PROCEEDINGS, 45th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 10-12, 2020
SGP-TR-216

# The Thermal Springs of Low Temperature Geothermal System at Bantarkawung Geothermal Area, Brebes, Central Java, Indonesia

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**Keywords:** Low Temperature, Hot Springs, Geothermal Fluids, Brebes-Central Java, Indonesia

## ABSTRACT

Indonesia has many geothermal areas which are associated with non-volcanic environment. One of them is Bantarkawung, Brebes, Central Java. Characteristic of the Bantarkawung hot springs is described in this paper. The methodology using in this study are field observation, taking samples, laboratory analysis and data interpretation. The geothermal manifestations are only Pangebatan hotsprings, Buaran, Muara, and Parasi warmsprings. The temperatures are about 39.5-56.7$^{o}$C with neutral pH. Geologically, it is consisted of igneous rock, sedimentary rock, volcanic rock, and aluvial.Bantarkawung manifestation has chloride-bicarbonate type of water based on Cl-$SO_4$-$HCO_3$ diagram and plots in partial equilibrium zone based on Na-K-Mg diagram. The temperature of reservoir is about 100-117$^{o}$C from Na-K geothermometer (low temperature).

## 1. INTRODUCTION

Central Java has at least 14 geothermal areas which several of them have high temperature systems such as: Gunung Lawu, Dieng, Baturaden-Gunung Slamet, etc. (Geological Agency, 2018). Despite the abundance of high temperature systems of geothermal energy, the investigation for low temperature geothermal systems should not be neglected. Bantarkawung geothermal area has several warm springs (Buaran, Muara, and Parasi) and a hot spring (Pangebatan), their distance is about 20 km west side from Baturaden-Gunung Slamet (figure 1). The administrative area is at Bantarkawung district, Brebes Regency, Central Java and the coordinat area is at 7$^{o}$12'-7$^{o}$20' S and 108$^{o}$53'-109$^{o}$01' E. This paper only focuses on Bantarkawung geothermal manifestations which the data were collected in March 2016. Prawiranegara et al (2015) identified that Buaran/Bantarkawung and Paguyangan (hotsprings at Paguyangan district, 10 km from Bantarkawung) are different system, where Paguyangan is an outflow from Baturaden-Gunung Slamet and the Buaran/ Bantarkawung is controlled by intrusion of northen area of Bantarkawung.Oktoberiman, Prawiranegara, Rizki, and Alya (2014) in the FFD study in Bantarkawung also stated that this geothermal area indicated an outflow area from Mount Slamet. Although there is a possibility that Bantarkawung is an upflow from the Bantarkawung geothermal system which is in a different reservoir zone from Paguyangan, (Prawiranegara et al., 2015). The early data of fluids chemistry interpretation in this paper shows that Bantarkawung has only low temperature geothermal system.

