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# GEOCHEMISTRY OF THERMAL WATERS FROM JARIKASINAN AND BANYUKUNING HOTSPRINGS, MOUNT PANDAN, EAST JAVA

Sutanto, Bambang Prastistho, Jagranatha, Dwi Fitri Yudiantoro, and Intan Paramita Haty

Geothermal Research Center UPN Veteran Yogyakarta
Jl. SWK 104 Condong Catur, Sleman, Yogyakarta, 55283
e-mail: intanparamitahaty@upnyk.ac.id

## ABSTRACT

Preliminary research at Mount Pandan found geothermal manifestation. Indication of geothermal in Mount Pandan is characterized by the appearance of geothermal manifestations such as hot springs in the Banyukuning and Jarikasinan.

The location of the preliminary research administratively in Nganjuk, Madiun, and Bojonegoro district, East Java Province.

The aims of this research is to determine the physical characteristics of hot springs, hot springs chemical properties, and type of the hot springs in the Mount Pandan.

The research method is collecting geological data, geochemical data, and laboratory analysis.

Based on the field observations there were two hotsprings, Jarikasinan and Banyukuning. Jarikasinan hotspring temperature is 38 ° C - 39 ° C with air temperature 32 ° C, 1930-1940 TDS, pH 6, flow 0.67 L / s and konduktivity of 2.58 ms. Banyukuning hotspring temperature is 38 ° C with an air temperature of 24 ° C, 1295 TDS, pH 6-7, discharge ranged between 1 L / s and konduktivity by 1.92 ms.

*Key word : geothermal, geothermal manifestation, geochemical.*

## INTRODUCTION

Hot springs that show to the surface, indicates the existence of a geothermal system. It caused by the presence of geological activity such us volcanism and tectonic. The water in subsurface warm up, then appear on the surface as hot springs (Herman, 2005).
Geothermal prospect areas in East Java based on the distribution of geothermal potential in Indonesia issued by the Geological Agency, Ministry of Energy and Mineral Resources, 2011 there were 11 sites with 1206.5 MWe (*Table 1)* can be optimized from seven mountain areas dispersed in Pacitan, Ponorogo, Madiun, Mojokerto, Probolinggo, Sumenep, Banyuwangi, Bondowoso, and Situbondo.

One of potential geothermal areas is Mount Pandan, with 50 MWe of electric energy, located in three district; Nganjuk, Madiun, and Bojonegoro, East Java *(Figure 1)*.

*Table 1: The (hipotetic) potential of geothermal energy in East Java*

| Locations | Geothermal Potential (MWe) |
|---|---|
| Ngebel-Wilis | 120 |
| Gunung Pandan | 50 |
| Arjuno-Welirang | 92 |
| Rejosari | 25 |
| Melati | 25 |
| Songgoriti | 25 |
| Cangar | 100 |
| Gunung Lamongan, Tiris | 92 |
| Argopuro | 185 |
| Blawan-Ijen | 185 |
| Tirtosari | 12,5 |


*Figure 1: Locations of the geothermal prospect areas in Mount Pandan*

## REGIONAL GEOLOGY

### Physiography and Morfology

The research area consists of hills with the rock layers slope relative on the south. These hills almost 80%, with the slope angle between 18.8% - 55%, included in the steep-sloping classification (Van Zuidam, 1983). These forms are formed due to endogenous and exogenous processes in the area.

Based on Novianto. A., 2002 the area of Mount Pandan consists of three unit forms. They are Volcanic Origin, Structural Origin, and Fluvial Forms Unit (Novianto. A., 2002).

### Stratigraphy

Based on the research, Mount Pandan is divided in to seven formation, from the older were Kalibeng Formation, Klitik Formation, Sonde Formation, Pucangan Formation, Volcanic Deposition Pandan, Andesite Intrution, and Alluvial Deposition.

