Subsurface structure investigation of Sangubanyu geothermal field

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Abstract. Exploration of geothermal systems can be initiated from an assessment of surface manifestations. The manifestations of the Sangubanyu hot springs are scattered on the banks of the Lampir River along the 800 m. This study aims to characterize the geothermal field based on geomorphology, lithology, structure, and geohydrology. The geological investigation was done by observation and direct measurement in the field of geological phenomena, such as geomorphology: landscape, river flow pattern and geomorphology stage; stratigraphy: spreading and rock unit relationships, rock outcrop profile; geological structure; manifestations and geothermal symptoms on both active and fossilized surfaces. The geological structure of the study area is interpreted as a fault, and the hydrological data shows that hydrothermal water flows through the fault line below the shallow groundwater levels. Groundwater discharge in the form of springs at the research area is widespread in almost every topographical cutting or at the bottom of the valley cliff.

1. Introduction

Sangubanyu geothermal field is a manifestation of hot water located in the Batang district area. On the regional geological map, Banjarnegara-Pekalongan sheets belong to the Bawang area (sheets 1408-444). The appearance of its manifestation is in the form of hot springs scattered along the river Lampir. All this time this manifestation was used only for the benefit of public baths. There has been no attempt by the local government to utilize it further. The management of the bathing place is carried out by the village government which is managed directly by residents around the location.

Exploration of geothermal system resources is related to the measurement of physical properties of the earth. The intended measurement relates to the physical properties of the earth's surface and subsurface structure [1]. The measurement of the character of the geothermal system is generally carried out by estimating the existence of how much rock the geothermal reserve is in the form of rock formations, porosity and fracture structures, the material being exposed so that rock formations can be modeled to estimate the level of risk of failure to carry out further drilling stages [2]. A detailed study of a geothermal field can be carried out further by exploring where the source of the fluid comes from. Some good methods are applied for this purpose, both through geophysical methods, geology and hydrogeological methods. The combination of several methods has been successfully carried out to characterize the reservoir system with a fairly balanced cost with the results obtained[3][4].
application of gravity methods can contribute to exploring the geometry of complex subsurface aquifers. The interpretation of this method is based on the difference in rock density properties from anomaly fields so that the structure of the geological structure can be well described. In characterizing the detail of the hydrothermal flow pattern of a geothermal system, several geophysical methods are also applied with the aim to determine the pattern of rock layering and the existence of structures such as faults and burrows which are the main components of hydrothermal fluid trajectories. Based on the resistivity properties of the rock can be distinguished between layers[5][6][7] which will describe a well-structured hydrothermal flow system. Before applying the geophysical method, it is necessary to clarify the hydrothermal fluid flow pattern based on the geological mapping. The geological method is a fairly effective step to find out the basic principles to describe how the heat transport system occurs in the lithosphere[8].

This study aims to characterize the Sangubanyu geothermal system based on geomorphology, lithology, structure, and geohydrology. The shape description of the landscape and the process of formation is a part that can predict changes in the future of the mass based on a combination of field observations and modeling.

2. Geology of the research area
Physiographically, the geomorphology of Central Java is divided into 7 physiographic lines (Figure 1)[9], namely:
1. Quarterly volcano
2. Alluvial plain of north Java basin
3. Anticlinorium Rembang – Madura
4. Anticlinorium Bogor-North Serayu-Kendeng
5. Trees and domes at the central depression
6. Depression of Java and Randublatung zone
7. The mountain of South Serayu

Based on the division of the physiographic pathway, the study area was in the North Serayu Mountains Zone bordering the Quaternary Volcano Zone. The northern part borders the Coastal Alluvial Plain and the southern part is bordered by the depression of Central Java.

![Figure 1](image.png)

**Figure 1.** The location of the study area is based on physiographic pathways[9]

The geographical point of view of the location and its relationship to the geothermal system, the research area, has a fairly close distance to the Dieng area. Dieng area is located on the backarc side of the Quaternary Sunda volcanic arc. This bow has been active since the Tertiary as a result of subduction of the northward movement of the Indo-Australian plate under the Eurasian plate[10]
According to Van Bemmelen (1949), the Dieng Plateau is located in a weak zone and is the northern wing of the Java geanticlinal line with east-west direction, extending to the West, from the Dieng Plateau to Mount Slamet. The second fracture consists of a series of young Sindoro-Sumbing cones that extend to the southeast of the Dieng Plateau. This plateau consists of several peaks and craters. Faults and straightness of volcanoes in the Dieng Plateau are generally trending north-west and west-east. Volcanic faults are around the center of the eruption. The fault zone which runs almost west-east is located in the south, which limits Batur’s depression. The southern part of the relative rise is referred to as the Tilting Block. Structural faults are ladder faults cutting the Rogojembengan lava indicated by the presence of a wedge seen from Dieng trending northwest-southeast and also reflected by the linear ridge on Prau Peak[11].

Based on the Regional Geological Map of Banjarnegara-Pekalongan Sheet, the study area is composed of three formations[12], namely:

1. The Kaligetas Formation (Qpkg) consists of volcanic breccias, lava flows, tuffs, tuffaceous sandstones, and claystone. Flow breccia with inserts of fine lava and tuff to coarse. The lower part is found in claystone containing mollusks and tuffaceous sandstones. Volcanic rocks that decay are reddish brown and often form large blocks. Thickness ranges from 50-200 m.
2. Jembangan volcanic rock (Qj) in the form of andesite lava and volcanic clastic rocks. Especially hypersten-augite andesite; local contains hornblende and also olivine basalt. Lahar and alluvium deposits consist of volcanic debris, lava flows, and breccia.
3. Kipas Alluvium (Qf) consists of volcanic debris.

