Fault control on distribution of sag-ponds in Imogiri, Bantul, Yogyakarta, and Its implications for the existence of the Opak active fault

Al Hussein Flowers Rizqi[1*], *Fadhilah* Elsa Putra[1], *Fanssyah* Widianto[1], *Muhammad* Erlandi[1], and *Ghani* Abdillah Ahmad[1], *Rober*t Timotius Tuska[1], *Evan* Rosyadi Ogara[2]

[1]Departement of Geological Engineering, Institut Teknologi Nasional Yogyakarta, Yogyakarta, Indonesia
[2] Departement of Geological Engineering, Institut Teknologi Sumatera, Lampung Selatan, Lampung, Indonesia

Abstract. Sag-ponds, a prominent geological feature, may be found near the summit of Gagak Hill in Bantul Regency, Yogyakarta. These depressions, which form within volcaniclastic rocks, are strongly tied to the Opak Fault's activity. The site is made up of Semilir Formation rocks from the Western Southern Mountains Zone, which were exposed along the Mengger Hills escarpment. The purpose of this study is to determine the location and orientation of sag-ponds governed by the Opak Fault. The method is based on structural geology analysis, which is backed by field observations such as lithological descriptions, sag pond dimensions, and documenting of structural elements such fracture planes, lineaments, shear and gash fractures. The sag-ponds range in shape from round to rectangular and elongated, with lengths of 1 to 15 meters and widths of 1 to 9.2 meters. Their depths, which are often filled by rainfall, range between 0.8 and 3 meters. The development of these sag-ponds corresponds to the Opak River's east-west diversion north of Watu Gagak Hill, which caused isolated depressions along the fault zone. Overall, the presence and position of these sag ponds indicate that the examined area is being impacted by the active Opak Fault.

1 Introduction

Utilize the most well-known active fault in Yogyakarta is the Opak Fault. This fault has drawn more attention since the 2006 Yogyakarta earthquake [1]. The active Opak Fault extends from Prambanan to the mouth of the Opak River Figure 1. In the west, the Yogyakarta plain is a downward block created by the Opak Fault, while in the east, the Baturagung Sub Zone is a high (footwall) that is reflected as the hanging wall of the Opak Fault [2].

* Corresponding author: alhussein@sttnas.ac.id

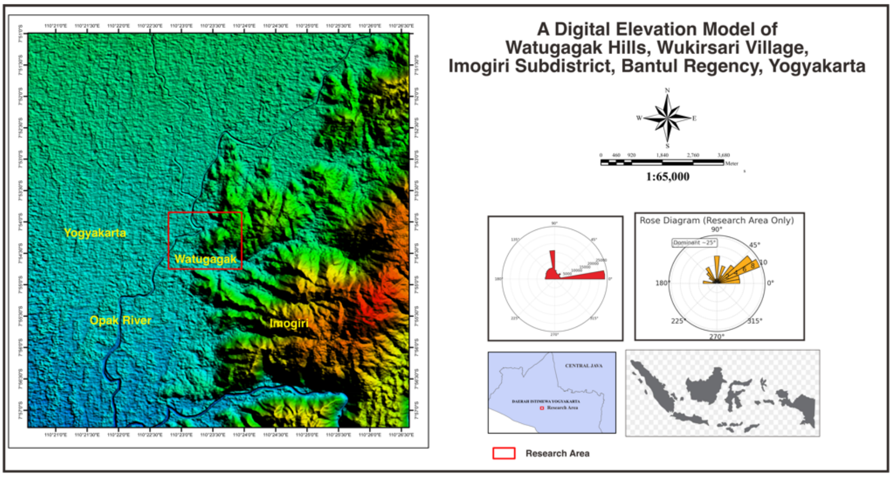

Fig. 1. DEM map of the research area located on the east side of the Opak River and Yogyakarta City

The research area is located on the Bukit Gagak plateau in Bantul Regency, Yogyakarta Special Region Province. The Opak Fault appears to be intricately tied to the formation of several basins within volcaniclastic rock strata [3]. Random layers of rocks with a relative westward slope can be seen at the Bukit Gagak tourism area. It is located within the physiographic zone of the Southern Mountains on a regional level [4]. It belongs to the Semilir Formation in terms of regional stratigraphy [5].