1) Kalibeng Formation : consists of marl, tuff, tuffaceous sandstone and kalkarenit. The age of Kalibeng Formation is Miocene to Lower Pliocene.
2) Klitik Formation : the age of Klitik Formation is Middle Pliocene, consist of clastic limestone, marl and clay.
3) Sonde Formation : the feature of this formation are clay, tuffaceous sandstone, and limestone. The age is Middle Pliocene.
4) Pucangan Formation : the age of Pucangan Formation is Plio-Plistocene, consist of breccias and tuffaceous sandstones.
5) Volcanic Deposition of Mount Pandan : consists of tuffaceous breccia, tuffaceous sandstone, andesite lava (auto breccias).
6) Andesite Intrution : composed of andesite lava volcanic with lava dome appearance.
7) Alluvium Deposition : The youngest stratigraphic unit in the Mount Pandan area is alluvium deposition, composed of clay, sand, gravel and gravel.

The geological map is given in *Figure 2* (APPENDIX).

### Structural Geology

The main structural geology in the research area is fault. Geological structures in this area are the result of tectonic activity during Neogene. The geological structure are Banyukuning reverse fault, the strike slip fault with the direction almost north-south, normal faults with the main direction nearly east-west and north-south, and joint structure which almost found in all igneous rocks, especially on, breccia, Kerek Formation, Kalibeng Formation, and Mundu Formation (ESDM Jatim , 2012).

Based on the preliminary research there are seven strike slip fault (Kali Sambongrejo fault, Gedibal fault, Bladogan fault, Kali Jati fault, Kali Banjar fault , Kali Gandong fault, Gunung Prabu fault) and two reverse fault i.e Kali Gandong fault and Tengaring Kidul fault as shown in *Figure 3* (APPENDIX)

## THE RESEARCH METHOD

The research methods are literature review, fieldwork and laboratory analysis.

*1)* Literature review conducted by studying the literature about the research area before go to the field, to collect the relevant data. All the matters that relating to the research area is very useful for the further research, so the previous studies are important as a reference and comparison.

*2)* The field research conducted to take and measurements all the data (geology and chemistry data) focused on manifestation area. This stage is divided in two sections, the first is observations (manifestations, morphology, distribution and rock types, geological structures in the study area). The second is collecting the field (geological structure, lithology, type of manifestation, manifestations temperature, air temperature around the manifestation, and manifestation sampling).
The sampling in the manifestation for chemical element content analysis carried out during the dry season (sunny weather). The equipment and preparation that used to take the hot springs samples are 500 ml of polyethylene bottles (resistant to acid, heat, corrosive), filter paper with 0.45 µm porosity, syringe, GPS, altimeter, stop watch, the digital pH meter, camera, map work. Parameters of the sampling hot springs in the manifestation are temperature manifestation, air temperature on the manifestation area, water pH, coordinates and altitude of the sampling locations.

3) Samples from the manifestations (hot springs) will be analyzed to know the number of element (anions and cations). Anions elements such as $SO_4$, Cl, F, Br, $NO_3$, $SiO_2$, and $HCO_3$ . Cations element are Na, K, Ca, Mg, $NH_4$, dan Fe. These elements will be used to determine the characteristics of geothermal from the hot springs manifestations.

## RESULT AND DISCUSSION

### Geothermal Manifestation

Based on the field observations, there were two hot springs that can be used as a geothermal manifestation. These hot springs are found in Jarikasinan and Banyukuning as seen in *Figure 4* (APPENDIX).

Jarikasinan hot springs location in UTM 590360 9180530 (*Figure 4)*. The manifestation is already made shelter and used directly by the public as a public bath. The temperature of Jarikasinan hot springs is 38 ° C - 39 ° C with the air temperature range 32 ° C, TDS 1930-1940, pH 6, flow 0.67 L / s and conductivity of 2.58 ms. The location around the springs suspected yellow precipitate and the precipitate travertine (carbonate sinter) found in several places around the Jarikasinan hotspring manifestation *(Figure 6)*.

