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Geoelectrical resistivity survey to determine sliding surface of landslides prone area case study in Ponjong subdistrict Gunung Kidul regency Indonesia

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ABSTRACT

The research area is located in Ponjong Subdistrict, Gunung Kidul Regency. Ponjong area specific at Tambakromo village is one of potential in landslides disaster since 2011. The outspread information about landslide and mitigation should be done in research area. The aim of this research is to get the subsurface condition and determine of landslide surface based on geoelectrical resistivity in Tambakromo area, Ponjong Subdistrict, Gunung Kidul regency. The method of this research is used geoelectrical survey by using Dipole - dipole configuration. The result of this research is the lithology of sliding surface is claystone – fine tuffaceous claystone with resistivity value of 29.9 ohmmeter based on Dipole – dipole subsurface cross section at Grogol village. The sliding surface could be found at 5 metres to 20 metres underground. At Sumberejo village, based on dipole-dipole subsurface the lithology of sliding surface is claystone – fine tuffaceous claystone with resistivity value of 6.18 to 29.9 ohmmeter at depth of 20 to 25 metres. Based on the regional stratigraphy correlation showed that the claystone or tuffaceous claystone is included in Semilir Formation. This research should be able to held for local government to proved landslide mitigation in research area.

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1. INTRODUCTION

Gunung Kidul is one of regency in Yogyakarta that has 18 subdistricts with potential of landslide disaster [1]. Ponjong is one of subdistrict that has potential of landslide disaster. According to [2] the landslide is a natural disaster that has high frequent recently. Some of landslides disaster occurred in Ponjong area last decade. In 2011, the landslide disaster occurred in Jambedawe, Tambakromo village, Ponjong Subdistrict, Gunung Kidul Regency with length of valley about 20 metres and wide of areal about 4 metres [3]. In 2017, the road that connect to Ponjong and Semin damaged due to landslide disaster and five local people refuged to the safe place [4].

Landslide is defined by one slope movement down that triggered by soil mass and rocks. General people used the term of landslide for all kind of mass movement that through sliding surface or no sliding surface. [5] definitively also used this term of landslide for all kind of mass movement. Landslide is included in geological processed that occurred due to interaction of some condition such as geomorphology, lithology, structural geology, hydrogeology, and land use [6]. Those condition is supported each other that caused the slope condition to move down [7]. The process of landslide move down and emit of slope included in rocks, soil, artificial fill, or both of combination that move like falling, rotation, translation, spreading, or flowing.

Geological factors that caused of landslide are loosening material, weathering, discontinuity (fault, material rock contact), difference of permeability and or tight material [8]. Generally, the landslide disaster potential area is zone within high rainfall rate (up to 2500 mm/year). The landslide is one of mass movement or rock mass movement occurred at slope of 20°-40° with rock mass movement such as residual soil, colluvial material and weathered volcanic rock[9].

Based on overviewed the landslide disaster that occurred in Ponjong Subdistrict specific at Tambakromo village, Gunung Kidul Regency, the research about the potential of landslide disaster in research area is needed. The aim of this research such as to get the subsurface condition based on geolectrical resistivity data in Tambakromo village, Ponjong subdistrict, Gunung Kidul Regency, Special Region of Yogyakarta. Based on subsurface condition from 2 D cross section of dipole dipole configuration, the sliding surface, the rocks, the stratigraphical and structural geology data could be determined.

2. RESEARCH METHOD

This research is started with study of literature about the geological condition in the research area (Figure 1). Geomorphology, lithology, and structural geology of this research area were studied by some authors. The research area is consisted of karst topography [10] and dominated by Mandalika Formation, Semilir Formation, and Wonosari Formation [11].

Field observation was conducted to the geological mapping and geoelectrical resistivity. The result of geological mapping would produced the geological map. Geological map showed that the factors that caused the landslide included in slope, lithology, structural geology, and land use.

The geophysics included in geoelectrical survey. The geolectrical resistivity survey measured the rock resistivity in 2 studies site with dipole-dipole configuration. The result is 2 D resistivity cross section which showed that the subsurface condition in research area. The sliding surface is interpreted by rock resisitivity value that has a small resistivity value and included in claystone [12].

