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Thermal Fluids Characteristics of Low Temperature Geothermal Systems at Kalimantan Island, Indonesia

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ABSTRACT

The low temperature geothermal areas of Indonesia are abundant and about approximately 20% from 349 Indonesia geothermal areas. This paper will point out the preliminary characteristics of fluids low temperature geothermal systems in several geothermal areas in Kalimantan (West Kalimantan: 1. JagoiBabang, 2. Meromoh, 3. Nanga Dua; South Kalimantan: 4. Batubini, 5. Tanuhi, 6. Hantakan; East Kalimantan: 7. Sungai Batuq; and North Kalimantan: 8. Sebakis, 9. Semolon, 10. Mengkausar).The low temperature geothermal systems at Kalimantan Island have range temperature reservoir of 72-122^{o}C. They are at low terrain and the manifestations only warm springs (<50^{o}C) and hot springs (58-60^{o}C), thermal springs that mostly partially equilibrated and sulphate and bicarbonate type. The concentration of fluids of thermal waters only show low concentration if compared with others high temperature system. Indonesia has a challenge for developing the low temperature geothermal systems in the future, so knowing the characteristics of geothermal fluids is a necessary.

1. INTRODUCTION

Kalimantan Island is part of Borneo that belonging to Indonesia territory. It is one of five big islands in Indonesia (Sumatera, Java, Sulawesi, Kalimantan, and Papua). Geological Agency by December 2018 has been inventory 349 Indonesia Geothermal locations with total potency about 25.3 GWe. Kalimantan Island itself has 14 geothermal areas, consisted of 151 MWe speculative potency; 18 MWe hypothetic potency; 13 MWe possible potency; 0 MWe probable potency; and 0 MWe proven potency, and still none of installed capacity.

The low geothermal systems at Kalimantan are about 10 geothermal areas or 71% from 14 geothermal areas (Figure 1). They are spreading at : West Kalimantan: 1. JagoiBabang, 2. Meromoh, 3. Nanga Dua; South Kalimantan: 4. Batubini-Lokbahan, 5. Tanuhi, 6. Hantakan-Pembakulan; East Kalimantan: 7. Sungai Batuq; and North Kalimantan: 8. Sebakis, 9. Semolon, 10. Mengkausar. They are speculative resources and only Tanuhi has hypothetical resources.

Since geothermal systems only requires at least three main factors (Goff and Janik, 2000), i.e.: permeable reservoir rock, water to carry heat from the reservoir to earth's surface, and heat source; so geothermal systems could be constructed from any geological environment that possible for it, such as at active volcanoes or regions which has favorable heat flow. Geologically; Kalimantan has no active volcanoes right now, mostly it is sedimentary environment. Hochstein and Browne (2000) explained that. The''true''low-temperature systems are rare in volcanic arc settings, whereas they are common where topography and tectonics allow small heat-sweep systems to develop. Low-temperature systems can form even in brittle crust with an average terrestrial heat flux (60 mW/m^2).

2. DATA AND METHODS

The characteristics fluids of low temperature geothermal systems at Kalimantan Island are 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. And it is configuring also from secondary data from many literatures.

Low Temperature Geothermal systems in Kalimantan Island distributed in almost all Kalimantan. They are consisted of 10 geothermal areas (figure 1) and 18 warmsprings, i.e.:

2.1 South Kalimantan: Batubini-Lokbahan, Tanuhi, and Hantakan-Pembakulan (Muria-Maratussubduction)

2.1.1 Batubini-Lokbahan:

Batubini warm springs manifested at limestone, coordinate of (312542mT, 9686695mU), elevation of 50asl,temperatureof 39.4 ^{o}C (ambient temperature 27.4 ^{o}C), pHof 7,32 conductivity of 472 µS/cm, and flow rate of 0.1 l/s.
Lokbahan warm springscoordinate of (315800 mT, 9681469 mU), elevation of 80asl,temperatureof 41.5^{o}C (ambient temperature 27.4 ^{o}C), pHof 8.28 conductivity of 485 µS/cm, and flow rate of 0.1 l/s.