The second manifestation is Bayukuning hot springs located at UTM coordinates 9176772 589142 *(Figure 7)*. As in Jarikasinan hot springs, hot springs are located on the streams with rock breccia lithology. It also used directly by the public as a public bath. Based on observations in the field, the Banyukuning hot springs has a temperature of 38 ° C with the air temperature is 24 ° C, TDS 1295, pH 6-7, discharge ranged from 1L / s and conduktivity of 1.92 ms.

*Figure 5: Jarikasinan hot spring in Mount Pandan*

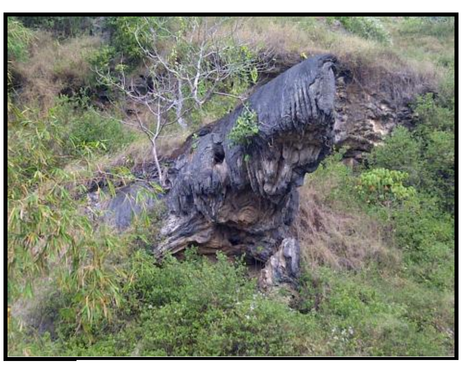


*Figure 6 : The precipitate of travertine around the Jarikasinan hotspring.*

*Figure 7: Banyukuning hot spring in Mount Pandan*

### Geochemical Laboratory Analysis

Fluid chemistry is an important tool in analyzing characteristic of a geothermal field (Mussofan, W., 2012).

Two water samples are taken to analyze the fluid chemistry of geothermal system in Mount Pandan. One water sample were taken from Jarikasinan hotspring, and one water sample were taken from Banyukuning hotspring. These samplings were done to analyze the water chemistry. The result of fluid chemistry analysis is given in *Table 2*.

*Table 2: Laboratory data analysis of Jarikasinan and Banyukuning hotsprings*

| Parameter* | Jarikasinan | Banyukuning |
|---|---|---|
| pH | 6.99 | 6.75 |
| DHL | 5270 | 3020 |
| $SiO_2$ | 95.69 | 168.23 |
| B | 29.80 | 8.56 |
| $Al^{3+}$ | 0.00 | 0.09 |
| $Fe^{3+}$ | 0.02 | 0.10 |
| $Ca^{2+}$ | 32.04 | 128.10 |
| $Mg^{2+}$ | 9.00 | 71.50 |
| $Na^{+}$ | 746.1 | 289.20 |
| $K^{+}$ | 72.60 | 31.20 |
| $Li^{+}$ | 4.70 | 1.35 |
| $As^{3+}$ | 0.00 | 0.00 |
| $NH_4^{+}$ | 24.28 | 4.86 |
| $F^{-}$ | 0.52 | 0.00 |
| $Cl^{-}$ | 557.65 | 316.25 |
| $SO_4^{2-}$ | 229.04 | 18.99 |
| $HCO_3^{-}$ | 939.62 | 891.57 |
| $CO_3^{-}$ | 0.00 | 0.00 |

* unit in mg/L (except pH)

### Water Type

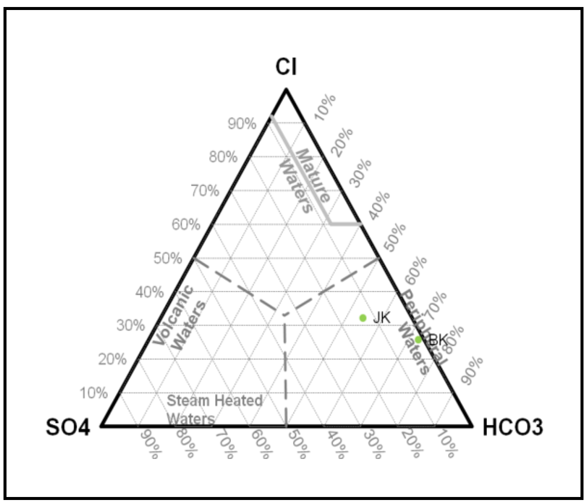
Water type of Mount Pandan manifestation can be determined by analyzing the concentration of three anions, i.e. $Cl^-$ (chloride), $HCO_3^-$ (bicarbonate) and $SO_4^{2-}$ (sulfate) as shown in table 3.