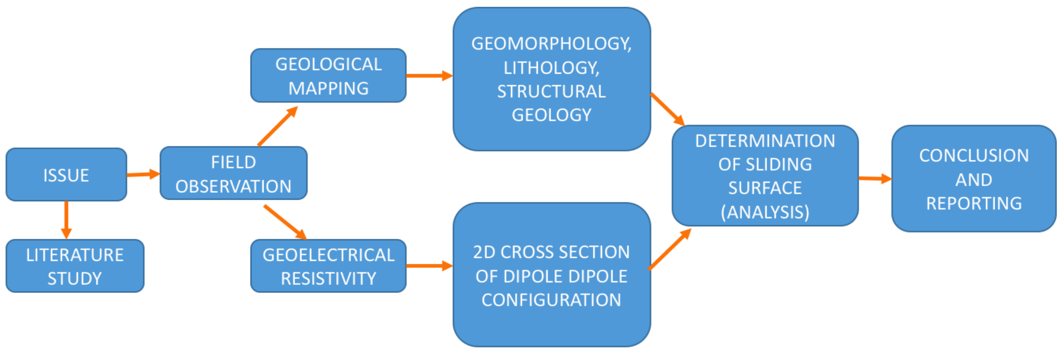

Figure 1. Flow Chart of Research Method

3. RESULT AND ANALYSIS

Several geological data observations including geomorphology, lithology, and structural geology in research area. The presence of surface data (geological data) would be correlated with subsurface condition. Geomorphological data is presented in Geoomorphological Map (Figure 2) and the rock distribution and structural showed in 3 D geological map (Figure 3).

a. Geomorphological Data

The geomorphology condition in research area based on slope calculation and elevation (morphometric) and morphogenetic [12]. The geomorphological unit is divided into seven geomorphological unit such as

a. Weakly undulated fluvial unit (F5)
b. Strongly hill structural denudation unit (D11)
c. Weak to strongly undulated structural denudation unit (D5)
d. Strongly undulated to hilly structural unit (S3)
e. Weak to strongly undulated hill (S1)
f. Strong hilly karst unit (K5)
g. Weakly undulated karst unit (K10)

The drainage pattern in research area such as rectangular, parallel, and multibasin. The research area stadium included in mature stadium [13].

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Table 1. Geomorphological unit in research area.

No.	Geomorphological Unit	Slope (%)
1.	Weakly undulated fluvial unit	6.92
2.	Strongly hill structural denudation unit	23.46
3.	Weak to strongly undulated structural denudation unit	11.62
4.	Strongly undulated to hilly structural unit	14.81
5.	Weak to strongly undulated hill	12.79
6.	Strong hilly karst unit	40.97
7.	Weakly undulated karst unit	7.08