2.1.2 Tanuhi:

Tanuhi warm springs: manifested at granitic,coordinate of (327968mT, 9691379 mU), elevation of 150asl, It is clear, confirmed with gas bubbling, no odour, temperatureof 48.8ºC (ambient temperature 30ºC), pHof 7.54 conductivity of 977 µS/cm, and flow rate of 0.2 l/s.

2.1.3 Hantakan-Pembakulan:

Hantakan warmsprings:manifested at granitic fractures, coordinate of (329598 mT,9706799 mU), elevation of 100asl, It is clear, no odour, temperatureof 49.4ºC(ambient temperature 32.4ºC), pHof 8.02, conductivity of 1,205 µS/cm, and flow rate of 0.2 l/s.
Pembakulan warmsprings:manifested at granitic fractures, coordinate of (339580 mT,9716324 mU), elevation of 70 asl, It is clear, no odour, temperatureof 44.8ºC(ambient temperature 32.4ºC), pHof 7.68, conductivity of 672 µS/cm, and flow rate of 0.2 l/s.

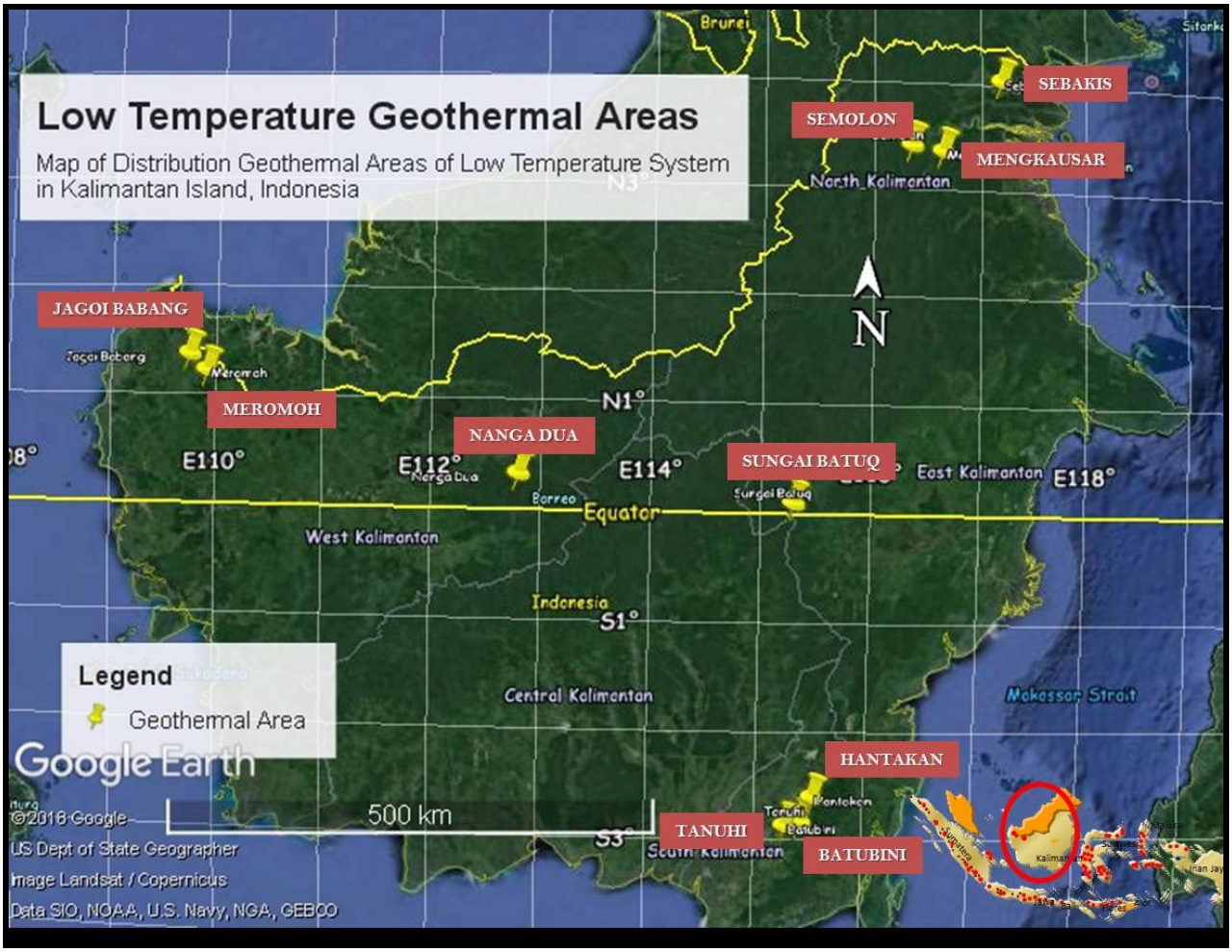

Figure 1: Map Location of Low Temperature Geothermal Systems at Kalimantan Island, Indonesia

2.2 East Kalimantan: Sungai Batuq (Kutai basin)

2.2.1 Sungai Batuq warm spring:

Sungai Batuq warm spring: coordinate of (313717 mT, 14686 mU), elevation of 99 asl, It is clear, no odour, temperatureof 47.7ºC(ambient temperature 31.8ºC), pHof 7.69, conductivity of ,3140 µS/cm, and flow rate of 1 l/s.

2.3North Kalimantan: Sebakis, Semolon, and Mengkuasar (Tarakan Basin)

2.3.1 Sebakis warm spring:

Sebakis warm spring: manifested at limestone fractures, coordinate of (524362 mT, 450490 mU), elevation of 26 asl, It is clear, no odour, temperatureof 51.2ºC(ambient temperature 27.6ºC), pHof 6.43, conductivity of 1,465µS/cm, and flow rate of 1.2 l/s.

2.3.2 Semolon warm spring:

Semolon warm spring: consisted of 3 warm springs Semolon-1,2, and 3, coordinate of (430856 mT, 381271 mU), elevation of 101-135 asl, It is clear, no odour, temperatureof 51-60.2°C(ambient temperature 25.2°C), pHof 6.91-7.07, conductivity of 5,310-7,790µS/cm, and flow rate of 0.1-0.9 l/s.

2.3.3 Mengkuasar warm spring:

Mengkuasar warm spring: coordinate of (463153 mT, 375871 mU), elevation of 13 asl, It is clear, no odour, temperatureof 60.5°C(ambient temperature 28°C), pHof 6.79, conductivity of 2,110µS/cm, and flow rate of 0.5 l/s.

2.4West Kalimantan: Nanga Dua, JagoiBabang, Meromoh (Melawai-Ketungan Basin)

2.4.1 SipatnApi-Nanga Dua warm spring:

Sipatn Api-Nanga Dua warm spring: manifested at sandstones fractures, coordinate of (703462 mT, 39590 mU). It is clear, no odour, temperatureof 38°C(ambient temperature 25.2°C), pHof 7.63, conductivity of 1,155µS/cm, and flow rate of 2 l/s.

2.4.2 JagoiBabang warm spring:

Jagoi Babang warm spring: coordinate of (364163 mT, 155161 mU). It is clear, no odour, temperatureof 38°C, pHof 7.

2.4.3 Meromoh warm spring:

Meromoh warm spring: coordinate of (382626 mT, 138419 mU). It is clear, no odour, temperatureof 29°C, pHof 7.