*Table 3: Ratio concentration calculating of* $Cl^-$*,* $HCO_3^-$*, and* $SO_4^{2-}$ *in Jarikasinan and Banyukuning hotsprings*

| | Jarikasinan | | Banyukuning | |
|---|---|---|---|---|
| | mg/L | % | mg/L | % |
| $Cl^-$ | 557.65 | 32.4 | 316.25 | 25.8 |
| $HCO_3^-$ | 939.62 | 54.4 | 891.57 | 72.7 |
| $SO_4^{2-}$ | 229.04 | 13.2 | 18.99 | 1.5 |
| Total | 1726.31 | 100 | 1226.81 | 100 |

The $Cl^-$, $HCO_3^-$, and $SO_4^{2-}$ ternary diagram is one diagram to classifying natural water (Giggenbach, 1991). Using this diagram, several types of thermal water can be distinguished : mature water, peripheral waters, steam-heated waters, and volcanic water. The chemical composition of the water was investigated using the $Cl^-$, $HCO_3^-$, and $SO_4^{2-}$ triangular diagram that is use to classify geothermal water on the basis of major anion concentrations (Mnjokava, 2007).

High value of $Cl^-$ indicated a contribution of geothermal reservoir water.




(*Figure 8 : Water type in geothermal manifestations of Mount Pandan using Cl –* $HCO_3$ *–* $SO_4$ *diagram. Note : JK = Jarikasinan, BK = Banyukuning*).

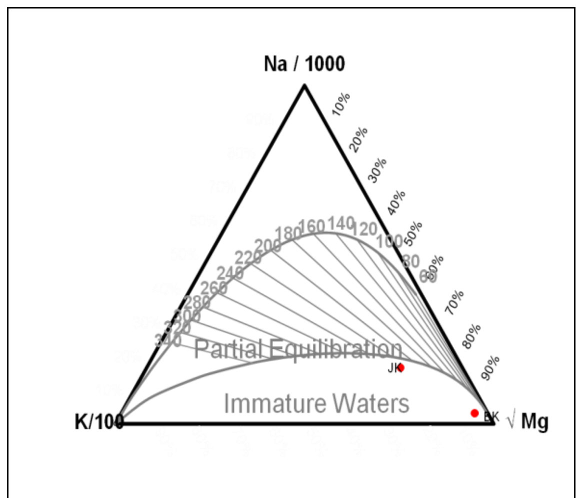
Based on the result of plotting $Cl^-$, $HCO_3^-$, and $SO_4^{2-}$ as seen in Figure 8, Jarikasinan and Banyukuning hotspring located in the $HCO_3^-$ and can be classified as peripheral waters. Both of the hotsprings are not reservoir water, but that may have mixed with cold groundwater or $CO_2$ from a magmatic source. So, the concentration of Jarikasinan and Banyukuning hotspring can't be use to determine the geothermometer.

The laboratory analysis data was also used to calculate the ratio of the content of Na/1000 – K/100 - √Mg (Table 4)

*Table 4: Ratio concentration calculating of* Na/1000 - K/100 - √Mg *in Jarikasinan and Banyukuning hotsprings*

| | Jarikasinan | | Banyukuning | |
|---|---|---|---|---|
| | mg/L | % | mg/L | % |
| Na/1000 | 0.746 | 16.69 | 0.289 | 3.20 |
| K/100 | 0.726 | 16.23 | 0.312 | 3.44 |
| √Mg | 3 | 67.08 | 8.455 | 93.36 |
| Total | 4.472 | 100 | 9.056 | 100 |

Na/1000 - K/100 - √Mg ternary diagram is used to classify water into fully equilibrated, partially equilibrated, and immature waters. It can be use to predict the equilibrium temperature and also the suitability of geothermal waters for application of ionic geothermometers. It is based on the temperature dependence of the full equilibrium assemblage of potassium and sodium minerals that are expected to form after isochemical recrystallization of average crustal rock under conditions of geothermal interest (Giggenbach, 1988).




