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An Early Geothermal Fluids Characteristics Interpretation at Nif Warm Springs at Bula Basin, East Seram Regency, Maluku, Indonesia

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ABSTRACT

An early interpretation on surface geothermal features characteristic, especially in chemistry characteristic fluids is necessary as the door for the next step research of the geothermal system. The inventory was conducted in 2018 and the methods are inventory of surface geothermal features, sampling the waters of them, classifying the type of geothermal manifestation, and interpreting for thermal water analysis for the type of the water and consideration the temperature reservoir through the water geothermometers. Bula Basin is a non-volcanic area, located at East Seram Regency, Maluku, Seram Island, Indonesia. Generally, it is included in the Outer Banda non-volcanic arc which consist of metamorphic rocks in the Permian-Triassic. The geothermal manifestation was inventoried in 2018, at Bula basin, near the oil field, and only warm springs (Nif-1 and Nif-2) and light alteration were found. The Nif warm springs are in the Bula basin and is based on the regional geological map of the Bula, Watubela and Maluku sheets. The Nif warm springs are located in the Salas Complex rock, which consists of various exotic boulders with a clay matrix, aged Mio-Pliocene. It is located at Dawang village, Teluk Waru district, East Seram regency, and the coordinates are 669877 mE, 9639782 mS, with an elevation of 83 asl. The only geothermal manifestations are two clusters warm springs, i.e.: Nif-1 and Nif-2 warm springs with temperatures of about 44.9-49.1°C, neutral pH, the electrical conductivity of about 4,810-5,380 µS/cm, and the flow rate of 0.1-3 l/s. The warm springs are manifested at limestone lithology; clear, sulphur odour, and oily smell because of oil seepage near the warm springs. The Nif warm springs are plotted in the middle of the $Cl-SO_4-HCO_3$ diagram; chloride-bicarbonate and sulphate-chloride water type based on the $Cl-SO_4-HCO_3$ diagram and mostly plotted in a partial equilibrium zone based on the relative Na-K-Mg diagram. The temperature of the reservoir is medium at about 155°C from Na-K Giggenbach geothermometer. The type of Nif-Bula geothermal system could be a fractured system or a heat sweep system, and this still needs additional geophysical data. The Indonesian government is focusing on the development of Eastern Indonesia. The early interpretation characteristic of geothermal chemistry fluids of Nif warm springs in Bula Basin would be a useful consideration for the next step investigation using more completed methods to understand the Nif-Bula geothermal system.

1. INTRODUCTION

Indonesia is an archipelagic country, blessed with many medium and small islands that are scattered in all its territory. Because of its geological setting, Indonesia acquires the abundant of geothermal resources. The geothermal energy is sometimes placed in small and medium islands, and also in remote islands. December 2020, Geological Agency, MEMR has inventoried 357 geothermal areas, with total potency about 23,73 GWe which is consisted of 5,981 MWe of speculative potency; 3,363 MWe of hypothetical potency; 9,547 MWe of possible potency; 1,770 of probable potency; and 3,104.5 of proven potency; but the installed capacity is still about 2,175.7 MWe. Maluku and North Maluku province are part of Zone of Eastern Indonesia, have at least 35 geothermal areas and total potency about 1,259 MWe. Several of them (164 MWe) are in Seram Island and have medium temperature reservoir. Seram Island has an area of about 18,625 km^2, length of 340 km and width of 60 km. It is located in the north of Ambon Island, Maluku province (figure 1). There are 3 (three) regencies: West Seram, Middle Maluku, and East Seram. The geothermal areas of Seram Island are 5 areas, i.e.: Kelapa Dua, Pohon Batu, Banda Baru, Tehoru, and Nif-Bula. The potential is consisted of West Seram: Kelapa Dua (25 MWe speculative potency); Central Seram: Tehoru (35 MWe possible potency), Banda Baru (33 MWe hypothetic potency and 21 possible potency), Pohon Batu (37 MWe speculative potency and 13 hypothetic potency); and East Seram: Nif-Bula (only inventory of the hot springs); but there are none of proven potential and still none of installed capacity. The availability of energy is important for local economic circulation, such as fisheries, plantation, forestry, tourism, and mining. Indonesia government is focusing on the development of eastern Indonesia. The characteristic of geothermal chemistry fluids in Nif-Bula Basin could be a consideration for those who will develop geothermal at Maluku whether it is for direct use and for indirect use. Indonesia's government is focusing on the development of Eastern Indonesia and developing small scale geothermal power plant. The early interpretation characteristic of geothermal chemistry fluids in Nif-Bula Basin could be a consideration for the next step investigation using more completed methods to understand the Nif-Bula geothermal system. Primary data collection for the Nif warm springs was carried out in 2018.