Due to their diverse sizes, shapes, and distribution, researchers investigated the causes of sagpond formation in the study area. Lithological and geological structural analyses are thought to be crucial in this investigation in order to determine the rocks found in sagponds. Stereographic identification of faults and the general orientation of geological formations in the study area can be used to determine the origin of Watugagak Hill and other sagponds. Research on the formation of sagponds will have an impact on the presence of the active Opak fault in the study area. Because of the displacement caused by the active Opak fault, the base of the Sagpond basin has experienced significant changes.

2 Methods

As shown in detail in Figure 3, the writing of this research is often completed in four stages: preparation, data collecting, data analysis, and the final stage. The phases of this study consist of:

2.1 Preparation stage

Data collected from earlier researchers for example the previous research from [6], [7], and [8] and a number of regional reviews of the Southern Mountains, particularly in the research area encompassing the Imogiri area and its environs, comprise this stage's literature study, which will be used as support.

2.2 Field observation stage

There are two parts to this stage: primary data and secondary data. Geological structure and lithology data are examples of primary data that were gathered on-site at the study site. The main information gathered is lithology observations, or observation data, and sagpond dimension data, which includes the sagponds' length, width, and depth. Additional information gathered includes the surface outcrop's geological structure, which includes fracture planes, straightness, and joints (shear and gash fractures). Secondary data is information gleaned from earlier researchers' investigations into the study site and its local geology such as previous study from [9] and [10].

2.3 Studio analysis, interpretation, and evaluation stage

Stereographic analysis of field-sourced geological structure data is used to complete this step. A number of the chosen fracture data are good. Software Dips includes gash fractures as well as shear fractures. The fault plane to the primary stress vector can be identified in the stereographic projection manufacturing process. The primary fault is named according to the classification in [11] based on the rake/pitch and fault dip data. Shape, straightness, depth, and dimensions were used to analyze the distribution of sagponds in the study area. The active Opak fault may cause changes in sagponds [12].

2.4 Making a scientific article

Data results in the form of stereographic projections of the main fault plane and the compilation of multiple sagpond data into a map of the distribution of sagponds in the research region are the outputs of the production of a scientific paper draft.

3 Result and discussion

3.1 Lithology and geology of the research area

The research area is on highly land close to Opak River. The lithology of the research area is dominated by alternating coarse and fine tuff formed from volcanic ash from the Semilir Formation. Almost all sagponds contain an alternating of coarse and fine tuff. Coarse tuff has a grain size of 1-2 mm, thin layers of 3-10 cm, and a volcanic clastic structure. It is composed of lithic minerals, quartz, and fine volcanic debris. Fine tuff has a finer size of less than 1 mm, a thin layering structure of 1-3 cm, volcanic clastic texture, and is made up of fine volcanic dust particles, a small amount of quartz, and volcanic rock fragments.

3.2 Identification of sagponds

There are at least 8 sagponds in the research region (Figure 2). The sagponds varied in length, width, and depth; in particular, sagpond 3 has two sagponds that are close to one another. There are a few sagponds, such 1, 2, and 5, that lack typical surface faults. However, the majority of the controlling faults in sagponds 3, 4, 6, and 7 are normal faults shown in Table 1).

Table 1. shows the size, depth, and orientation of the joints and faults in each sagpond.

No	Sagpond	lithology	Length (meter)	width (meter)	depth (meter)	fault	fracture
1	Sagpond 1	coarse - fine tuff	15,5	9,2	2-3	*no*	SF - GF
2	Sagpond 2	coarse - fine tuff	1,9	1,8	1,2	*no*	SF >>, GF
3	Sagpond 3a	coarse - fine tuff	22	5	1,5	*normal fault*	SF
	Sagpond 3b	coarse - fine tuff	2,5	1	2,6	*normal fault*	no
4	Sagpond 4	coarse - fine tuff	3,46	2,5	0,77	*normal fault*	SF >>, GF
5	Sagpond 5	coarse - fine tuff	8	6	1,2	*no*	SF >>, GF
6	Sagpond 6	coarse - fine tuff	3	2,5	0,8	*normal fault*	SF >>, GF
7	Sagpond 7	coarse - fine tuff	2,8	1,2	1	*normal fault*	SF - GF

Sagponds 1, 2, and 5 are among those that lack typical surface faults. nevertheless, the controlling faults in sagponds 3, 4, 6, and 7 are primarily normal faults. The general orientation of normal faults tends to be in relation to the N 30° E,/73°, N 355°E / 78° – N 128° E /84° shown in Figure 2.

