.
Table 2. Rosset diagram summary (blue: NW – SE set, yellow: NE – SW set, green: E – W set, orange: N – S set)

| Station | Rosset Diagram |
|---------|----------------|
|         | SLFRC | P-SLFRC | P-ALLFRC |
| U2      | ![Diagram](image1.png) | ![Diagram](image2.png) | ![Diagram](image3.png) |
|         | P10 = 1.41/m | P10 = 0.94/m | P20 = 0.019/m2 |
| U1      | ![Diagram](image4.png) | ![Diagram](image5.png) | ![Diagram](image6.png) |
|         | P10 = 0.83/m | P10 = 0.83/m | P20 = 0.031/m2 |
| S1      | ![Diagram](image7.png) | ![Diagram](image8.png) | ![Diagram](image9.png) |
|         | P10 = 0.38 | P10 = 0.58/m | P20 = 0.0337 |

4.2.2 Fracture density value (P10). Generally, this value has significance difference from each method. The higher density value by scanline means this method could capture more detail fracture per meter length than photogrammetry does. Otherwise, the fracture density value in U1 station show similar value. This fact also show the ability of photogrammetry can provide fracture data as detail as scanline survey in some condition. Table 3 summarize P10 value of each station from scanline and photogrammetry survey.

Table 3. P10 value comparison between two methods

| Station | Scanline | Photogrammetry |
|---------|----------|----------------|
| U2      | 1.41     | 0.94           |
| U1      | 0.83     | 0.83           |
| S1      | 0.93     | 0.58           |

The difference from U1 and other station is the compaction/strength grade. The U1 lithology has high compaction that equivalent with R5 grade, while the others station only has moderate compaction with R3 – R4 ISRM grade. Moreover, the fracture condition at U1 station with solid lineament and less influence by water flow erosion help the identification through photogrammetry. Based on the condition of high compaction and solid fracture lineament, it will improve the ability of photogrammetry to identify more detail fracture. Moreover, in general condition, the scanline survey has more ability to define the 1-Dimension density (P10) value accurately.

5. Conclusion

These research found the research area has three main fracture set, 1) Northwest – Southeast, 2) Northeast – Southwest, and 3) East – West, with anomaly the north – south set only on S1 station with significance different of P10 Value between both methods. Furthermore, the photogrammetry survey has excess for determine fracture
orientation set and pattern at larger area with less time. Lithological with high compaction will increase the photogrammetry ability to identify fracture. While the scanline survey is more optimum to capture detailed fracture density since P10 value from this method is higher than photogrametry. From this research we conclude scanline and photogrammetry survey is complement to each other for structural geology study

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