2. METHOD

The methods are using inventory of surface geothermal features, sampling the waters of them, classifying the type of manifestation, and interpreting for thermal water analysis for type of the water and consideration the temperature reservoir with water geothermometer. The characteristics were identified from the type of manifestations and the result of water analysis. Water samples were analyzed at laboratory of Center for Mineral, Coal, and Geothermal Resources. The cation-anion analysis was 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. This interpretation also combines secondary data from several literatures.

3. A BRIEF OF GEOLOGY

Seram is an island of the outer Banda Arc, eastern Indonesia. Based on the heat flow database at SE Asia region, Seram Island geothermal areas are having the heat flow >80 mWm^2 at the middle to the west part of island and lower of heat flow about < 80 mWm^2 at the middle to the east part of island, (Figure 2, Hall and Morey (2004)). The heat flow pattern on a region could affect the favorable heat source for a geothermal system. Surface thermal springs are extracting the heat from the depth, So, Seram Island considerably has moderate heat flow to build a geothermal system.

Hill (2013) described that Seram is placed between the passive margin tectonics of Australia's Northwest Shelf and the active margin tectonics of New Guinea, both of which have played an important role in the structure of this region. It is a confluence of three tectonic plates: Australian Plate, Pacific-Philippine Plate, and Eurasian Plate. Seram Island is limited by 2 (two) horizontal fault systems, namely the fault system in the northern part of Sorong and the Tarera - Aiduna fault in the south. The configuration of Seram Island was formed from thrust faults to sharp angles to horizontal faults. Seram has complex tectonic order, in general, upward and anticline axes that are northwest - southeast trending indicate that the deformation in this area is affected by compression that travels northeast – southwest (Imbron, 2017).