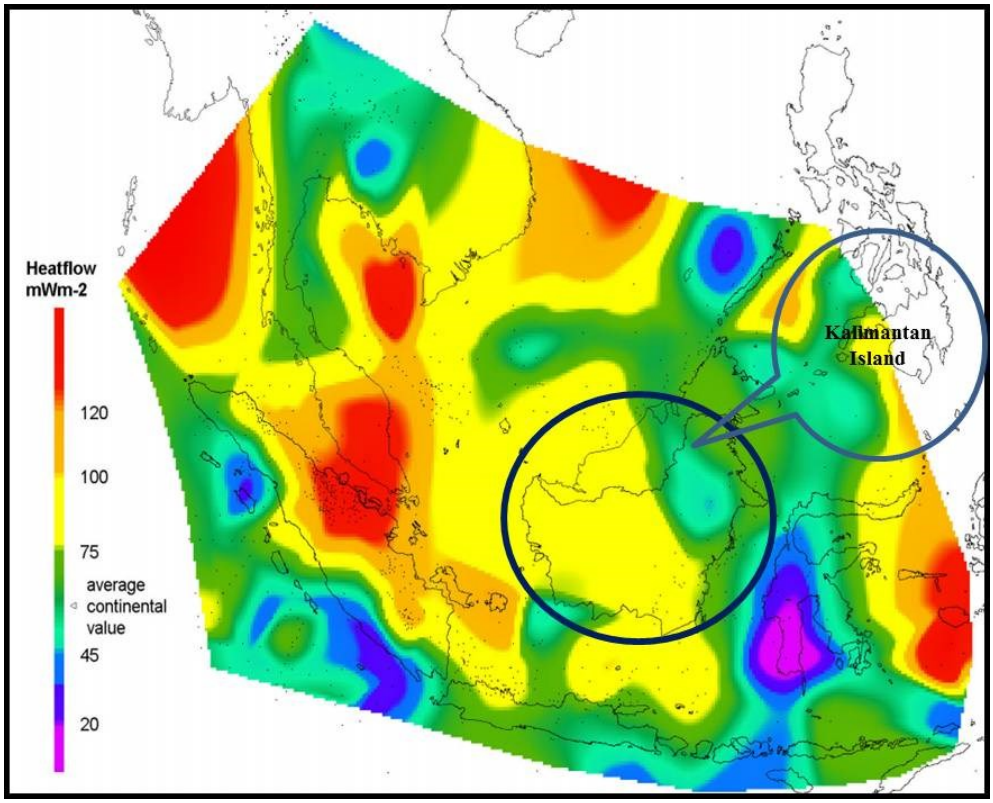

Figure 2: Map of Heat Flow for Sundaland Region(Hall, 2002)

3. RESULTS AND DISCUSSION

The heat flow map of Sundaland region (Hall, 2002) showed that Kalimantan island geothermal areas mostly are having more higher of heat flow rather than average continental value, about 75-100 mWm2 compared to the others area, except for North Kalimantan has nearly with average continental value (Figure 2). So, this region probably has moderate favorable heat source for a geothermal system.

Briefly, Kalimantan Island is at southeast of Eurasia plate; in the north it is bordered by a marginal basin of the South China Sea, in the East by Makassar strait, and in the South by Java sea. The northern part of Kalimantan is dominated by the Crocker-Rajang-Embaluh

accretion complex age Cretaceous and Eocene-Miocene. In the South of this complex is formed the Melawi-Ketungai basin and Kutaibasin during Late Eocene, and separated by the ofiolit-melangeLupar-LubokAntu and Boyan zones. Map of simplified geology of Borneo is in figure 3 (Hall and Breitfeld, 2017)

