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Study of the Digital Geological Compass in Increasing the Effectiveness and Efficiency of Measuring Geological Structure Data in the Field

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Abstract

This study compares the use of analog geological compasses and digital geological compasses in measuring fracture planes on crystalline rocks at the Lampung region. The measurement results demonstrate that using digital compasses yields higher time efficiency than analog compasses, with a reduction in measurement duration of over 50%. Although the dominant directions of the fracture planes were similar between the two methods, the inclination values and accuracies of each plane were not always consistent. Data processing using rose diagrams and stereonets indicates that the RockD application provides comparable results to measurements obtained using analog compasses. Therefore, the use of digital compass applications such as RockD can serve as an efficient alternative for geologists in collecting field data related to rock fractures, particularly in the context of quantitative data. However, analog geological compass is still recommended for measuring planes with on single-plane characteristics, such as rock bedding and fault mirrors. This study demonstrates the potential for development and transformation from analog geological compasses to digital geological compasses, and further research is needed to investigate the minimum number of fractures that can be measured with a digital geological compass to be considered statistically valid.

Keywords: Digital Geological Compass, RockD, Rocklogger, Smartphone.

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Introduction

A geological compass is an essential instrument utilized by geologists for lithological and structural mapping. Field geologists are proficient in employing analog geological compasses equipped with clinometers (Assali et al., 2014) and field books that document measurements across hundreds to thousands of locations daily (Allmendinger et al., 2017). The analysis of geological structures, including fault networks, lava flow directions, sedimentary rock bedding, lineation, and foliation, necessitates the measurement of various orientations via a geological compass (Jaud et al., 2022). Consequently, field measurements utilizing a geological compass require focused study by students or aspiring geologists to present sedimentological and structural data accurately (Novakova & Pavlis, 2017; Senger et al., 2021).

Engineers generally obtain discontinuity data using a geological compass, clinometer, measuring tape and scale. This process necessitates a certain level of expertise (Ibrahim & Musa, 2020; Liu et al., 2022; Singh et al., 2021; Vöge et al., 2013), rendering it generally challenging, time-intensive, and prone to data bias (Li et al., 2019), in both scanline (1D) and window sampling (2D) measurements (Kong et al.,

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2020; Watkins et al., 2015). Conversely, since 2010, there has been significant innovation in the geological compass through the development of a digital application for smartphones and tablets, which is relatively cost-effective and practical (Novakova & Pavlis, 2017; 2019). Aspiring or novice geologists can likely produce more reliable field data utilizing a digital compass compared than an analog compass, which requires greater consistency and skill (Whitmeyer et al., 2019).

Worldwide since 2016, more than 3.9 billion people have been using smartphones (Lee et al., 2018). Digital geological compasses, available as smartphone applications, offer an alternative for aspiring geologists and professionals alike to gather data effectively, much like how GPS has been replaced by applications like Avenza or digital cameras by smartphone cameras and other features (Lee et al., 2018; Wong et al., 2019). Moreover, smartphones and tablets with mapping applications that integrate digital compasses make field data collection accessible, even for those without in-depth geological knowledge (Whitmeyer et al., 2019; Whitmeyer & De Paor, 2014). This trend necessitates further examination to assess the accuracy and time efficiency provided by digital compasses.

Materials and Methods

The research was conducted quantitatively by comparing the results of fracture plane measurements using various geological structure measurement methods. The locations were selected based on the presence of abundant geological structures in the Lampung region (Figure 1). The measurement objects were crystalline rocks located at three different sites, each featuring a significant number of fracture planes (Figure 2). Shear fractures have been found on north-south and east-west direction while joint and vein tend to have a northeast-southwest orientation (Hendrawan et al., 2024). The measurements were conducted by a final-year student with excellent measuring skills who has previously conducted research in the area. Collecting data can be seen in Figure 2 (left) where the process can use a field book or clipboard placed on the plane surface, especially for rough surfaces.