(*Figure 9 : Na/1000 - K/100 - √Mg ternary diagram for Jarikasinan and Banyukuning hotspring. Note : JK = Jarikasinan, BK = Banyukuning*).

The diagram using the Na – K equation (Arnorsson et al., 1983) and the K/Mg equation (Giggenbach, 1988) was used for interpretation of analytical of analytical data from hot springs (Mnjokava, 2007).

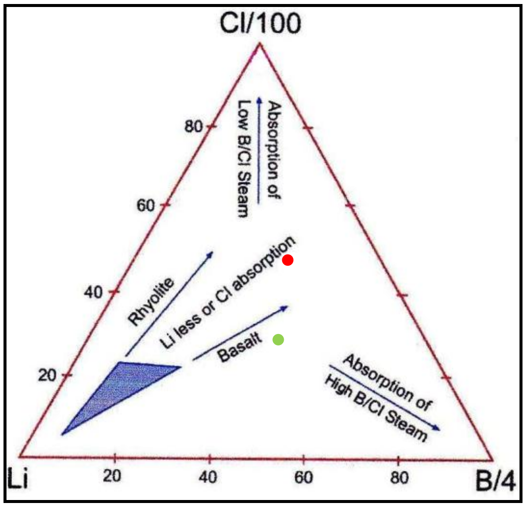
According to Figure 9, Jarikasinan and Banyukuning hotsprings located in the area of immature waters close to the √Mg corner (except Jarikasinan hotspring which is not close to the √Mg corner). It is mean that Jarikasinan and Banyukuning have a high proportion of cold groundwater. It is also have no attained equilibrium and it is not suitable to estimate discharge temperature.

The concentration Cl – Li – B from laboratory analysis was used to determine the classification of the hotspring (Table 5)

*Table 5: Ratio concentration calculating of* Cl/100 - B/4 - Li *in Jarikasinan and Banyukuning hotsprings*

| | Jarikasinan | | Banyukuning | |
|---|---|---|---|---|
| | mg/L | % | mg/L | % |
| Cl/100 | 5.57 | 31.43 | 3.16 | 47.52 |
| B/4 | 7.45 | 42.04 | 2.14 | 32.18 |
| Li | 4.70 | 26.53 | 1.35 | 20.30 |
| Total | 17.72 | 100 | 6.65 | 100 |

Lithium is used as a tracer, because it is the alkali metal least affected by secondary processes for initial deep rock dissolution and as a reference for evaluating the possible origin of two important 'conservative' constituents of geothermal waters, Cl and B. Once added, Li remains largely in solution. The B content of thermal fluids is likely to reflect to some degree the maturity of a geothermal system; because of its volatility it is expelled during the early heating up stages (Mnjokava, 2007).




(*Figure 10 :* Cl/100 - B/4 - Li *ternary diagram for Jarikasinan and Banyukuning hotspring. Note : symbol* ● *= Jarikasinan, symbol* ● *= Banyukuning*).

Based on ratio concentration calculating of Cl/100 - B/4 - Li and Cl/100 - B/4 - Li ternary diagram for Jarikasinan and Banyukuning hotspring, show that the hotspring located in Boron zone, this in indicating that the fluid come from volcanic environments.

## CONCLUSION

Stratigraphy of the research area consist of seven formation, from the older were Kalibeng Formation, Klitik Formation, Sonde Formation, Pucangan Formation, Volcanic Deposition Pandan, Andesite Intrution, and Alluvial Deposition.

Geothermal manifestation in the research area consist of two hots springs, Jarikasinan and Banyukuning. From the laboratory analysis data in hotsprings sample were analyzed, suggesting that the hot spring including into bicarbonate water type located in the area of immature waters. It is mean that Jarikasinan and Banyukuning have a high proportion of cold groundwater. It is also have no attained equilibrium and it is not suitable to estimate discharge temperature.

Utilization of geothermal energy in the research area is used to public swimming baths and development of a tourism.