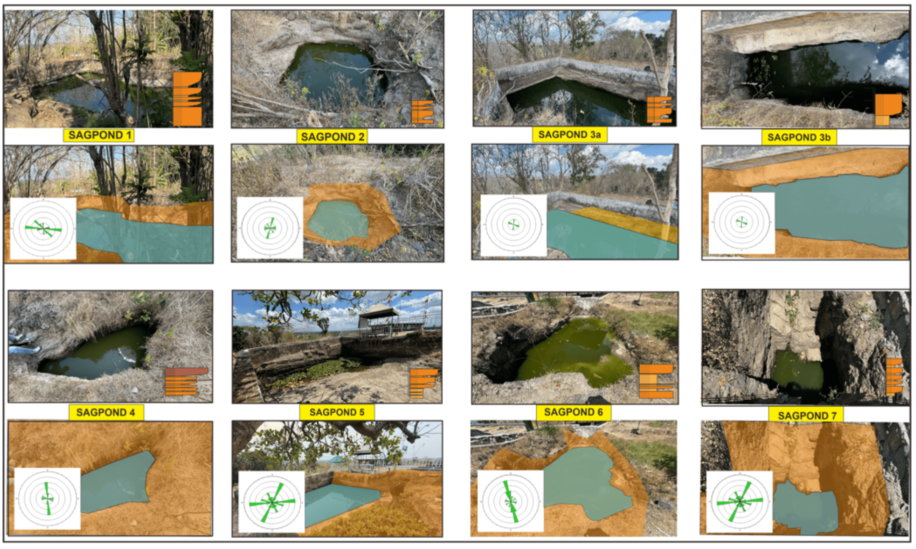

Fig. 2. Compilation of fracture lineament and lithology profile on sagponds in research area

3.3 The existence of sagponds and their implications for the active opak fault

The Watugagak SagPond's fault interaction structure includes a second generation fault, a west-east strike-slip fault, in addition to the northeast-southwest oriented Opak-Watugagak Fault extended. The formation of the sagpond is caused by the interaction features of these two faults in various displacement orientations of the extensional antithetic fault set and the synthetic fault set pair.

The two defects are considered to lack geometric connection based on their interaction characteristics. The possibility of strain in the interaction zone, which is roughly 3–12 m wide, is determined by this spatial arrangement. In tectonic nomenclature, these strain zones are commonly referred to as pull-apart basins, whereas in morphotectonic terminology, they are equivalent to sag-ponds. The Watugagak Hill Sagpond is mostly governed by normal faults and fractures. The direction of these fractures typically varies, primarily from west-east to north-south shown in Figure 3.