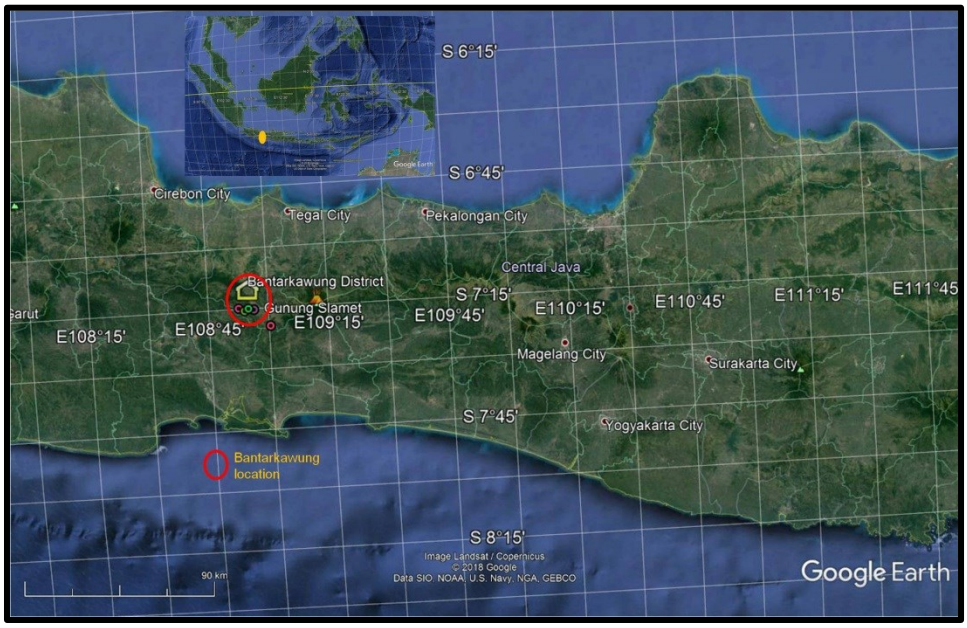


**Figure 1: Map Location of Bantarkawung Geothermal Area.**

## 2. DATA AND METHOD

Fluids characteristics of Bantarkawung geothermal area is interpreted by the surface geothermal geochemical method. The characteristics were identified from type of manifestations and the result of water manifestation analysis which could be interpreted from reservoir which already involved several processes. Water samples were analyzed at laboratory of Center for Mineral, Coal, and Geothermal Resources. The cation-anion analyses were determined by volumetric method, UV-VIS spectrophotometry, Atomic Absorption Spectrophotometry, and ion chromatography. Analysis of stable isotopes ($^{18}O$ and $^{2}H$) used PICCARO L2130-i laser spectrometer.

Geothermal manifestation of Bantarkawung (figure 2) is consisted of one hot spring (Pangebatan, 56.7$^{o}$C) and 3 warm springs (Buaran, Muara, and Parasi, 39.5-46.4$^{o}$C). They are manifested at low altitude (77-260 asl), relatively low terrain. Muara is located at the higher altitude (260 asl) than the others.

Pangebatan hot spring: manifested at sandstones fractures, coordinate of (270341mT, 9198352 mS), elevation of 77 asl, side of Pangebatan river, Bantarkawung district. It is clear, no odour, deposited of thin sinter carbonate around the hot spring, temperature of 56.7 $^{o}$C (ambient temperature 33.3 $^{o}$C), pH of 8.6, conductivity of 380 µS/cm, and flow rate of 0.4 l/s.

Buaran warm spring: manifested at sandstones fractures, coordinate of (272882 mT, 9197829 mS), elevation of 78 asl, Buaran village, Bantarkawung district. It is clear, confirmed with gas bubbling, no odour, temperature of 45.7-46.4$^{o}$C (ambient temperature 30$^{o}$C), pH of 9, conductivity of 225 µS/cm, and flow rate of 0.3 l/s.

Muara warm spring: manifested at sandstones fractures, coordinate of (265856mT, 9198663mS), elevation of 260 asl, side of Muara river, Karangpari village, Bantarkawung district. It is clear, no odour, temperature of 39.5$^{o}$C (ambient temperature 32.4$^{o}$C), pH of 7.9, conductivity of 386 µS/cm, and flow rate of 0.1 l/s.

Parasi warm spring: manifested at sandstones fractures, coordinate of (268538mT, 9197376mS), elevation of 152 asl, side of Parasi River, Parasi village, Bantarkawung district. It is clear, no odour, temperature of 41.5$^{o}$C (ambient temperature 31.8$^{o}$C), pH of 7, conductivity of 548 µS/cm, and flow rate of 0.5 l/s.