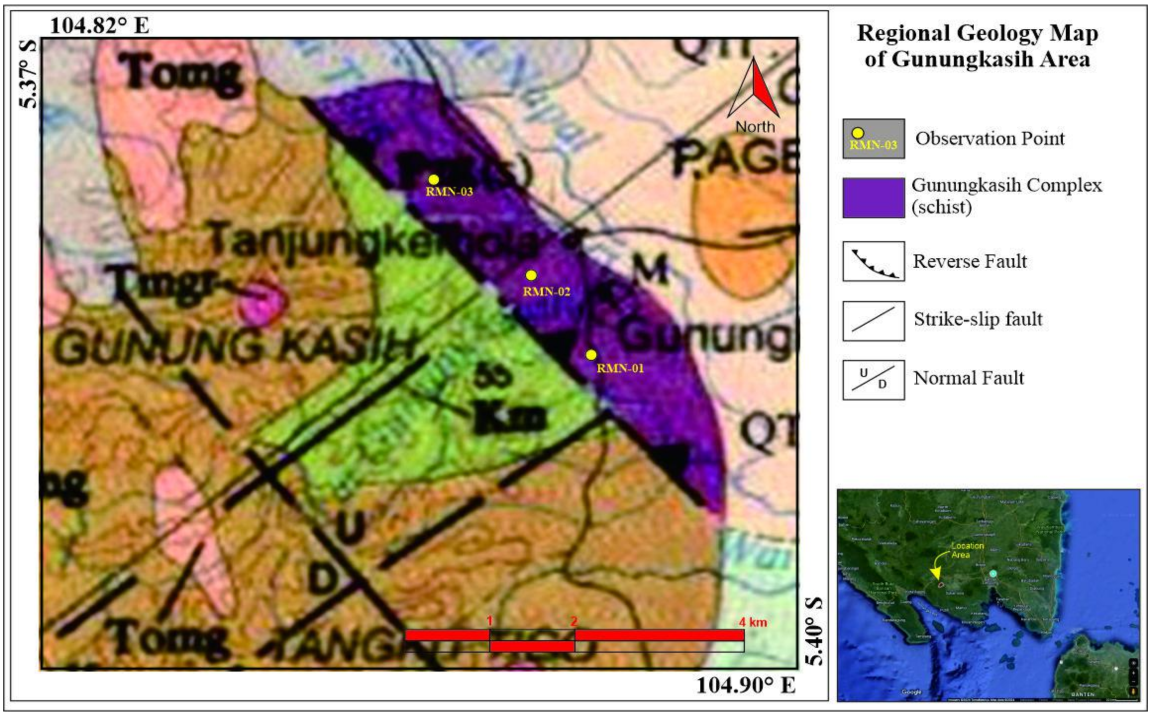

Figure 1. Observation point in Gunungkasih Area, modified Regional Geology Map (Amin et al., 1993).

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Figure 2. An outcrop of rocks serves as the observation site for geological structure plane measurements.

The measurement of natural fractures at the mesoscale outcrop level in the field was conducted using the window scan method over an area of 1m² (Koesmawardani et al., 2021). At each outcrop point, measurements were taken using two different methods: the strike-dip method and the dip-dip direction method. These measurements utilized both an analog geological compass (Brunton compass) (Zewdie & Asmare, 2023) and a digital compass application on a smartphone, performed by the same individual. According to Novakova & Pavlis (2017), smartphones equipped with various sensors, such as a magnetic field sensor, accelerometer, and proximity sensor, can be used as digital compass instruments, provided they are calibrated beforehand. This study utilized the Samsung Galaxy A50, which meets the necessary specifications for these sensors (Samsung, n.d.).

There are many digital compass applications available for Android devices. FieldMove Clino has the highest number of reviews and ratings on the Play Store, followed by the Rocklogger app (Novakova & Pavlis, 2019; Whitmeyer et al., 2019; Whitmeyer & De Paor, 2014). However, in practical use, FieldMove Clino is less convenient as it requires the smartphone to always be in portrait mode. Therefore, an alternative application, RockD, was selected to function as a digital geological compass. Both applications were used for comparison in terms of data accuracy. Details of these applications are listed in Table 1.

Table 1. Geological Compass Application on Smartphones based on Android Platform (data accessed from Google Playstore on August 2024).

Name	Developer	Installation	Rating/ Review
FieldMove Clino	Petroleum Exp. Ltd.	50.000+	4.5/689
Rocklogger	RockGecko	50.000+	4.4/360
RockD	UW Macrostat	100.000+	4.5/378

The collected field data was processed using Microsoft Excel 2019 and Dips 6.0 software to generate comparison graphs, as well as distribution plots of planes and points on stereographic and rose diagrams. This data analysis will allow for evaluation of the time efficiency of each method and instrument, as well as the accuracy achieved by each method.