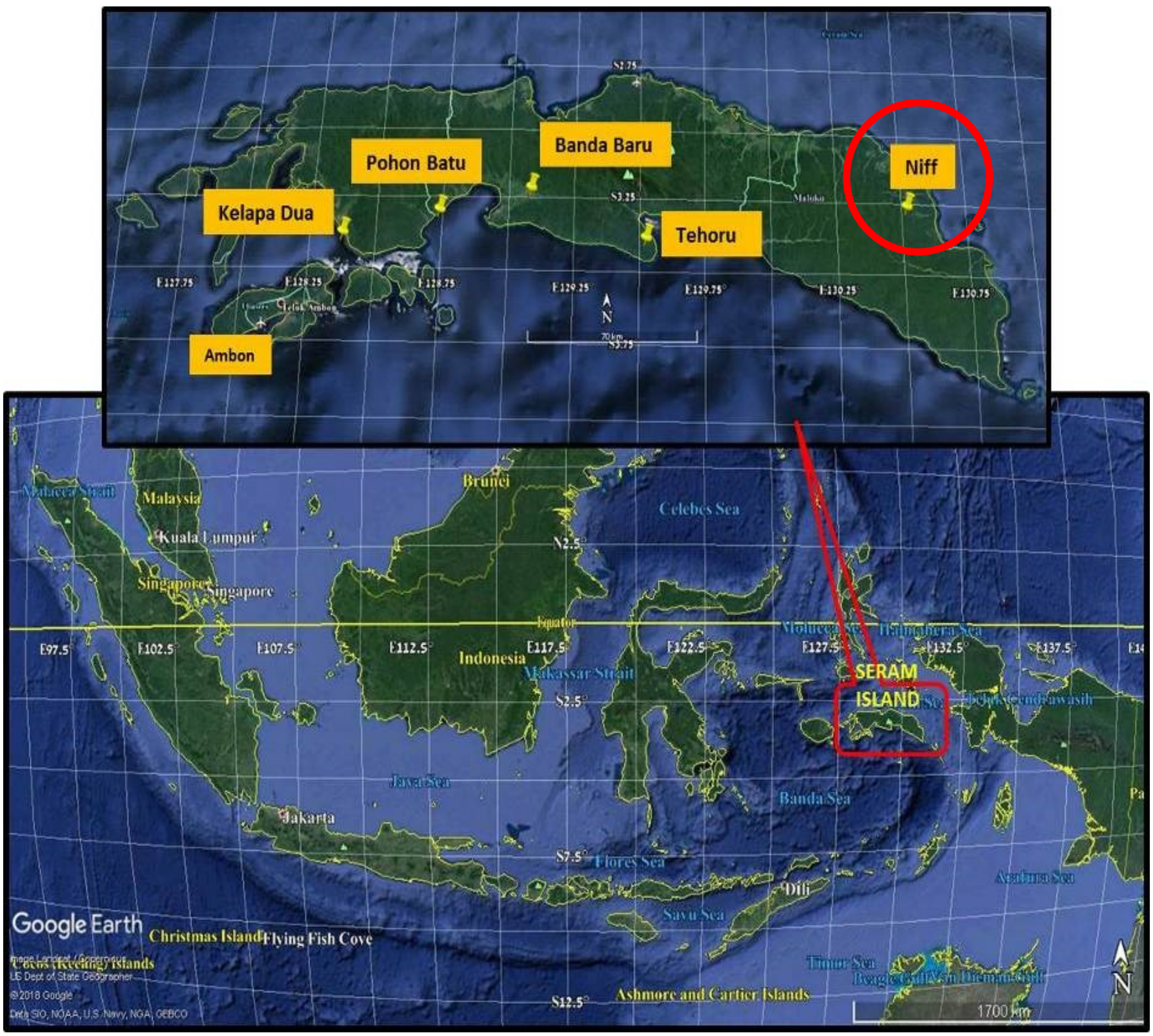

Figure 1: Map location of Nif-Bula Geothermal Area, Seram Island, Indonesia (Google Earth)

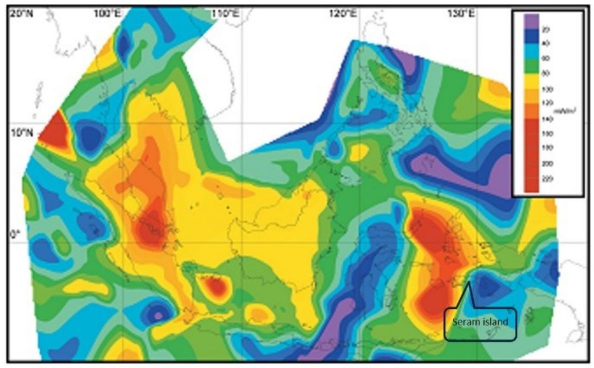

Figure 2: Contoured heat flow map for SE Asia (based on the database of *Pollack et al.* [1990; 1993] and oil company compilations *Kenyon and Beddoes*, 1977; *Rutherford and Qureshi*, 1981, in Hall and Morey, 2004)

The lithology of Seram island is consisted of non-volcanic rocks age Permian (Paleozoicum) until Holocene. Briefly, Pairault, Hall, and Elders (2003) explained that geologically, Seram Island could be divided into two zones: the northern belt and southern belt. A northern belt, covering the north part of the island in the west and all of it in the east, consists of imbricated sedimentary rocks of Triassic to Miocene age whose fossils and facies resemble those of the Misool and New Guinea continental shelf. The southern belt is dominated by low-grade metamorphic rocks.

The area of Seram Island and Ambon Island are part of the Banda Arc. Based on the the stratigraphic data also shows the development of tectonics from Paleozoic to Miocene. The tectonic development of the two islands is very closely related tectonic development of the continent of Australia. Convergent interactions between the Eurasian, Indo-Australian and Pacific plates in the Late Miocene followed by rotation of the Bird's Head counterclockwise in Mio-Pliosen have led to tectonic development for the two regions are different, so that lithology units from Seram and Ambon Island can be divided into Australian Series and Seram Series.