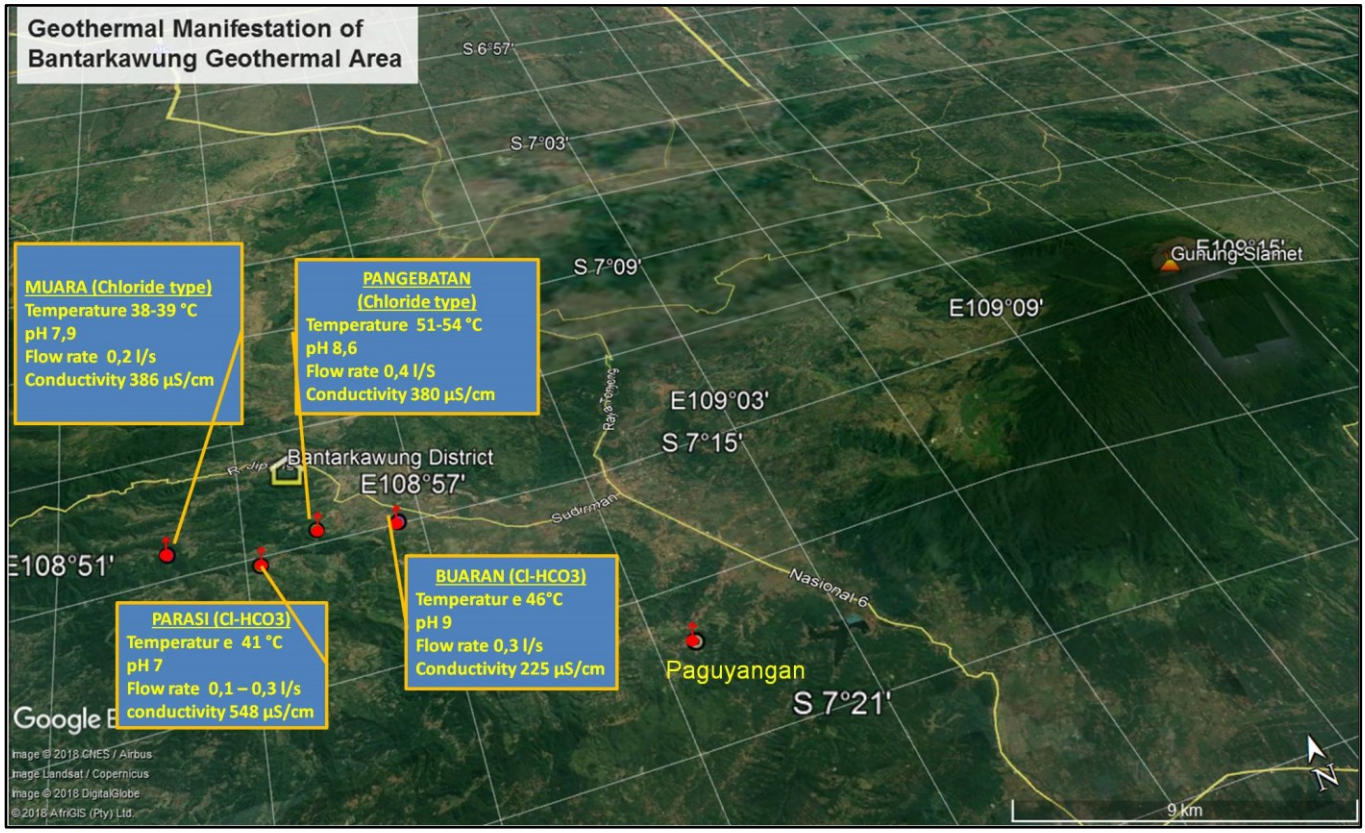


**Figure 2: Thermal Manifestation of Bantarkawung Geothermal Area**

## 3. RESULT AND DISCUSSION

Geologically, central Java is being influenced by two mega faults of Pamanukan-Cilacap and Kebumen-Muria (Satyana, 2007 in Prawiranegara, 2015). Bantarkawung itself is located in the Pamanukan-Cilacap Fault Zone (PCFZ), this resulting the tertiary volcanism and pull-apart basin opening and transpression due Pliocene compression (Prawiranegara et al., 2015). The lithology is consisted of igneous rocks intrusion, sedimentary rock, volcanic rock, and aluvial (Yushantarti et al, 2017). The intrusion of Buaran is diorite intrusion which the most probably as the heat source of Bantarkawung geothermal system (Prawiranegara et al., 2015).