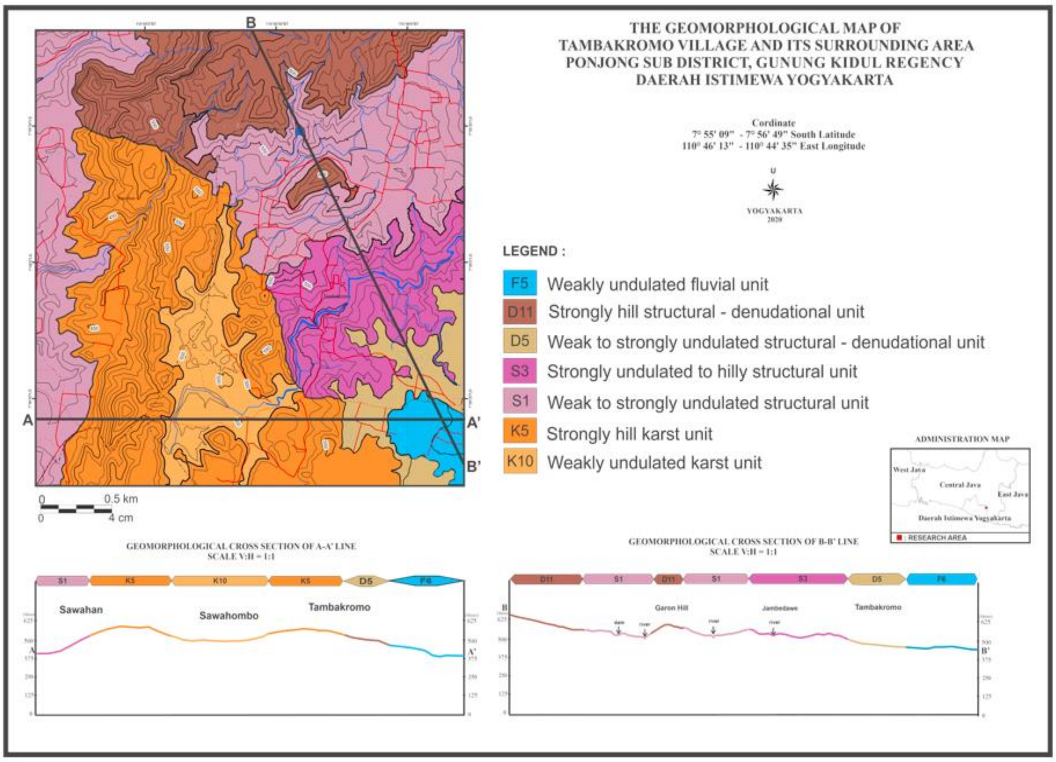

Figure 2. The Geomorphological Map in research area

b. Stratigraphical Data

Geological mapping produced the stratigraphy in research area. The rock consisted from oldest to newest such as Mandalika andesitic breccia unit, Semilir tuffaceous lapillistone unit, and Wonosari Crystalline limestone, and clay to sand deposit unit (Figure 3).

In order to observation detail in geological mapping, the stratigraphical data was conducted by measuring section. Based on stratigraphical measuring section, Andesitic Breccia unit was deposited at age of N 2 – N 4 (Late Oligocene to Early Miocene) [14]. Andesitic breccia unit is consisted dominantly by andesitic breccia, tuff, siltstone, and lava. Andesitic breccia distributed in the northern part of research area. This breccia was produced from volcanism activity. The source of this volcanic rock was interpreted by proximal facies [15]. The Panggung Massive Highland is interpreted as a source of Mandalika Formation in research area [11]. Some of andesitic breccias well altered in Sumberejo village. The andesitic fragment of breccia altered to chlorite minerals from grayish colour become greenish colour. The matrix is composed by tuffaceous sandstone to siltstone. Altered matrix has greenish colour. The altered matrix (tuff) might be interpreted as rock or lithology factor caused the landslide in research area.

The tuffaceous lapillistone unit deposited overlying the andesitic breccia in Early Miocene (N4 – N5) [14]. The tuffaceous lapillistone unit is consisted of coarsening tuff, fining tuff, and lapilli breccia. This unit is composed by tuffaceous claystone and tuffaceous soil in Grogol village and Sumberejo village. The Garon hill is a hill where the landslide occurred in 2011 to 2017. The Wonosari clastic unit limestone was deposited unconformity overlying at N 8 – N 10 [16]. This limestone distributed dominantly in research area. The clastic limestone was distributed in the western part of research area especially in Krenceng River. The clastic limestone has a direction of layer dipping at southeast and south. Crystalline Boundstone was distributed in southern and southeasten part of research area.

c. Structural Geological Data

The structural geology data was obtained in field such as fractures and faults. Other structural data that supported the presence of faults such as valley lineament, springs, and rock layers offset. The main fracture in research area is dominated by shear fractures and extension fractures. The general direction of shear fracture is northeast – southwest (NE-SW) and north – south (N-S). The extension fracture has direction of northeast – southwest (NE-SW) and northwest – southeast (NW-SE).

Structural geology data was analyzed in stereography analysis with Dips 6 Software. The fault planes, gauge, lineaments, slicken side, and offset of rock layers are structural geology data that supported the fault analysis (Figure 4). The faults data were processed to get the main fault and name of faults based on [17]. There were 5 faults in research area that included in strike slip fault (Table 1).