## ACKNOWLEDGEMENT

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**APPENDIX**

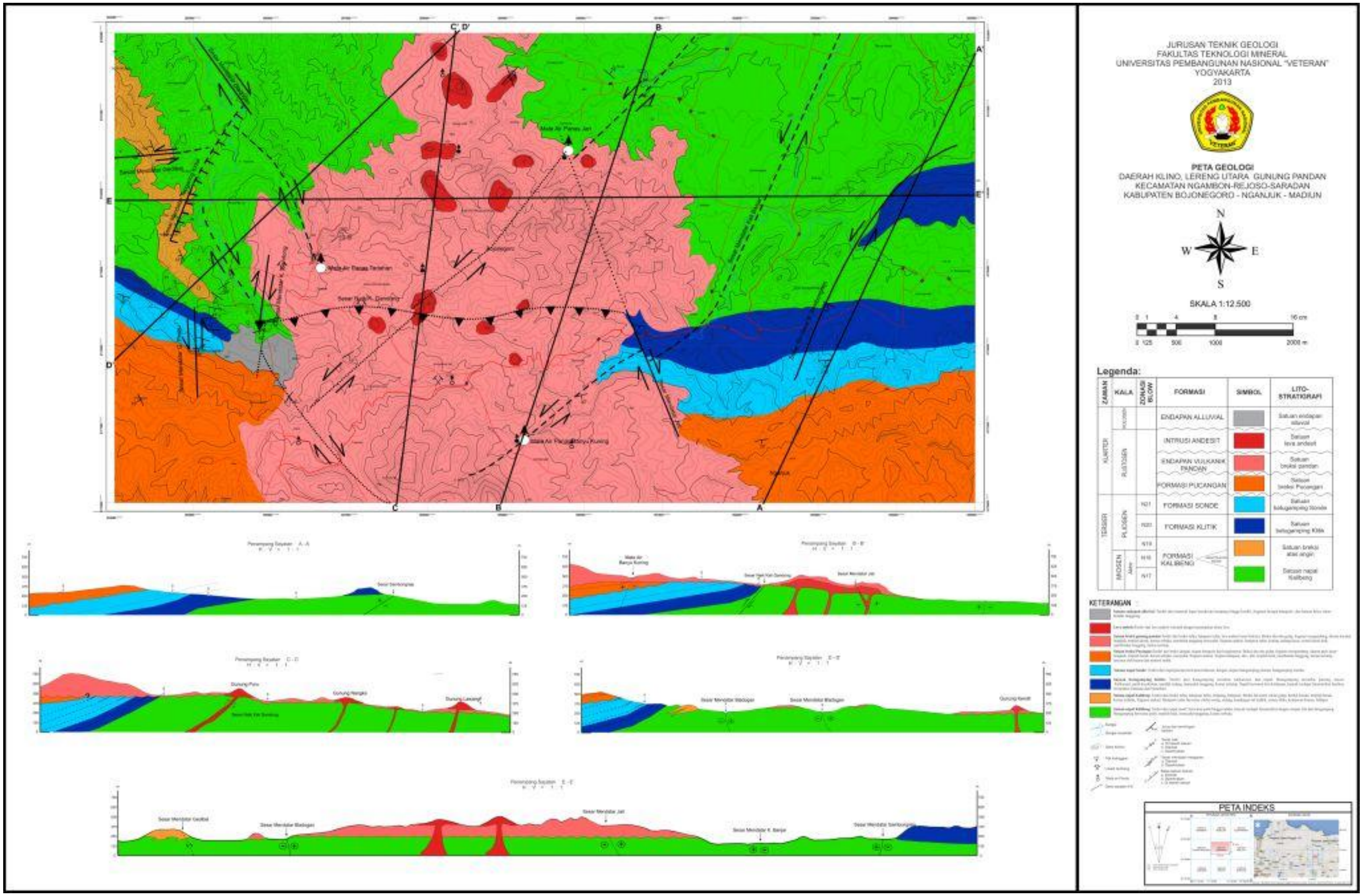