The manifestations are all neutrals and the water analysis results only low concentration of all constituents. Muara, Pangebatan, and Parasi have Cl concentration (98-116 mg/l) higher than Buaran (42 mg/l), but Parasi has the highest bicarbonate (131 mg/l). Silica (25-49 mg/l) and Calcium (2.91-10.33 mg/l) are low concentration, while Mg has concentration about 0.01-2.05 mg/l (showing no mixing with shallow ground water), and Na reach 46-87 mg/l only.

The relative concentration of $Cl\text{-}SO_4\text{-}HCO_3$ (Giggenbach, 1991) shows the type of the waters (Figure 3). Muara and Pangebatan hot spring are tend to at Cl -mature waters zone ($Cl\text{-}HCO_3$ type) and the others (Parasi and Buaran warm springs) are at the middle of $Cl\text{-}HCO_3$ axis. The cold springs are at bicarbonate corner.

Muara and Pangebatan thermal waters could be indicating waters from reservoir, since they are Cl type and being at low terrain only, and also they are partially equilibrated (figure 4). Parasi and Buaran with chloride-bicarbonate concentration similar could have an indication that they are associated with CO2 gas condensation into shallow aquifer or mixing with shallow groundwater. The degree of water-rock interactions could be interpreted from Na-K-Mg diagram (figure 4).

The degree of water-rock interaction in Bantarkawung geothermal system could be interpreted as diagram Na-K-Mg (figure 4, Giggenbach 1988). All cold waters and Parasi warm spring are at Mg corner (immature waters), while Buaran, Pangebatan, and Muara are in the partial equilibrium zone.