Table 1. Several faults in research area

No.	Name of fault (Rickard, 1972)	Geographical Fault Name	The Azimuth of Fault Plane
1.	Left Slip Fault	Plarung Sinistral Fault	N 202º E/73º
2.	Reverse Left Slip Fault	Sawahan Sinistral Fault	N 357º E/86º
3.	Reverse Left Slip Fault	Sumberejo Sinistral Fault Jambedawe	N 355º E/70º
4.	Right Slip Fault	Dextral Fault	N 51º E/73º
5.	Left Slip Fault	Garon Sinistral Fault	N 80º E/59º

Figure 4**.** The gauge in Krenceng river, Tambakromo, Ponjong (left). The springs in Grogol village, indicated the structural geology (center). The offset of rock layer (tuffaceous lapillistone and andesitic breccia (right)

d. Modelling of 2 D Subsurface

The acquisition of geophysical data was taken in Grogol and Sumberejo village with dipole – dipole configuration. The length of electrodes along of 280 metres in Grogol village and 220 metres in Sumberejo village. The azimuth of electrode array has East to West direction. The subsurface cross section showed the subsurface condition (Grogol and Sumberejo village) such as lithology and structural geology.

3.4.1 Grogol Village

The lithology in Grogol village is interpreted in some of rocks such as andesitic breccia, tuffaceous lapillistone, tuffaceous claystone, tuffaceous wet claystone, and soil of andesitic breccia. Andesitic breccia is interpreted by resistivity value of 700 ohmmeter.

The resistivity value from 29.9 to 140 ohmmeter is interpreted by tuffaceous lapillistone. Tuffaceous lapillistone is correlated to regional stratigraphy with Semilir Formation and has a rock contact with Wonosari Formation (limestone) in angular unconformity relationship (**Figure 5**). At depth of 15 to 20 metres, there is some lens of aquifer that showed in orange colour with resistivity value of 0.26 to 1.28 ohmmeter. The manifestation of surface water is presented by spring in the field.

The spring genetic is interpreted by the rock contact between tuffaceous claystone and tuffaceous lapillistone. The tuffaceous wet claystone has impermeable characteristic and could not be water storage. The tuffaceous lapillistone is underlying the tuffaceous claystone and capable to be water storage. In addition, the rock contact of tuffaceous claystone and tuffaceous lapillistone was interpreted as sliding surface.

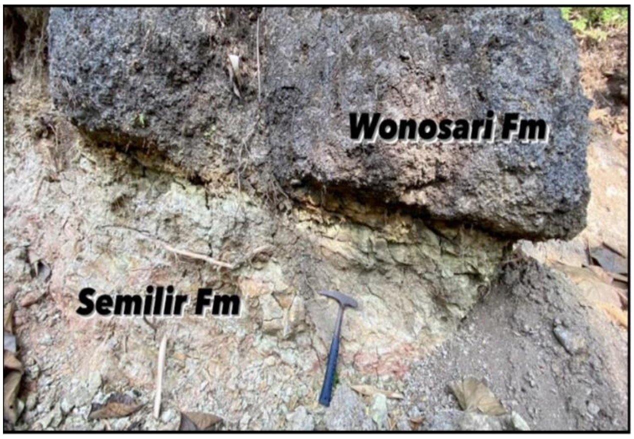

Figure 5. The rock contact formation of Semilir Formation and Wonosari Formation

The sliding surface is interpreted by resistivity value in between 1.28 and 29.9 ohmmeter. Based on those resistivity value, the sliding surface is a tuffaceous wet claystone in overlaying with tuffaceous lapillistone. The thickness of tuffaceous lapillistone is approximately 10 to 20 metres underground. By the slope and elevation observation, the estimation of landslide direction could be occurred in east to west (Figure 6).

Interpretation of structural geology data based on cross section is the normal fault controlled the rock layer in subsurface at 160 metres of resistivity array. It could be showed that the west part of cross section is relatively step as hanging wall. The presence of hanging wall could make the reason why the west part (Garon hill) occurred the landslide in several times. The eastern part at 0 to 160 metres of resistivity array could be interpreted as footwall. Another normal fault could be interpreted at 220 metres of resistivity array.