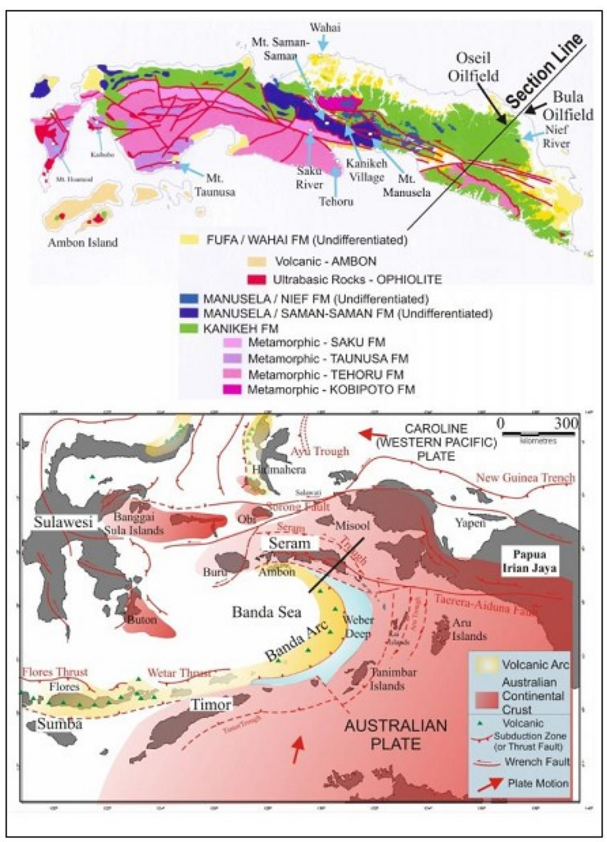

Figure 3: Tectonic setting of the Banda Arc and simplified geology map of Seram showing the location of the regional cross section (courtesy of Kufpec (Indonesia) Limited in Hill, 2012)

3.1 Regional Geology of Nif-Bula Warm Springs

The oldest sedimentary rock on Seram Island is the Kanikeh Formation which is deposited on the outer neritic zone, in the form of sandstones and mudstones and is out of alignment above igneous and metamorphic rocks (basement) (Pairault, Hall, and Elders, 2003). The age of the Kanikeh Formation is the Central Triassic - Late Triassic. Above the Kanikeh Formation, there are gradations in the Saman-Saman Formation in the form of limestone. Then on a runway above the Saman-Saman Formation, there is the Manusela Formation in the form of limestone and deposited in the neritic environment - Bathyal. The Salas complex is deposited on the outer shelf -bathyal, which consists of claystone, mudstones, and contains clastic, lumps and blocks of rock before experience rapture. In addition to the Salas Complex, erosion from the removal of rocks on Seram Island also caused the Wahai Formation to be deposited in the form of clastic deposits on the –bathy outer shelf in the Pliocene - Early Pleistocene. Above the Wahai Formation, there is the Fufa Formation which is a shallow (nile zone) sea sediment from erosion when the lifting process still takes place at the beginning of leistocene. Wahai Formation consists of mudstones, claystone, sandstones, siltstone, conglomerates, and limestones. Based on regional geological maps of Bula and Watubela sheets, Maluku, (S. Gafoer, et all, 1993), Nif warm springs are located in the Salas Complex rock, which consists of various exotic boulders with clay matrix aged Mio-Pliocene.