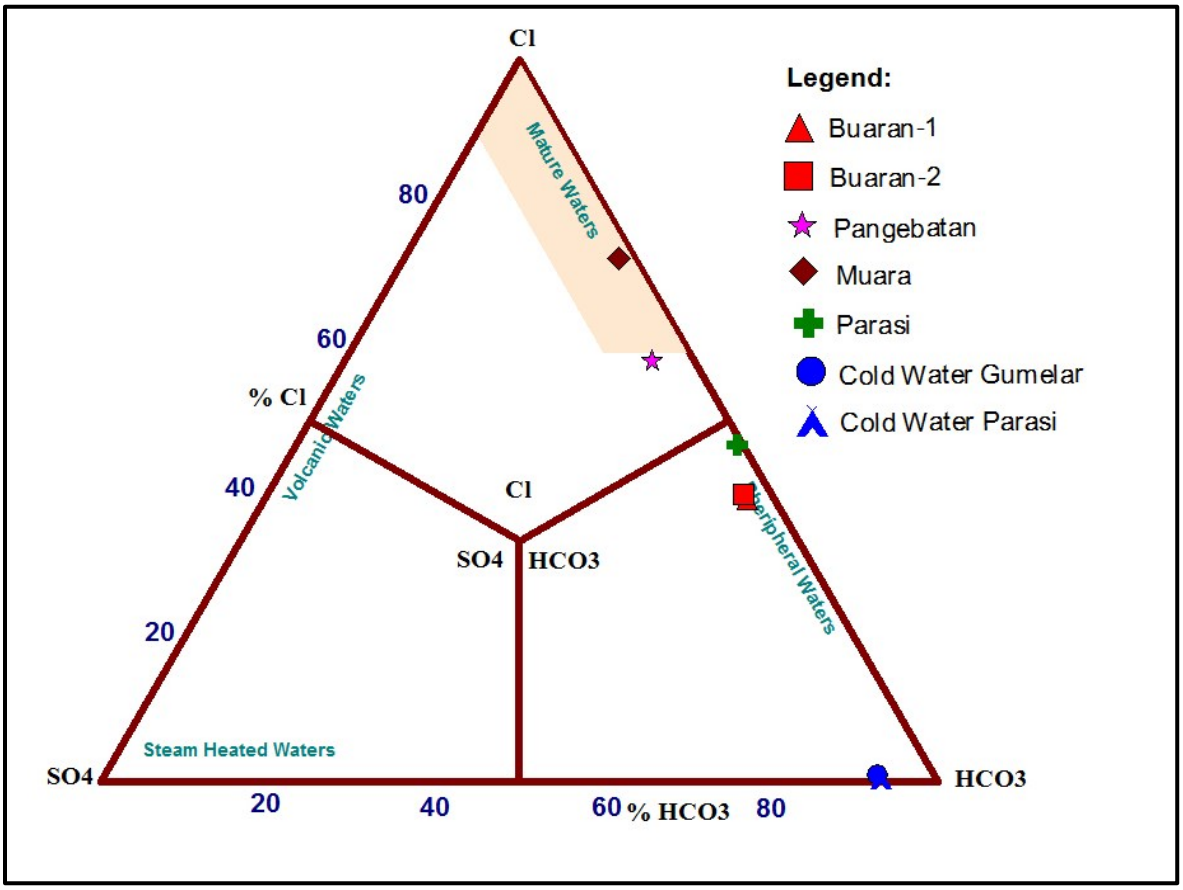


**Figure 3: Ternary Diagram of Relative SO4-Cl-HCO3 of Bantarkawung**

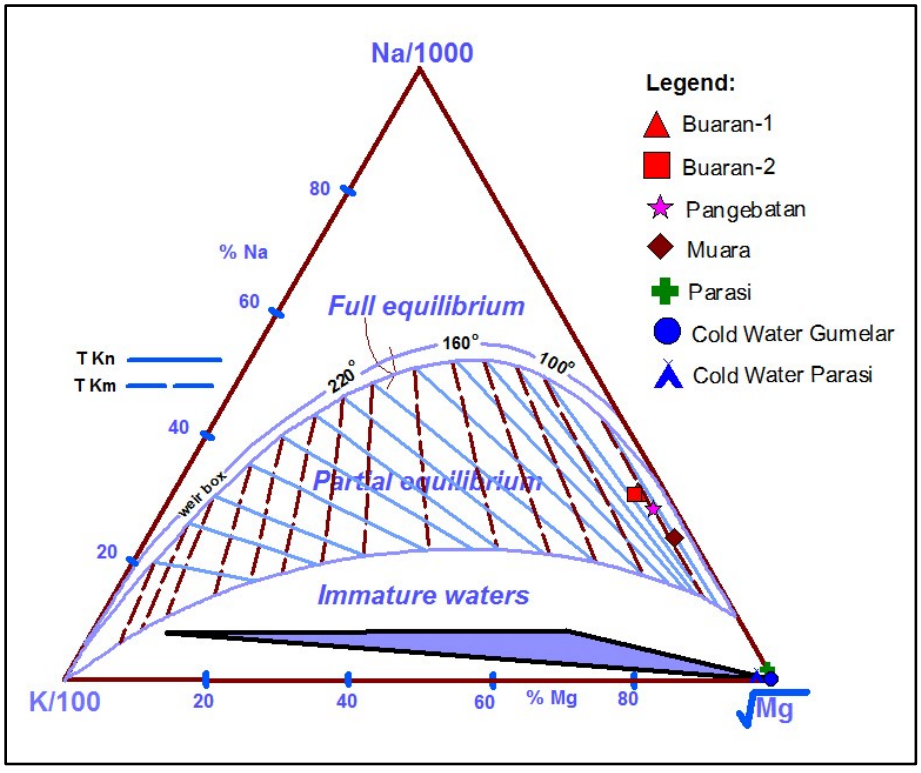


**Figure 4: Ternary Diagram of Relative Na-K-Mg of Bantarkawung**

The figure 5 shows equilibration status through cation ratio (normalized Na/K versus Ca/Mg, Giggenbach, 1988) plot of the thermal waters at Bantarkawung. This could be confirmed that all waters are partially equilibrated, because very close to the equilibrium line. This plot is strengthen the figure 4, that all thermal waters have already well enough water-rock interaction at the reservoir Bantarkawung, not only dissolution of rocks.