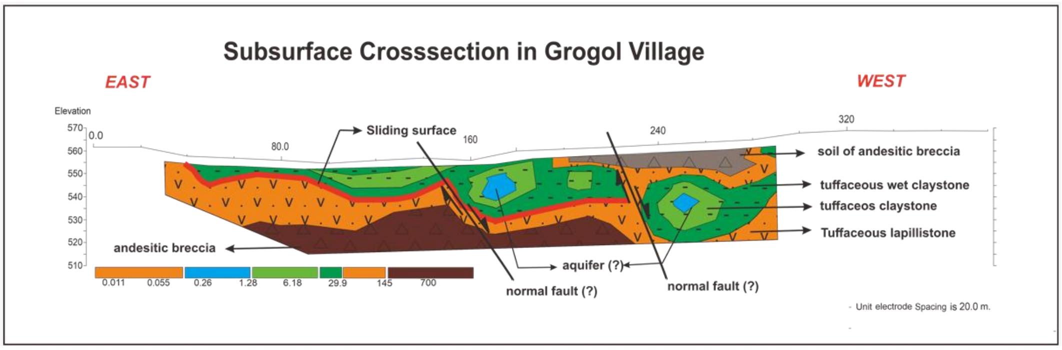

Figure 6. The subsurface condition in Grogol village showed that the sliding surface in red line colour

3.4.2 Sumberejo Village

The lithology in Sumberejo village is consisted of andesitic breccia, tuffaceous lapillistone, and tuffaceous claystone. The basement or the oldest rock layer is interpreted by andesitic breccia in brown colour with resistivity value of more 574 ohmmeter. Andesitic breccia included in Mandalika Formation [14]. The tuffaceous lapillistone is included in Semilir Formation with resistivity value in range of 131 to 574 ohmmeter. The rock contact Formation of Mandalika and Semilir Formation was observed in the field. The stratigraphical relationship between Mandalika andesitic breccia and Semilir tuffaceous lapillistone is interfingering (Figure 7).

The presence of aquifer is interpreted as a lens of rock with resistivity value in range of 0.36 to 29.9 ohmmeter. This aquifer is interpreted at depth of 18 to 20 metres. This aquifer location is in a depression in between two highland at east part of and west part of subsurface cross section (Figure 8). The resistivity value of 1.26 to 29.9 ohmmeter is interpreted as altered clay. This altered clay could be a sliding surface for landslide (Figure 7 – right). The kind of landslide is included in rotational landslide [18].

The traditional mining operations also increase the risk for landslide hazards in the research area [19]. It caused the kind of toppling landslide which is occurred in Patuk area [20]. Altered clay in subsurface is overlaying to clastic limestone. The clastic limestone is interpreted by resistivity value of 29.9 to 131 ohmmeter. This Clastic limestone is included in Wonosari Formation. The altered clay is controlled by the fault in research area. The Northeast – southwest (NE-SW) has triggered this area for rock weathering and some rocks were altered. The fault also triggered the rock stability in Pindul cave, in the western part of research area [21].

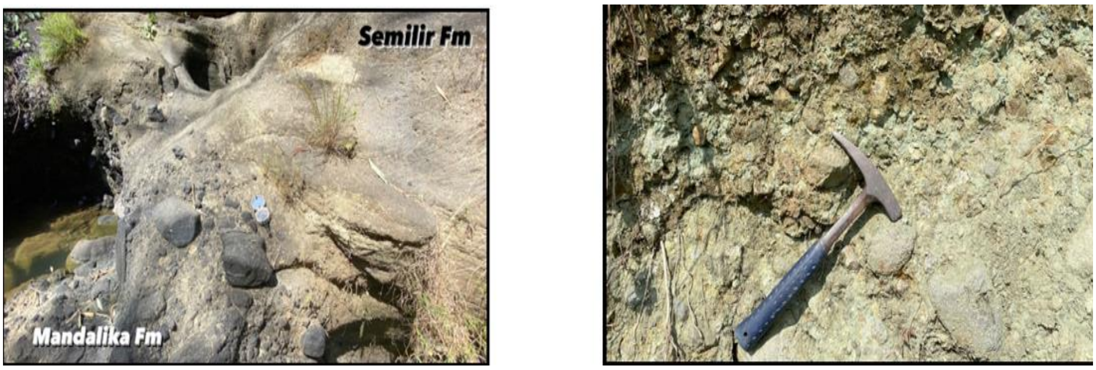

Figure 7. The rock contact formation of Mandalika Formation and Semilir Formation (left). The altered clay that derived from altered fragment and matrix of andesitic breccia (right)