Results and Discussion

Data collection was conducted at three sites, designated as RNH-01, RNH-02, and RNH-03, all of which are composed of crystalline rocks. Across these three

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sampling locations, a total of 292 fracture planes were measured using both analog and digital compasses. The measurements employed various methods: analog compass strike-dip (SDA), dip-dip direction (DDA), digital compass strike-dip using the RockD application (SDH), and dip-dip direction using the Rocklogger application (DDH). The details regarding the measurement duration and the amount of data collected are provided in Table 2.

The measurement duration using various methods showed consistent differences at each observation station. According to Figure 3, a pattern emerged indicating that the more fracture planes measured, particularly using analog compasses (SDA and DDA), the longer the measurement duration. However, the DDA method was more time-efficient compared to the SDA method. On the other hand, the use of digital compasses did not significantly affect the measurement duration relative to the number of fractures measured. Furthermore, the graph in Figure 2 demonstrated a significant difference in measurement duration between the SDA-DDA and SDH-DDH methods, with an average reduction of more than 50%. This indicates that measurements using digital compasses (smartphones) are considerably more efficient than those using analog compasses.

Table 2. Fracture planes data measurement recap from observation points.

Measurement Duration	Minutes		
	RNH-01	RNH-02	RNH-03
SDA	14 min	17 min	16 min
DDA	13 min	16 min	12 min
SDH	6 min	8 min	8 min
DDH	5 min	8 min	7 min
Total Fractures	88 planes	132 planes	72 planes