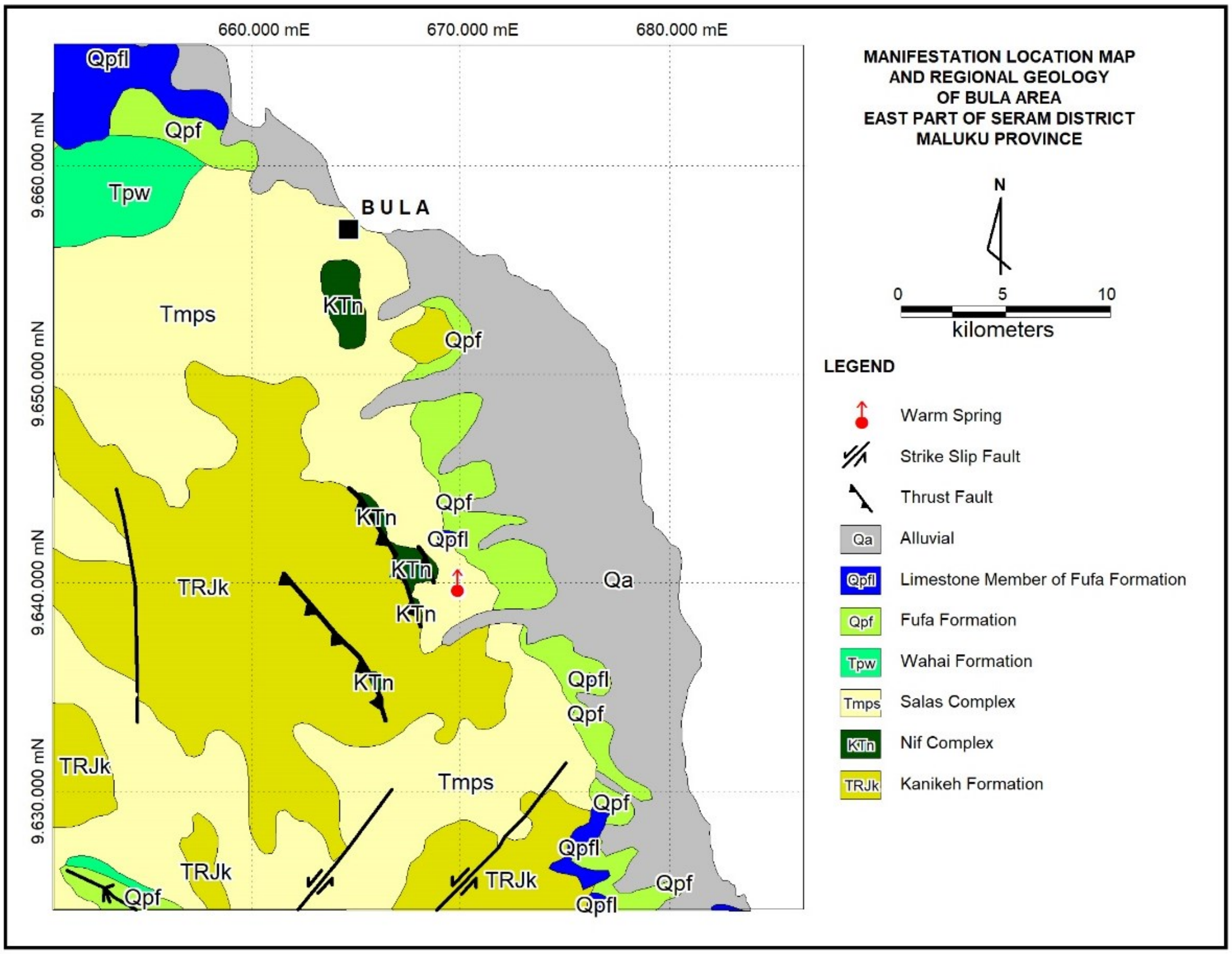

Figure 4: Location Map of Geothermal Manifestation in the Bula area overlaid with the Regional Geological Map of Bula and Watubela Sheets, Maluku (Modified from Gafoer, S., Suwitodirjo, K., and Suharsono, 1993)

4. SURFACE GEOTHERMAL FEATURES

Geothermal manifestations that are still active in the Bula area, East Seram, Maluku are only in the form as Warm springs, namely Nif-1 warm springs and Nif-2 warm springs which are located at an altitude of about 83 masl.

Figure 5: Photo of Geothermal Manifestation Location of Nif-Bula Warm springs (red circle) Compared with Image from Google Earth.

4.1 Nif-1 Warm springs

The Nif-1 warm springs and the Nif-2 warm springs are separated by a river about 6 m wide. The Nif-1 warm springs located in Nif hamlet, Dawang village, Teluk Waru sub-district, East Seram Regency, Maluku. The Nif-Bula warm springs are located at coordinates X = 669939 mE, Y = 9639742 mS, and Z = 76. The physics characteristics are the temperature of warm springs (44.9°C at air temperature 28.1°C), coming out of limestone, pH of 8.02, electrical conductivity of 5,380 µS /cm, and the flow rate of 0.5 l/sec. The Nif-1 warm springs is clear and smelly of oil because it is on the surface petroleum seepage is black. There are thin sulfur deposits on the surface of limestone.

4.2 Nif-2 Warm spring

The Nif-2 warm spring and the Nif-1 warm springs are separated by a river about 6 m wide. The Nif-2 warm springs located in Nif hamlet, Dawang village, Teluk Waru sub-district, East Seram Regency, Maluku. The Nif-2 warm spring are located at coordinates X = 669877 mE, Y = 9639782 mS, and Z = 83. The physics characteristics are the temperature of warm springs is measured as 49.1°C at air temperature 28.1°C, coming out of limestone, pH 7.21, electrical conductivity 4,810 µS/cm, and the discharge is about 3 l/sec. The Nif-1 warm springs is clear and smelly of oil because it is on the surface petroleum seepage is black, there are sulfur deposits on the limestone in surface.