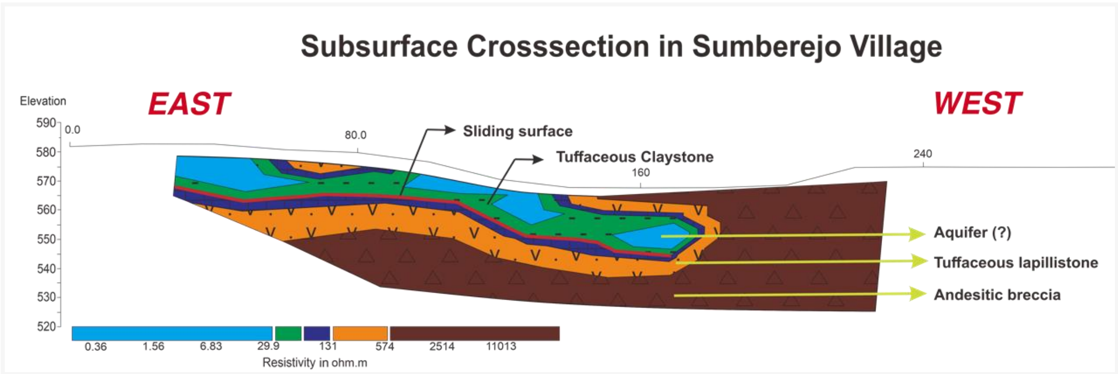

Figure 8. The subsurface condition in Sumberejo village showed that the sliding surface in red line colour.

4. CONCLUSION

The subsurface condition in research area is divided into two areas such as Grogol village and Sumberejo village. In Grogol village, sliding surface was interpreted in contact of wet tuffaceous claystone and tuffaceous lapillistone with the depth of 10 to 20 metres. The presence of normal fault could triggered the landslide occurred in research area. In Sumberejo village, the presence of the sliding surface was interpreted as altered clay in subsurface is overlaying to Wonosari clastic limestone. Both of sliding surface were founded in Semilir tuffaceous claystone with a less of difference characteristic. Grogol village has a wet tuffaceous claystone and Sumberejo village has altered tuffaceous claystone.

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REFERENCES

[1] “Warga Gunungkidul Tewas Tertimbun Longsor Saat Menambang Batu,” 2021. https://news.detik.com/berita-

jawa-tengah/d-5524823/warga-gunungkidul-tewas-tertimbun-longsor-saat-menambang-batu (accessed Feb. 28, 2022).

[2] B. And *et al.*, "Geo-Hazards Landslide Hazard Assesment On Java Island Case Study: Landslides In Warungkiara," *JSD.Geol*, vol. 23, no. 1, 2013.

[3] "Warga Jambedawe Buka Jalur Ponjong-Tambakromo - Tribunjogja.com." https://jogja.tribunnews.com/2011/02/07/warga-jambedawe-buka-jalur-ponjong-tambakromo (accessed Feb. 28, 2022).

[4] "Sorotgunungkidul - Media Berita Online Gunungkidul." https://gunungkidul.sorot.co/berita-94970-jalan-surodadi-ambyar-jalur-ponjong---semin-tutup-total.html (accessed Feb. 28, 2022).

[5] D. Varnes, "Slope Movement Types and Processes," *Spec. Rep.*, vol. 176, pp. 11–33, 1978.

[6] R. S. Raden Ayu Ramanda, D. Noor, and I. Ridwansyah, "The potential of landslide in Lake Maninjau Catchment Area, West Sumatra," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 311, no. 1, 2019, doi: 10.1088/1755-1315/311/1/012081.

[7] O. Trianda, R. Prastowo, and S. Novitasari, "Identifikasi Ketebalan Lapisan Lapuk di Daerah Kalirejo, Kulonprogo Berdasarkan Pengukuran Mikrotremor dalam Upaya Mitigasi Tanah Longsor," *Pros. Nas. Rekayasa Teknol. Ind. dan Inf. XIII*, vol. 2018, no. November, pp. 246–253, 2018.

[8] A. M. Ferrero, M. R. Migliazza, M. Pirulli, and G. Umili, "Some Open Issues on Rockfall Hazard Analysis in Fractured Rock Mass: Problems and Prospects," *Rock Mech. Rock Eng.*, vol. 49, no. 9, pp. 3615–3629, 2016, doi: 10.1007/s00603-016-1004-2.