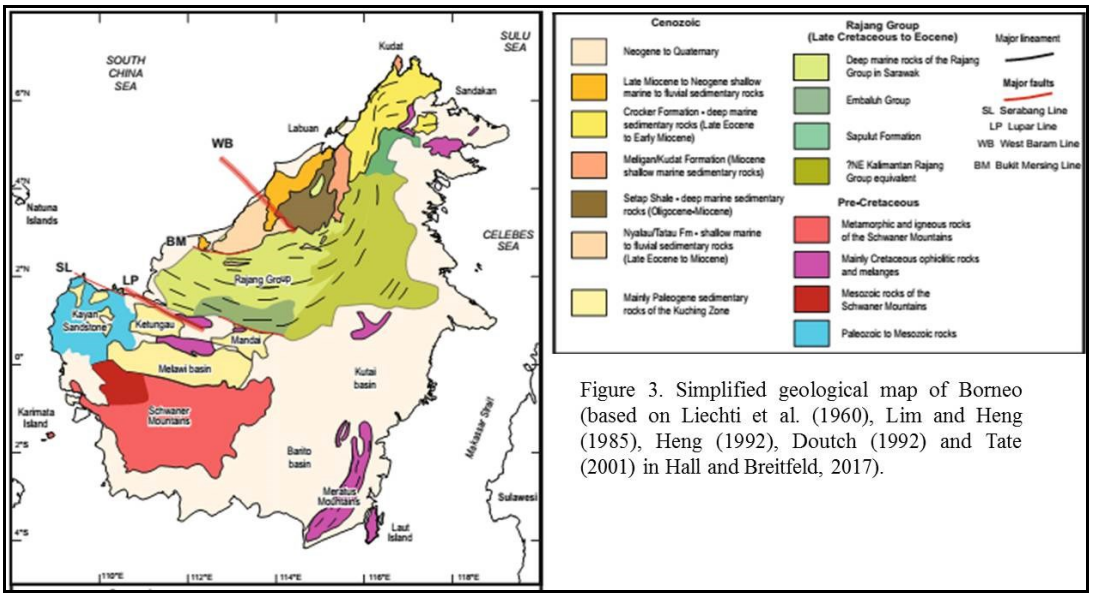

Figure 3. Simplified geological map of Borneo (based on Liechti et al. (1960), Lim and Heng (1985), Heng (1992), Doutch (1992) and Tate (2001) in Hall and Breitfeld, 2017).

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The manifestations are only warm springs and hot springs, all neutrals, manifested at low terrain, and the water analysis results only low concentration of mostly of the constituents (figure 4). All warm springs and hot springs have Silica (<100 mg/l), Cl (4.5-731 mg/l), Mg (0.01-15 mg/l), Na (9.74-1,049 mg/l), Sulphate (0.01-603 mg/l), and HCO3 (12-2,105 mg/l).