To compare the characteristics of Nif warm springs, it was sampled of a cold spring that the distance is about 5 m from Nif-2 warm spring, namely: Cold springs of Nif

Nif cold spring is located in Nif hamlet, Dawang village, Teluk Waru sub-district, East Seram Regency, Maluku. The cold spring is about 5 m from warm Nif-2 water, located at coordinates X = 669902 mE, Y = 9639791 mS, and Z = 83, cold spring temperature is measured at 26.3° C at air temperature 28.1°C, comes out of limestone, pH 7.88, the electric conductivity is 341 µS / cm, and the discharge is about 2 l / sec. The cold spring is clear water and smell of oil because there are black oil seeps on the surface.

Figure 6: Niff-1 warm springs

Figure 7: Niff-2 Warm springs

5. RESULT AND DISCUSSION

Geothermal manifestations that are still active in the Bula area, East Seram, Maluku are only in the form as Warm springs, namely Nif-1 warm springs and Nif-2 warm springs which are located at an altitude of about 83 masl.

Table 2: Table of Geothermal Surface Features and Cold Spring Description at Bula Basin, East Seram, Maluku

No	Name	Coordinate			Water Temperature (°C)	Ambient Temperature (°C)	pH	Conductivity (µS/cm)	Debit (l/sec)	Brief Explanation
		X (mE)	Y(mS)	Z(m)						
1	Warm springs of Nif-1	669939	9639782	76	44.9	28.1	8.02	5,380	0.5	Clear, smells of oil, there are thin sulfur deposits
2	Warm springs of Nif-2	669877	9639782	83	49.1	28.1	7.21	4,810	3	It is clear, smells oily, there are far more sulfur deposits than in Nif-1 warm water
3	Cold springs of Nif	669902	9639791	83	26.3	28.1	7.88	341	2	Clear, manifested at limestone

Table 2: Laboratory Result of Water Analysis at Bula Basin, East Seram, Maluku

No	Sampel	pH	Temperature	DHL	TDS	SiO_2	B	Al^{3+}	Fe^{3+}	Ca^{2+}	Mg^{2+}	Na^+	K^+	Li^+	As^{3+}	NH_4^+	F^-	Cl^-	SO_4^{2-}	HCO3	$CO_3^=$	ion balance
			(°C)	µS/cm		mg/l																
1	Nif Coldsprings	7.76	26.3	323.0	234	5.97	0.11	0.00	0.05	67.65	2.59	3.86	1.67	0.00	0.00	0.32	0.10	0.45	30.42	187.70	0.00	1.10
2	Nif-1 warmsprings	7.80	44.9	4430.0	3378	34.13	24.93	0.01	0.30	171.92	11.19	976.98	30.19	0.96	0.10	4.28	1.84	795.48	836.67	707.08	0.00	1.54
3	Nif-2 warmsprings	8.14	49.1	4090.0	3152	38.92	25.66	0.00	0.07	111.16	7.86	982.04	31.57	0.97	0.30	4.52	2.92	810.31	342.94	1056.43	0.00	2.73

5.1 Classification of the Fluids

During the geothermal fluid rises from the reservoir to the surface and appears as hot springs or warm springs, the fluids can undergo a cooling process as a result heat conduction process to surrounding rock, boilling process, mixing process with cold water, or the result of a combination of the three processes. Substances dissolved in the fluid can be a function as tracer components (tracers) and geo-indicators (Giggenbach, 1991). Giggenbach (1991) divides solutes into two categories, namely: 1) tracers, namely solutes that are chemically inert/non-reactive where when these components are in a fluid, they do not change and can be traced back to the origin. them (eg Cl, B, Li, and N_2); 2) geoindicator, which is a solute component that is reactive and reflects a specific equilibrium in a particular environment (eg Na, K, Mg, Ca, and SiO_2, which play a role in temperature-dependent interactions of the geothermal system with the source rock). The concentrations of these components are used as tracers and geoindicators by plotting on the Giggenbach triangle diagram (1991, the triangle diagram Cl-SO_4-HCO_3, relative of Na-K-Mg, and relative of Cl-Li-B). Using the concentration of these components as tracer and geoindicator can be done with how to plot the concentration of its components in the Giggenbach triangle diagram (1991).