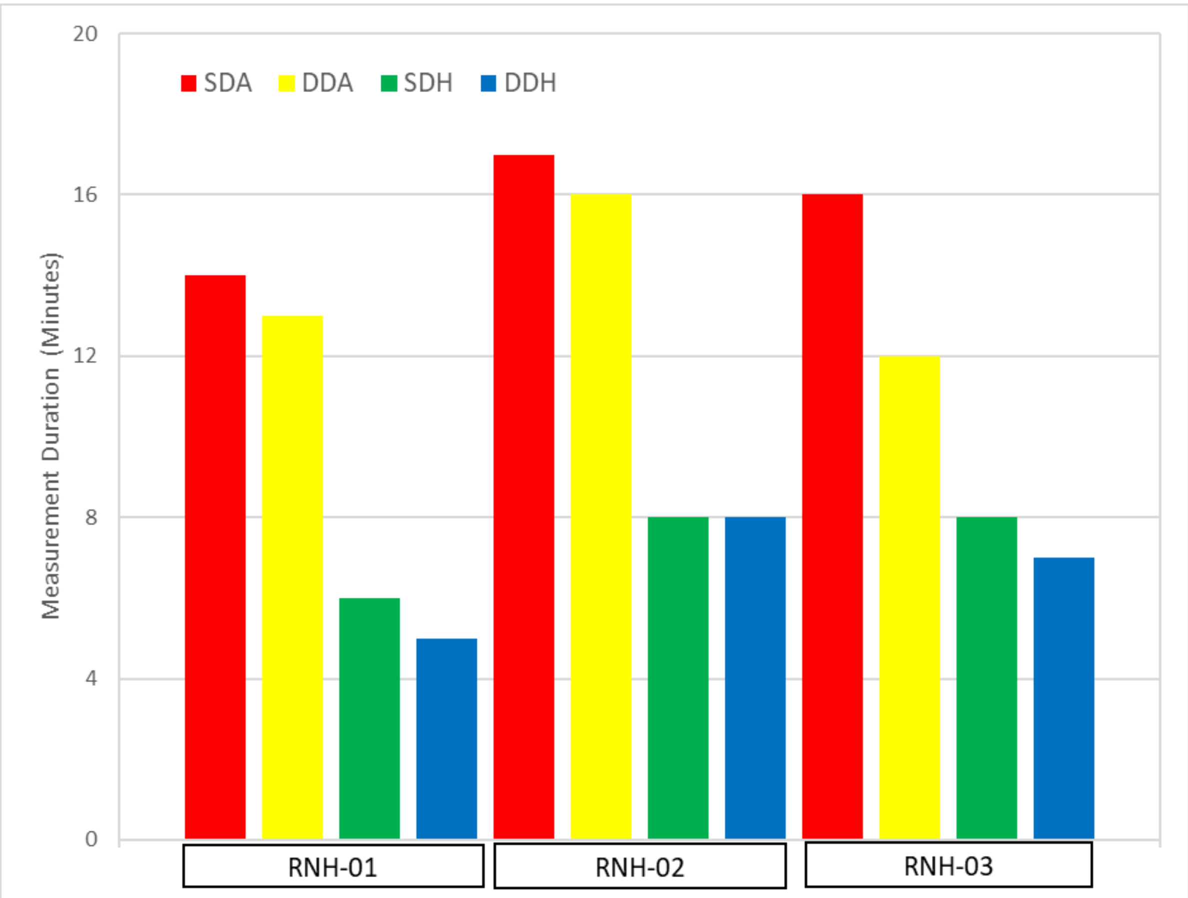

Figure 3. Comparison graph of measurement duration with several methods at each observation point.

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Figure 4 shows a comparison graph between strike and dip values of planes present on the outcrop using several methods. Based on Figure 4, it indicates that the structural plane data obtained are not always the same from each method. In RNH-01 and RNH-03, some points only have one point or method, including RNH-02 although not as many as the other points. This is caused by the difference in strike and dip values measured by each method. In general, the difference in dip values becomes an anomaly compared to the strike values. However, if we look at RMN-02, which has a larger amount of data taken, the data grouping becomes clearer. This needs to be validated by plotting the data in a rose diagram to get a complete picture of the data.