*Figure 2 : Geological Map of Mount Pandan, East Java*

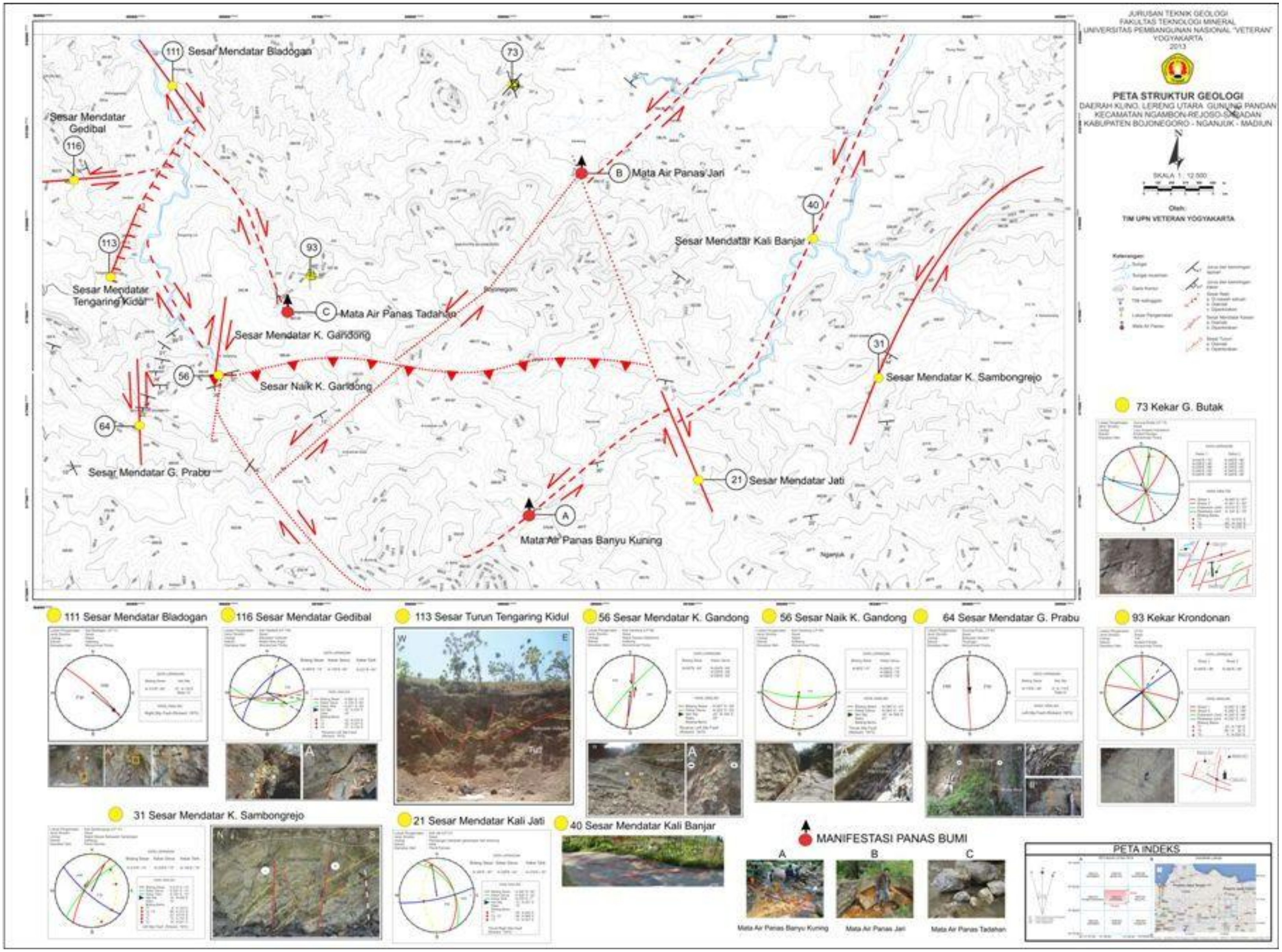


*Figure 3 : Geological Structure of Mount Pandan, East Java*