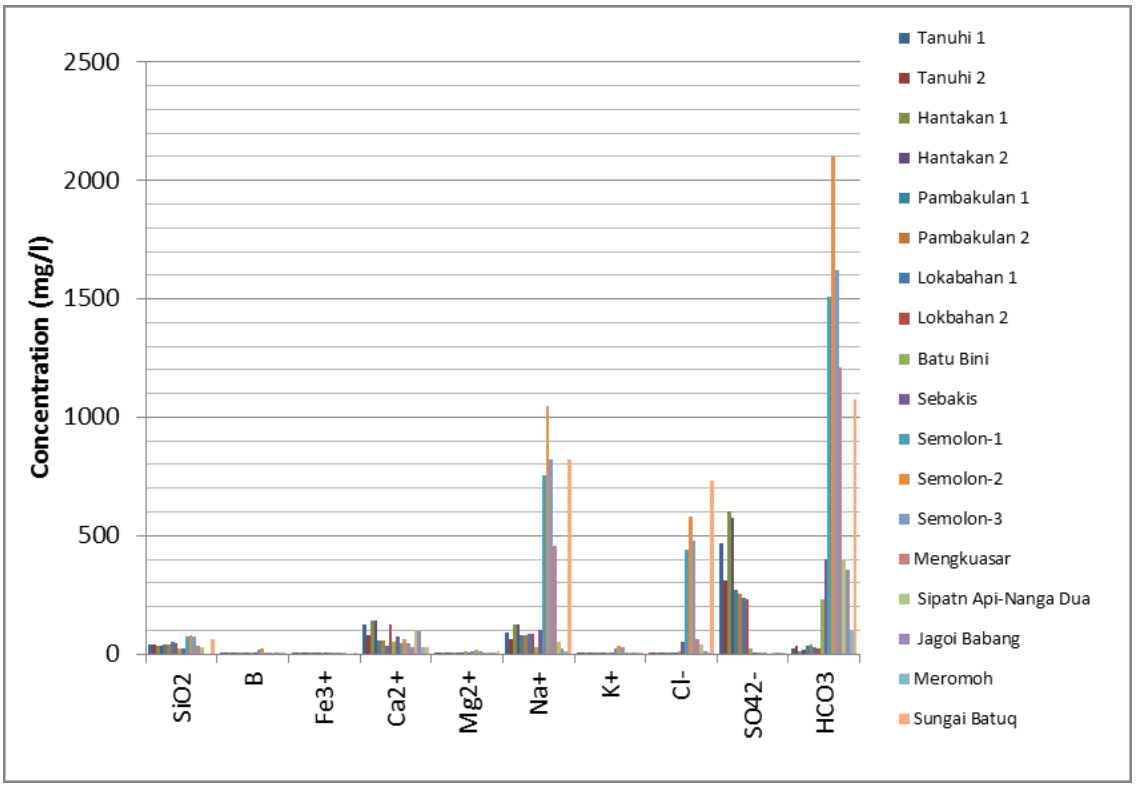

Figure 4: Diagram of Concentration of several constituents of Low Temperature Geothermal Systems at Kalimantan Island

The relative concentration of Cl-SO_4-HCO_3 (Giggenbach, 1991) showin the ternary diagram (Figure 5). The warm springs of South Kalimantan mostly are SO_4 type, i.e.: Lokbahan, Tanuhi, Hantakan, and Pembakulan. They are neutral waters, so the sulphate concentration could be because of evaporation process from sedimentary rocks which results minerals of gypsum, anhydrite, and barite. The rest of it, they have HCO_3 type, could have an indication that they are associated with CO_2 gas condensation into shallow aquifer or mixing with shallow groundwater.

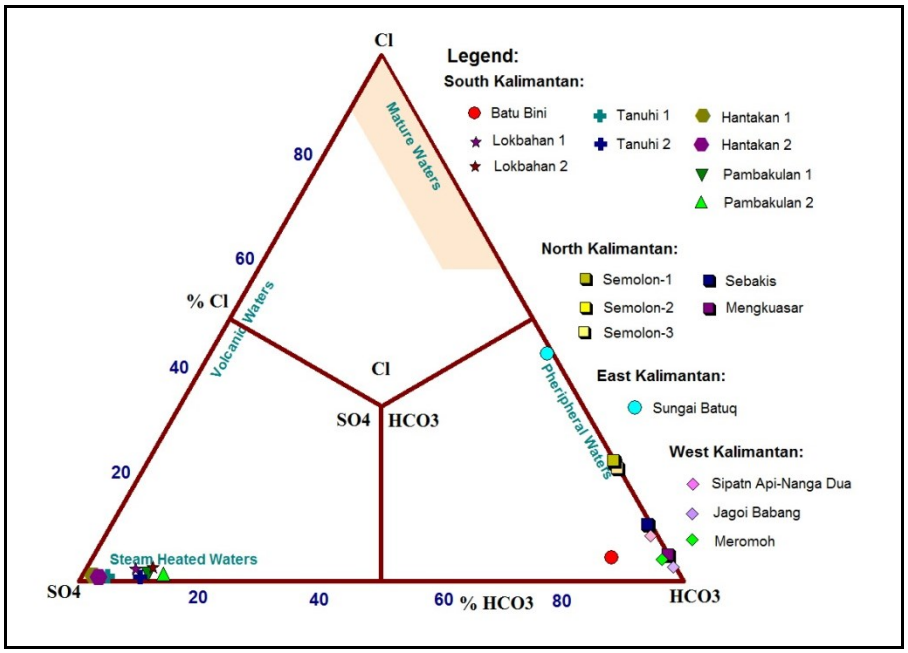

Figure 5: Ternary Diagram of Relative SO_4-Cl-HCO_3 of Low Temperature Geothermal Systems at Kalimantan Island

The degree of water-rock interaction of manifestations of low temperature geothermal system at Kalimantan could be interpreted as diagram Na-K-Mg (figure 6, Giggenbach 1988). Mostly they are on partial equilibrium zone, have enough water-rock interactions (Lokbahan, Tanuhi, Hantakan; Semolon, Mengkuasar; Sungai Batuq; and the others (JagoiBabang, Meromoh, SipatnApi-Nanga Dua, and Pembakulan) are on Mg corner (immature waters).