[9] K. Sassa, P. Canuti, and Y. Yin, "Landslide science for a Safer Geoenvironment: Volume 2: Methods of landslide studies," *Landslide Sci. a Safer Geoenvironment Vol. 2 Methods Landslide Stud.*, vol. 2, no. 2, pp. 1–851, 2014, doi: 10.1007/978-3-319-05050-8.

[10] R. S. A. Waskita, H. D. K. Wijayanti, and A. H. F. Rizqi, "Studi Provenance Dan Analisis Granulometri Endapan Pasir Di Daerah," *Geoda*, vol. 01, no. 01, pp. 35–49, 2020.

[11] S. Martosuwito, H. Samodra, and Sidarto, "Hubungan Lembah Sadeng, Cekungan B aturetno dan Teras BEngawan Solo, Jawa Bagian Tengah," *J. Sumber Daya Geol.*, vol. 23, no. 3, pp. 153–165, 2013.

[12] TelfordW.M, "Applied geophysics(2nd Edition).pdf." 1990.

[13] M. D. Fachrindra, B. Berliana, N. Rakhma, G. I. Sastrawiguna, and A. H. F. Rizqi, "Identifikasi Akuifer dengan Pemodelan Bawah Permukaan Menggunakan Metode Geolistrik Konfigurasi Schlumberger dan," vol. 2021, no. November, pp. 385–392, 2021.

[14] A. H. F. Rizqi, "Rekonstruksi Stratigrafi Jalur Sungai Krenceng, Ponjong, Gunung Kidul, Yogyakarta," *Journal.Itny.Ac.Id*, vol. 2020, pp. 255–271, 2020, [Online]. Available: https://journal.itny.ac.id/index.php/ReTII/article/view/1987.

[15] J. Martí, G. Groppelli, and A. Brum da Silveira, "Volcanic stratigraphy: A review," *J. Volcanol. Geotherm. Res.*, vol. 357, pp. 68–91, 2018, doi: 10.1016/j.jvolgeores.2018.04.006.

[16] A. H. F. Rizqi and Fatimah, "Penentuan Batuan Alas dan Penyekat berdasarkan Metode Geolistrik Konfigurasi Dipole-Dipole pada Telaga Gesing, Pucanganom, Kabupaten Gunung Kidul," *Pros. Nas. Rekayasa Teknol. Ind. dan Inf. XV Tahun 2020*, vol. 2020, pp. 247–254, 2020, [Online]. Available: https://journal.itny.ac.id/index.php/ReTII/article/view/1985.

[17] D. M. Ragan, *STRUCTURAL GEOLOGY An Introduction to Geometrical Techniques 3rd edition*, 3 rd. USA: Cambridge University Press.

[18] Y. Yatini and I. Suyanto, "Identification of slip surface based on geoelectrical dipole-dipole in the landslides hazardous area of Gedangsari District, Gunungkidul Regency, Province of Daerah Istimewa Yogyakarta, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 212, no. 1, 2018, doi: 10.1088/1755-1315/212/1/012013.

[19] F. A. Prihutama, M. D. Faruqi, D. N. Firmansyah, and E. T. Paripurno, "Landslide hazard potency using DEM-SRTM, Landsat 8, and aerial photo, case study at Ngawen Regency, Gunungkidul District, Yogyakarta," *AIP Conf. Proc.*, vol. 1987, 2018, doi: 10.1063/1.5047370.

[20] A. R. Yanuardian, I. G. B. Indrawan, and I. W. Warmada, "Analisis Kestabilan Lereng Di Desa Terbah Dan Sekitarnya, Kecamatan Patuk, Kabupaten Gunung Kidul Berdasarkan Slope Stability Probability Classification," *Ris. Geol. dan Pertamb.*, vol. 28, no. 1, p. 101, 2018, doi: 10.14203/risetgeotam2018.v28.745.

[21] N. Arasyi, F. Rizky, and B. Fahmi, "Identification of cave stability using integrated electromagnetic VLF, resistivity and rock mechanical method, case study: Pindul Cave Tourism, Gunung Kidul, Yogyakarta," *AIP Conf. Proc.*, vol. 1987, 2018, doi: 10.1063/1.5047333.