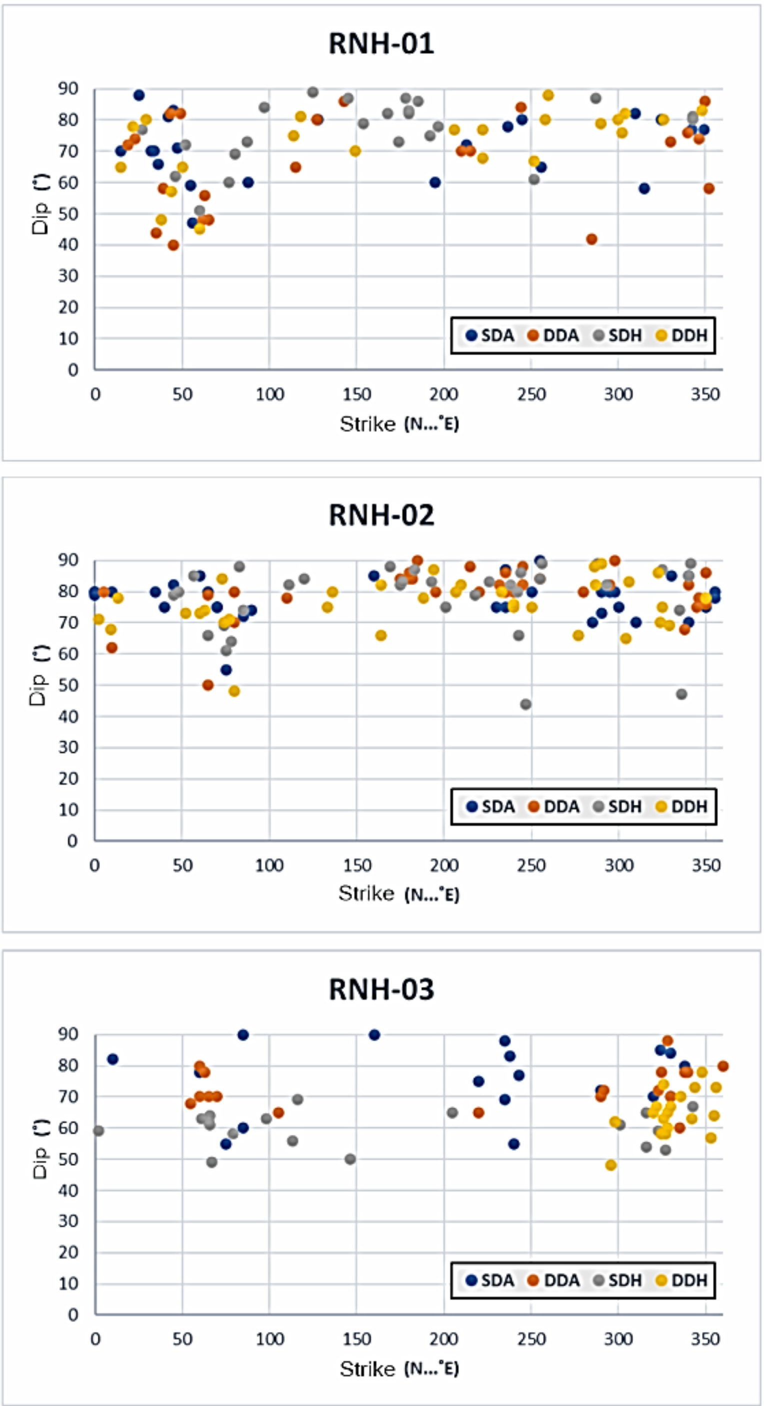

Figure 4. Strike and Dip Graph with several methods at 3 observation points.

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The fracture data is then processed using a rose diagram as shown in Figure 5. Comparing each station, in general, each measurement shows a relatively similar dominant direction or trend of strike and azimuth. For example, in Figure 4, station RNH-02 shows the same dominant direction from each measurement method, although not the same. Slightly different from the data at station RNH-01, which has far fewer measurements, showing a slightly different dominance from each measurement method. This indicates that the more data measured, the more accurate it will be in seeing the dominant direction of the fracture plane, especially for the azimuth or strike direction of the fracture plane.

The stereographic contour diagram is shown in Figure 6 by entering the strike and dip data spatially. In general, each measurement at each measurement station does not show a contour concentration in the same position. As seen in Figure 5, the data distribution is still too random. This indicates that the measurements taken do not show a consistent relationship between strike and dip using either an analog compass or a digital compass.

Based on the data processing and analysis conducted using several diagrams, it is evident that the use of smartphones with the RockD and Rocklogger applications shows a high level of efficiency, particularly in terms of measurement duration. Measurements with these digital compass applications can reduce the measurement duration by more than 50%. The applications used are also relatively easy to obtain and free, making them accessible to anyone with a smartphone, whether it is an Android or iPhone. Moreover, using digital compass applications to measure fracture planes does not require specific skills or extensive experience.