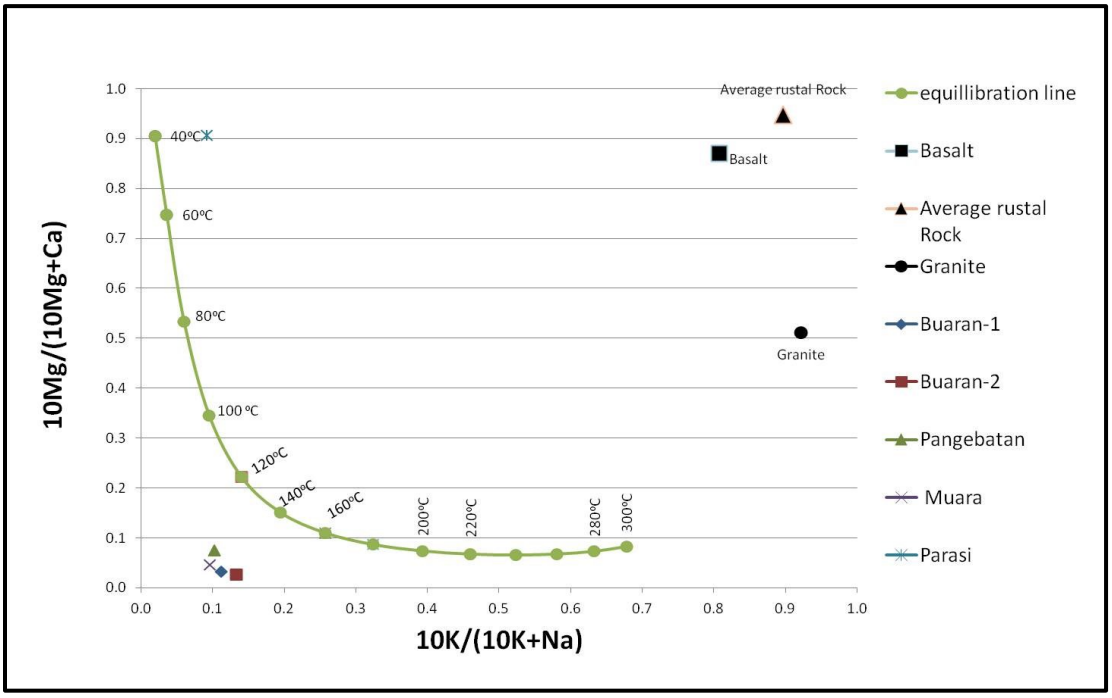


**Figure 5: Cation ratio plot of Bantarkawung**

Commonly, geothermal fluids will have process enrichment of isotope oxigen-18 from their origin of meteoric waters (Craig, 1963 in Nicholson, 1993). The thermal waters show not very much enrichment of oxigen-18, an indication that there is no much the degree of water-rock interaction. Since the type of water are tend to be chloride type and partially equilibrated, this could be interpreted that Bantarkawung is low temperature system or only little of mixing with shallow water.

The diagram isotop of Bantarkawung (figure 6) shows all thermal waters are close to the meteoric water line.Bantarkawung neutral thermal waters result the partially equilibrated cation compositions (Buaran, Muara, and Pangebatan) and have enough water-rock interactions (figure 4 & 5), so cation-based geothermometer probably could be applied using these thermal springs. The calculation is in table 1.