Tabel 1: Potency and Reservoir Temperature of Low Temperature Geothermal Systems at Kalimantan Island

No	No. map	Name	Region	Potency speculative (Mwe)	Potency hypothetic (Mwe)	Reservoir Temperature (°C)
1	184	Jagoi Babang	Bengkayang, West Kalimantan	10	0	88
2	185	Meromoh	Bengkayang, West Kalimantan	10	0	93
3	269	Nanga Dua	Kapuas Hulu, West Kalimantan	5	0	115
4	270	Batubini	Hulu Sungai Selatan, South Kalimantan	20	0	120
5	271	Tanuhi	Hulu Sungai Selatan, South Kalimantan	9	1	115
6	272	Hantakan	Hulu Sungai Tengah, South Kalimantan	20	0	120
7	320	Sungai Batuq	Mahakam Hulu, East Kalimantan	7	0	114
8	277	Sebakis	Nunukan, North Kalimantan	5	0	72
9	279	Semolon	Malinau, North Kalimantan	10	0	122
10	280	Mengkausar	Malinau, North Kalimantan	5	0	88

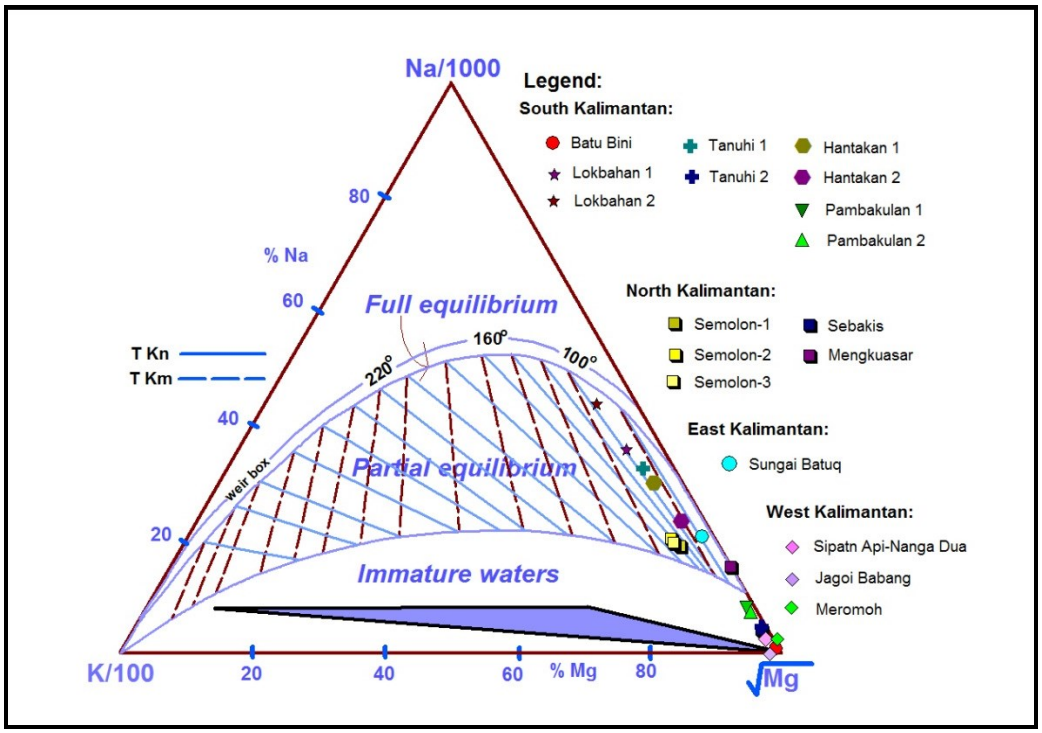

Figure 6: Ternary Diagram of Relative Na-K-Mg of Low Temperature Geothermal Systems at Kalimantan Island

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 eater-rock interaction. Since the type of water are tend to be bicarbonate and sulphate neutral type and partially equilibrated, this could be interpreted that they could be little bit mixing with shallow water.