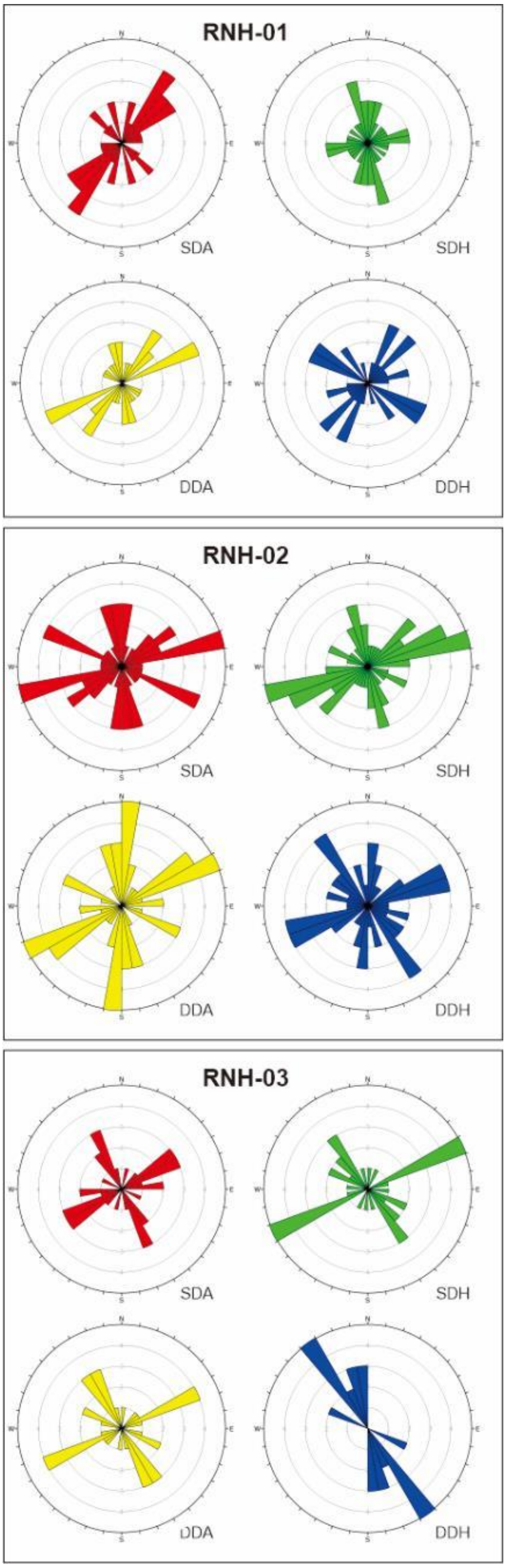

Figure 5. Rosset diagrams from observation points using data from each measurement method.

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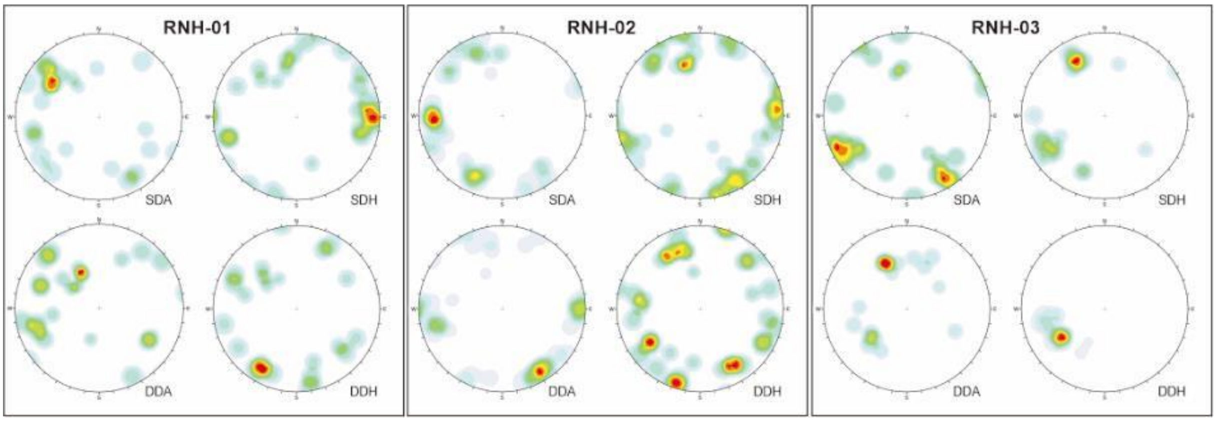

Figure 6. Contour stereonet diagrams which presented plane measurement results from outcrops with each measurement method.

Data processing using rose diagrams and stereonets shows that, in general, the use of digital compass applications on smart-phones will indicate the dominance of strike and azimuth direction, showing the same dominance. However, the dip values and accuracy of each plane cannot be considered accurate. This is not suitable for measuring single planes such as bedding planes, laminations, and fault planes. Measurements using digital compass applications are suitable for measuring rocks with many geological structures like fractures and for collecting quantitative data. Based on the data processing and analysis results, the RockD application is recommended because it tends to produce results like those obtained using an analog compass.

Conclusion

The use of digital compass applications like RockD and Rocklogger greatly assists geologists in conducting fieldwork. Some conclusions drawn from this research include Smartphones with the RockD application significantly facilitate the work of geologists, particularly for quantitative data (such as shear fractures, joints, or veins). Therefore, Digital geological compass applications make field measurements more efficient, allowing geologists to measure more planes in a single day of fieldwork. The use of digital geological compass applications requires a battery with normal performance (not in battery-saving mode) and needs periodic calibration although qualitative or single-plane data (rock layers, fault mirrors) are recommended to still be measured using an analog geological compass.

This research marks the beginning of the development and transformation from using analog geological compasses to digital geological compasses. Further quantitative research is needed to determine the minimum number of fractures that should be measured with a digital geological compass at a single point to be considered valid, using a more comprehensive statistical approach.

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Author Contribution

RNH proposed the idea, designed the study, performed the analysis, and wrote the paper. MI, AG, and ADZ conducted the field measurements and processed the data. AJW provided brainstorming input and support for the field activities.

Conflict of Interest

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The authors declare no conflict of interest.

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