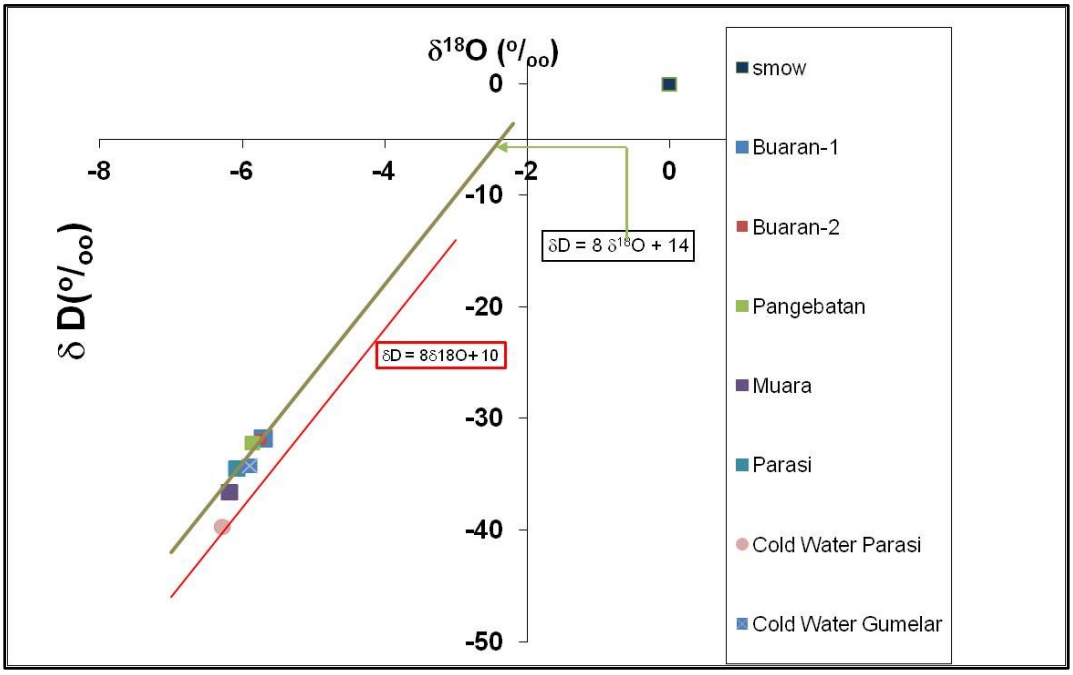


**Figure 6: Diagram Isotope of Bantarkawung**

**Table 1. Calculation of Bantarkawung Temperature Reservoir**

| Sample Name | Chalcedony cond | Quartz cond | Quartz adiabatic | Na-K-Ca | Na/K (Giggenbach) |
|---|---|---|---|---|---|
| Buaran-1 | 71 | 101 | 102 | 44 | 108 |
| Buaran-2 | 61 | 92 | 93 | 45 | 117 |
| Pangebatan | 77 | 107 | 106 | 51 | 103 |
| Muara | 40 | 72 | 77 | 32 | 100 |
| Parasi | 70 | 100 | 101 | 26 | 98 |

The several consideration for estimating the Bantarkawung temperature reservoir are they are all at low altitude or low terrain system, there are chloride type of the thermal waters, partially equilibrated, neutral, and having a good degree indication of water-rock interaction. Buaran, Muara, and Pangebatan are being representative manifestation for an indication that they are not much mixing with ground water and really close to the reservoir fluids of Bantarkawung. So, Na-K (Giggenbach) temperature reservoir probably could be close to the reservoir condition. The Bantarkawung most likely has temperature reservoir about 117ºC and classified as low temperature system. Even though there could be more possibilities than this estimation of reservoir temperature. So, the others method of geothermal exploration are compulsory to prove this indications.

## 4. CONCLUSIONS

The Bantarkawung has low temperature geothermal system about 117$^{o}$C. It is at low terrain and there are thermal springs that mostly partially equilibrated and chloride type. Since it is a low temperature geothermal system, the fluids of thermal waters only show low concentration if compared with others high temperature system.

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