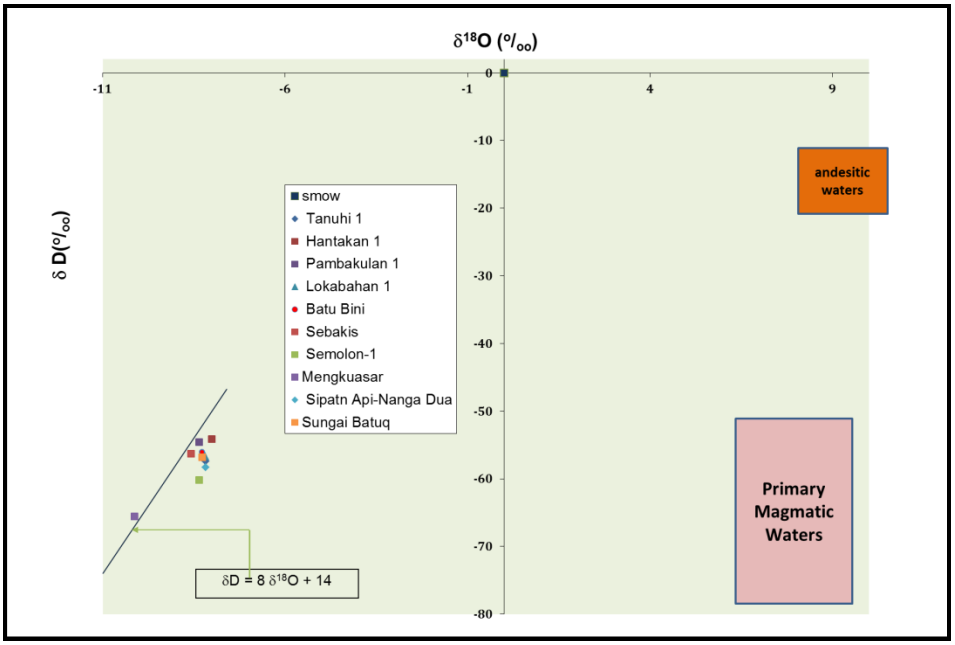

Figure 7: Isotope Diagram of Low Temperature Geothermal Systems at Kalimantan Island

Nowadays, geothermal application for low temperature systems is mostly for direct using such as tourism, balneology, plantation, and fish farms. But Febrianto et. al (2018) describe that low and medium temperature systems have been developed internationally, and pumped systems have been the dominant type of geothermal technology utilized in projects in the USA over the last 5 years. So, Indonesia has a lot of challenge for using low temperature geothermal systems using suitable technology.

Tabel 2: Heat Loss Value and Probable System of Low Temperature Geothermal Systems at Kalimantan Island

No	Name	Region	Heat Loss	Probably Geothermal System
1	Jagoi Babang	Bengkayang, West Kalimantan	1 kWth	sediment basin
2	Meromoh	Bengkayang, West Kalimantan	1 kWth	sediment basin
3	Nanga Dua-Sipatn Api warmspring	Kapuas Hulu, West Kalimantan	1,77 kWth	deep circulation (*extensional-driven*).
4	Batubini-Lokabahan	Hulu Sungai Selatan, South Kalimantan	0,35 kWth	geopressure-sedimentary environment
5	Tanuhi	Hulu Sungai Selatan, South Kalimantan	0,39 kWth	geopressure-sedimentary environment
6	Hantakan-Pambakulan	Hulu Sungai Tengah, South Kalimantan	3,09 kWth	geopressure-sedimentary environment
7	Sungai Batuq	Mahakam Hulu, East Kalimantan	1,5 kWth	Plistosen volcanic activity
8	Sebakis	Nunukan, North Kalimantan	1,65 kWth	sedimentary
9	Semolon	Malinau, North Kalimantan	3,25 kWth	deep circulation
10	Mengkausar	Malinau, North Kalimantan	1,11 kWth	deep circulation

4. CONCLUSION

The low temperature geothermal systems at Kalimantan Island have range temperature reservoir of 72-122 ^{o}C. They are at low terrain and the manifestations only warm springs (<50 ^{o}C) and hot springs (58-60 ^{o}C), thermal springs that mostly partially equilibrated and sulphate and bicarbonate type. The concentration of fluids of thermal waters only show low concentration if compared with others high temperature system. Developing low temperature geothermal systems at Kalimantan will be challenging for Indonesia.

5. ACKNOWLEDGEMENT

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