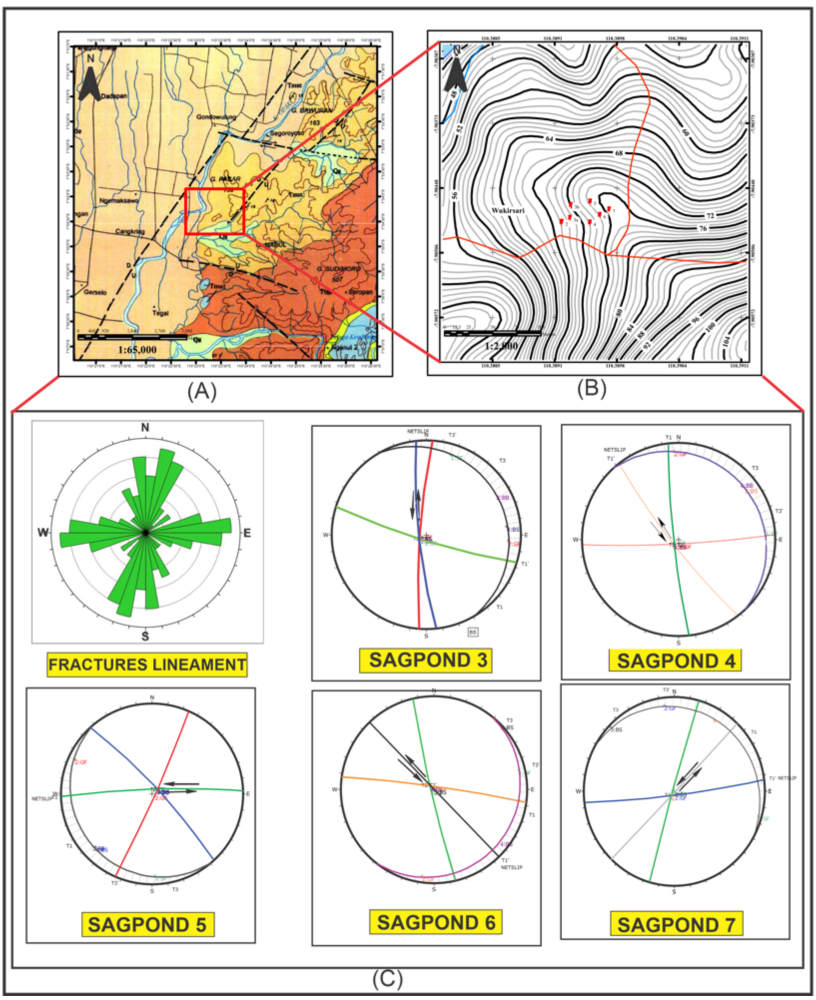

Fig. 3. Compilation of fracture lineament on sagponds in research area

The typical faults found in a number of these sagponds are strain faults that originate from the main stress direction, which is nearly north-south, The same direction as the study analyzed by [9]. These faults are caused by the northeast-southwest Opak sinistral fault (P1) and the west-east Watugagak right strike-slip fault (P2), which is characterized by the Opak river's diversion from north-south to west-east. The faults in sagponds 3, 4, 5, 6, and 7 are sinistral fault and run in different directions. In the research area, these faults are probably what cause sagponds to occur [13]. The north-south direction is the primary force that forms the left-strike slip faults shown in Figure 4. Several previous researchers indicated that the Opak Fault compressed with the major force direction north-south [14] and [15].

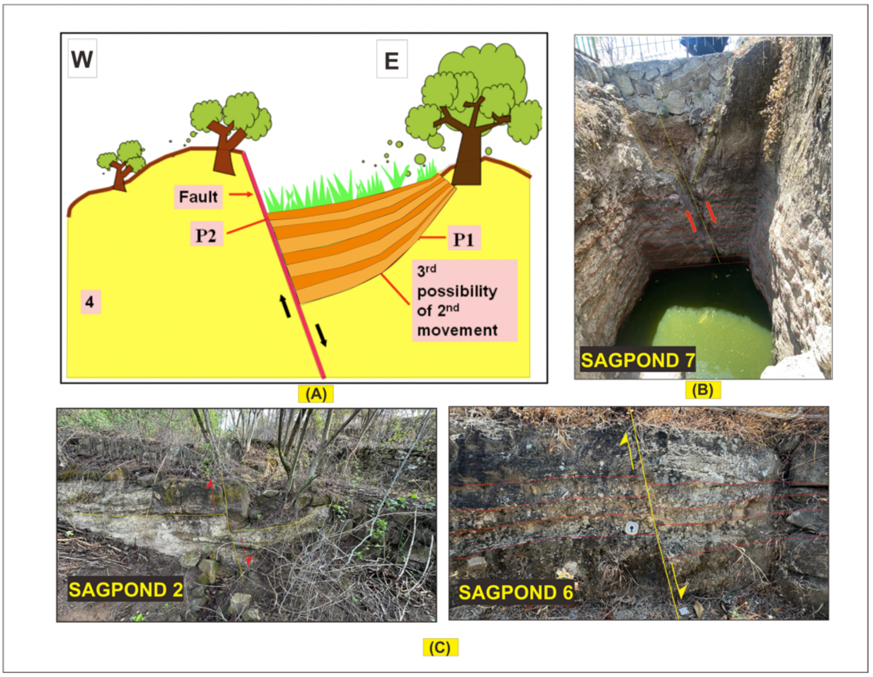

Fig. 4. A sketch of sagpond (A) and the presence of sagpond (B) and normal fault in research area (C).

4 Conclusion

A possible indication of the ongoing Opak fault movement in Yogyakarta is the presence of sagponds in the Watugagak Hill area. A west-east trending fault (Watugagak) that segments a sinistral strike-slip fault (Opak Fault) trending northeast-southwest causes fault segmentation in the research area's sagponds, which are basins with alternating coarse and fine tuff lithology and the result of left strike-slip faults interacting. The management of faults that tend northwest-southeast, west-east, north-south, and northeast-southwest affects the presence of sagponds in a variety of shapes and sizes.