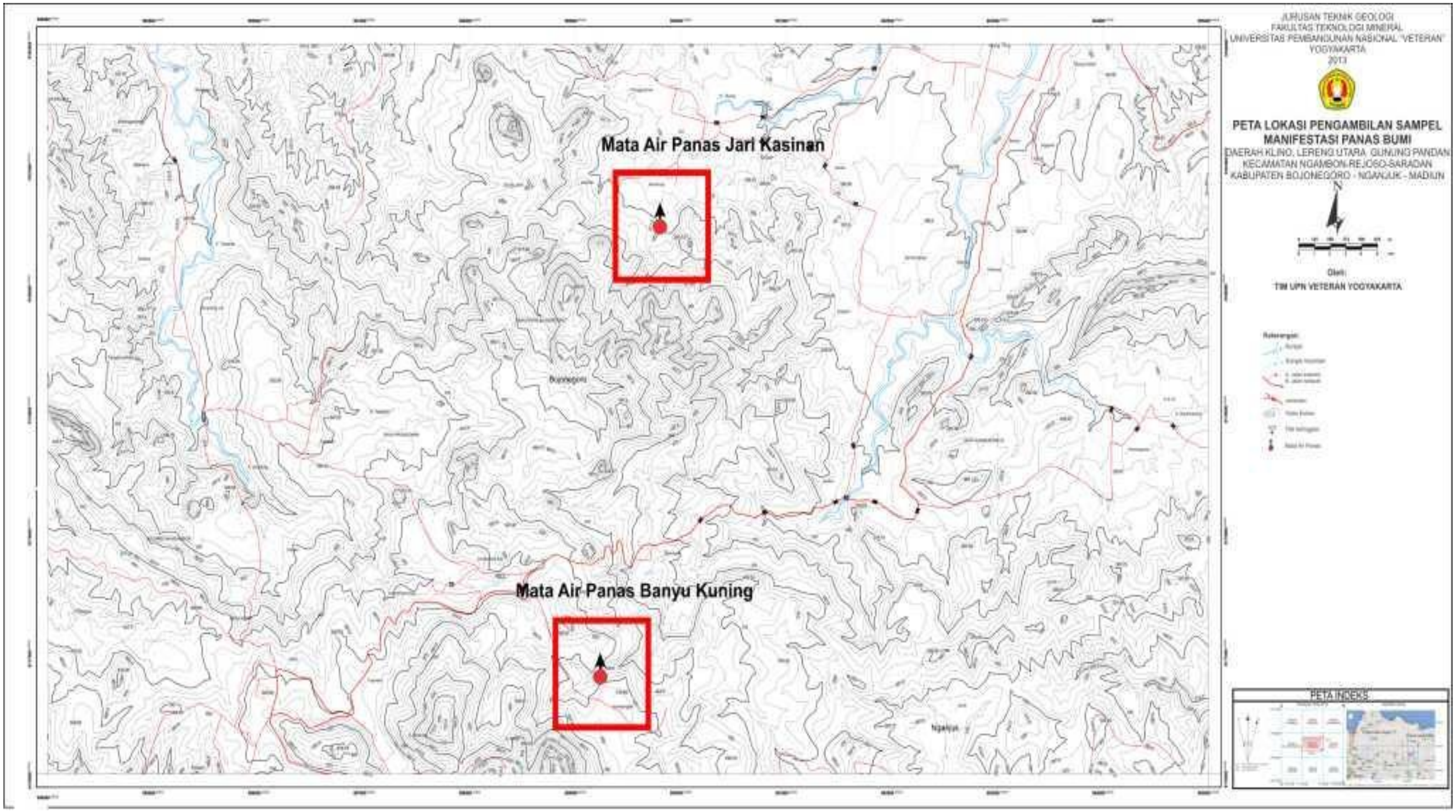


*Figure 4 : The Location of Jarikasinan and Banyukuning Hotspring in Mount Pandan, East Java*