3. Geomorphology

The discussion of the geomorphology of the study area was emphasized on naming landforms based on the quantity of percent slope [13] as listed in Table 1 and the morphogenesis process. Thus the naming of the geomorphological unit is based on these two things. Geomorphology endogenic and exogenic processes will play a major role in the formation of regions, the dominance of this endogenic or exogenic process gives different results between one geomorphological unit and another geomorphology unit. Exogenic processes include degradation, aggradation, and activities of organisms.

Degradation will give a negative formation or change in land shape to be lower while degradation provides the opposite form which gives a positive formation or an increase in the elevation of an area. This exogenic process involves weather, climate, water, wind with products in the form of erosion, transportation, and sedimentation while endogenic factors will be influenced by plate tectonic processes that occur in the area.

| Relief Unit              | Slope Angle | Topographical difference |
|-------------------------|-------------|--------------------------|
| Flat/almost flat        | 0 – 2 %     | <5 m                     |
| Wavy slope              | 3 – 7 %     | 5 – 10 m                 |
| Wavy tilt               | 8 – 13 %    | 5 – 25 m                 |
| Wavy hilly              | 14 – 20 %   | 25 – 200 m               |
| Steep hill              | 21 – 55 %   | 200 – 500 m              |
| Precipitous mountains   | 56 – 140 %  | 500 – 1000 m             |
| Steep Mountains         | >140 %      | >1000 m                  |
Based on the geomorphological unit classification, the research area can be divided into four geomorphological units, namely flat wavy denudational unit, steeply denudational hilly units, steep fluvial hilly units and undulating units of fluvial ramps (as shown on Figure 2). Based on the figure, it can also be seen that the flow pattern in the area of research is dendritic. The dendritic flow pattern is a flow pattern in which the branches of the river resemble a tree structure. It generally develops in uniformly resistant rocks, flat, or almost flat sedimentary rocks, massive igneous rock regions, folds, complex metamorphic regions.

4. Lithology

Based on field observations and interpretive analysis conducted, the mapping area is divided into several lithology units (Figure 3). Interpretation of the relative age of the lithology unit composing the mapping area is based on the Cross cutting Relation Ship law and the interpretation of the formation based on the geological map of Banjarmegara-Pekalongan sheet[12] The set of lithology units as listed in Figure 3 can be described as follows:

1. Breccia-tuff unit
2. Tuffaceous sand unit
3. Andesite breccia unit
4. Andesite intrusion unit
5. Alluvium unit

Breccia tuff unit is the oldest unit in the research area. This unit is composed of breccia with tuff inserts inside. The appearance of the field shows that this breccia has andesite fragments and sand matrices which are sometimes tuffaceous sand with tuff inserts. This breccia is generally yellowish brown, the size of gravel fragments to lumps, bad sorting, and packing are relatively open, with andesite fragments in the form of angular to subangular and tufan sandstone matrix.
Figure 3. Geological map of the Sangubanyu area

Petrographic analysis of thin incisions from breccia fragments in this area showed 50% plagioclase mineral composition, quartz 20%, hornblende 10%, biotite 12%, and orthoclasts 10% whereas the tuff insert shows a yellowish brown color, medium to coarse sand grain size, good sorting, massive, about 10-20 cm thick. The regional breccia-tuf unit is part of the Kaligetas Formation.

5. Geohydrology
The existence and pattern of groundwater flow are strongly influenced by the physical properties of the rock, especially its porosity and permeability, the conditions of the catchment area, and the topography of the area in question. Based on the Hydrogeological Map of Pekalongan Sheet, then the Bawang area and its surroundings have aquifer conditions that vary from aquifers with high productivity in the form of aquifers with flow through gaps and spaces between grains to areas with rare groundwater.

The research area located in Sangubanyu Village is included in the groundwater area with flow through intergroup gaps and spaces, namely in breccia and tuff sand and some parts through alluvial deposits. The existence of flow through the gap is seen by the number of stocky and straightness in the study area so that a line of line springs is found as an indication of a fault line. Regionally the main faults are in the northwest-southeast as shown in Figure 2.

However, in more detail in Sangubanyu, the pattern of groundwater flow is influenced by the existence of faults trending southwest-northeast through the Lampir River. The field observation results of shallow groundwater levels in the study area provide an overview of the webs of groundwater flow as shown in Figure 4. Based on the figure, it is seen that in general, the shallow groundwater flow comes from the west to the northeast in the direction of the river flow. Groundwater discharge in the form of springs at the research location is widespread in almost every cut topography or at the bottom of the valley cliff. In contrast to the distribution of hot springs found lined up in part of the existing fault pathway. This shows that the flow of hot water through a special line is the fault path itself at a depth below the shallow groundwater level.
6. Conclusion
The geomorphological unit of the research area can be divided into four geomorphological units, namely flat wavy denudational unit, steeply denudational hilly units, steep fluvial hilly units, and undulating units of fluvial ramps. Lithological unit of study area consists of Breccia tuff unit is the oldest unit in the research area. The appearance of the field shows that this breccia has andesite fragments and sand matrices which are sometimes tuffaceous sand with tuff inserts. The shallow groundwater flow comes from the west to the northeast in the direction of the Lampir river flow. Groundwater discharge in the form of springs at the research area is widespread in almost every topographical cutting or at the bottom of the valley cliff. In contrast to the distribution of hot springs found lined up in part of the existing fault pathway. Based on the above research we recommend that the geothermal heat source is located far away from the surface manifestation. The lateral flow of hydrothermal shows that the resource comes from the higher part of the research area.

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