References

1. T. Tsuji, K. Yamamoto, T. Matsuoka, Y. Yamada, K. Onishi, A. Bahar, I. Meilano, and Abidin, H. Z., Earthquake fault of the 26 May 2006 Yogyakarta earthquake observed by SAR interferometry. *Earth, Planets Sp.* **61**(7), 29–32 (2009). 10.1186/BF03353189.
2. S. Kurniawan, A.H.F. Rizqi, M. Erlandi, M. Nadhip, A.Y. Alansyah, D.C. Wibisono, W. Winarti, and M. Fatih Qodri, Kompilasi Penentuan Sesar berdasarkan Data Struktur Geologi Permukaan dan Implikasinya terhadap Keberadaan Sesar Mataram di Daerah Bokoharjo, Prambanan, Sleman, Yogyakarta, *Pros. Nas. Rekayasa Teknol. Ind. dan Inf. XVIII Tahun 2023*, (November 2023)
3. H. Heningtyas, N. B. Wibowo, and D. Darmawan, "Pemodelan 2D dan 3D Metode Geomagnet untuk Interpretasi Litologi dan Analisis Patahan di Jalur Sesar Oyo. *J. Lingkung. dan Bencana Geol.* 10(3), **115** (2020). 10.34126/jlbg.v10i3.157
4. A Toba-scale eruption in the Early Miocene: The Semilir eruption, East Java, Indonesia - Research - Royal Holloway, University of London. https://pure.royalholloway.ac.uk/portal/en/publications/a-tobascale-eruption-in-the-early-miocene-the-semilir-eruption-east-java-indonesia(2fc01d71-ba00-47f2-9d4e-27a3dce07ac1).html (accessed Jun. 14, 2022).
5. A. Nugrahini, V. Isnaniawardhani, A. Sudradjat, and N. Sulaksana, Characteristics of Semilir Formation in Relationship With the Period of Volcanic Activity. *Int. J. GEOMATE*, **16**(53), 154–162 (2019). 10.21660/2019.53.23442
6. A. Hubert-Ferrari, U. Avsar, M. El Ouahabi, G. Lepoint, P. Martinez, and N. Fagel, Paleoseismic record obtained by coring a sag-pond along the north anatolian fault (Turkey). *Ann. Geophys.* **55**(5), 929–953 (2012). 10.4401/ag-5460
7. T. K. Rockwell, Recognition of individual paleoseismic events in strike-slip environments. Crone, AJ and• Omdahl, EM, ads. Proceedings of Conterence XXXIX, (Directions in Paleoseismoiogyf USGS, Open-File Report, 87-673, 1987)
8. U. M.Lumbanbatu, C. Basri, S. Hidayat, and D. A. Siregar, "Pengaruh Tektonik Pada Runtunan Endapan Aluvial Depresi Padangsidempuan, Sumatera Utara," *J. Geol. dan*. **19**(3), 153–165 (2009)
9. A. Sutiono, B. Prastistho, C. Prasetyadi, and Supartoyo, Morfotektonik dan geometri meander kalitirto berbah dikontrol oleh karakteristik interaksi sesar aktif. Prosiding Seminar Nasional Teknologi Kebumian Dan Kelautan (Semitan II). **2**(1), 147–162 (2020)
10. V. B. Indranadi, C. Prasetyadi, and B. Toha, Pemodelan Geologi Sub-Cekungan Yogyakarta. *39th IAGI Annu. Conv. Exhib.* (2010)
11. C. Prasetyadi, I. Sudarno, V. Indranadi, and Surono, Pola dan Genesa Struktur Geologi Pegunungan Selatan, Provinsi Daerah Istimewa Yogyakarta dan Provinsi Jawa Tengah. *J. Geol. dan Sumberd. Miner.* **21**(2), 91–107 (2011)
12. A. Sutiono, B. Prastistho, C. Prasetyadi, and Supartoyo, Opak fault: A comparative review, *IOP Conf. Ser. Earth Environ. Sci.* **212**(1), (2018). doi: 10.1088/1755-1315/212/1/012049.
13. D. H. Barianto, E. Aboud, and L. D. Setijadji, Structural analysis using landsat TM, gravity data, and paleontological data from tertiary rocks in yogyakarta, Indonesia. *Mem. Fac. Eng. Kyushu Univ.* **69**(2), 65–77 (2009)
14. J. S. Perez and H. Tsutsumi, Paleoseismic studies along the Philippine fault zone, eastern Mindanao, Philippines,*Proceeding 2011 Japan Geosci. Union*, 0–9 (2011)
15. S. Ildrem, B. E., and S. A., Geotectonic Configuration of Kulon Progo Area ,

Yogyakarta Konfigurasi Tektonik Daerah Kulon Progo, Yogyakarta. *Indones. J. Geosci.* **8**(4), 185–190 (2013)