The laboratory result of the sample warm springs and cold spring is shown in the table 2. Some of the results of the concentration analysis are Cl (795-810 mg/l), SO_4 (342-836 mg/l), HCO_3 (707-1056 mg/l), Ca (111-171 mg/l), Na (976-982 mg/l), Mg (7-11 mg/l), SiO_2 is relatively low about 34-38 mg/l, B (34-38 mg/l). The warm springs are manifested at limestone rock, since the warm springs is the result of water-rock interaction and the heat source-reservoir fluids reaction, so the limestone could probably affect the relative concentration of the warm springs, such as Ca etc. The Mg concentration of 7-11 mg/l could indicate that the warm springs is only very slightly mixed with surface water. The Bicarbonate HCO_3 (707-1056 mg/l) may derive from CO_2 rich steam condensing or mixing with water, it is quite common in old geothermal waters or on the peripheries of geothermal areas in outflows. The sulphate SO_4 (342-836 mg/l) could be predict from the dilution of anhydrite because of the pH neutral of the warm springs. But,there is a unique light sulphur deposition (yellow colour) around the limestone which is the low steam from Nif warmsprings is condensed (Figure 7). The Cl could be also both from the gas of the heat source and from the wall of the host rock. Overall, the concentration is low to medium concentration, there is no anomaly (to high or very high) in this result of laboratory analysis of Nif warm springs. This most probably because of the medium temperature of the reservoir.

The silica concentration depends on the solubility of quartz/chalcedony, temperature dependent Al-silicate ion-exchange equilibria control Na/K, pH is controlled by salinity and Al-silicate equilibria involving hydrogen and alkali ions, Ca^{+2} and HCO^{-3} concentrations depend on pH and CO_2 concentration because of equilibrium between the fluid and calcite, F^- and SO_4^{-2} concentrations are related to that of Ca^{+2}, limited by solubility of fluorite and anhydrite and temperature and salinity dependent silicate equilibria control a very low Mg^{+2} concentration. The results of alteration studies show that the chemical composition of geothermal fluids originates in controlled reactions dependent on temperature, pressure and rock composition.

The Cl-SO_4-HCO_3 triangular diagram (Figure 8) shows that the warm springs of Nif-1 and Nif-2 are in the middle of the triangle diagram, warm springs Nif-1 tends to be of the type chloride-sulfate-bicarbonate, warm springs Nif-2 tends to be a chloride-bicarbonate type, while cold spring Nif is a bicarbonate type. These geothermal surface features could be a reservoir fluid that is not mixed with surface water too much.

Nif warm springs tend to be of the chloride-sulfate-bicarbonate type in the middle of the diagram, this can be indicates relatively little mixing with surface water. On the geothermal system at low terrain altitude of about 83 masl, usually types of geothermal water such as this could be hypothesized to be the upflow of the Bula geothermal system. However, this must be confirmed with geoscience data from other methods as well.

The Na-K-Mgtriangle diagram is in principle used to evaluate the hot springs conditions as the end result of the two processes that occur during the passage of the reservoir fluid to the surface, namely the process of dissolving rock and equilibrium. The process of dissolving rock by the fluid results in changes in rock structure and composition. Besides, the dissolving process will result the composition of the elements or compounds in the fluid also changes. The interaction process between the fluids and rock produces fluids with new characteristics which is determined by the level of equilibrium between the elements that are in the fluids with the elements that are in the rock. Eventhough the area is a non-volcanic environment and the host rock probably is the limestone itself, the concentration of Na will be affected of these two factors, but the result of laboratory analysis shows that Na concentration is not to high or very high which is indicated the dilution from the sediments. So, the assumption for indicators for water-rock equilibration temperatures at the reservoir (geothermally relevant temperatures (100°- 300°C)) are Na in the form of albite, Mg as chlorite, and potassium in the form of feldspar and a layer silicate.

In a triangular diagram comparing the concentrations of Na, K, and Mg(Figure 9) it can be seen that in general, Nif warm springs are in the partial equilibrium zone, while cold Nif spring is in Mg corner (immature waters zone). This indicates that the interaction between hot fluids with the rock below the surface has produced fluids with new characteristics as a result of the process partial equilibrium of the elements contained in the rock with the constituent elements of the hot fluid. Or it could indicate a dilution or mixing with relatively little surface water. This matter reinforces the indication on the water type diagram that Nif warm springs is a representative fluid from the Bula geothermal reservoir, so a good data for an early interpretation.

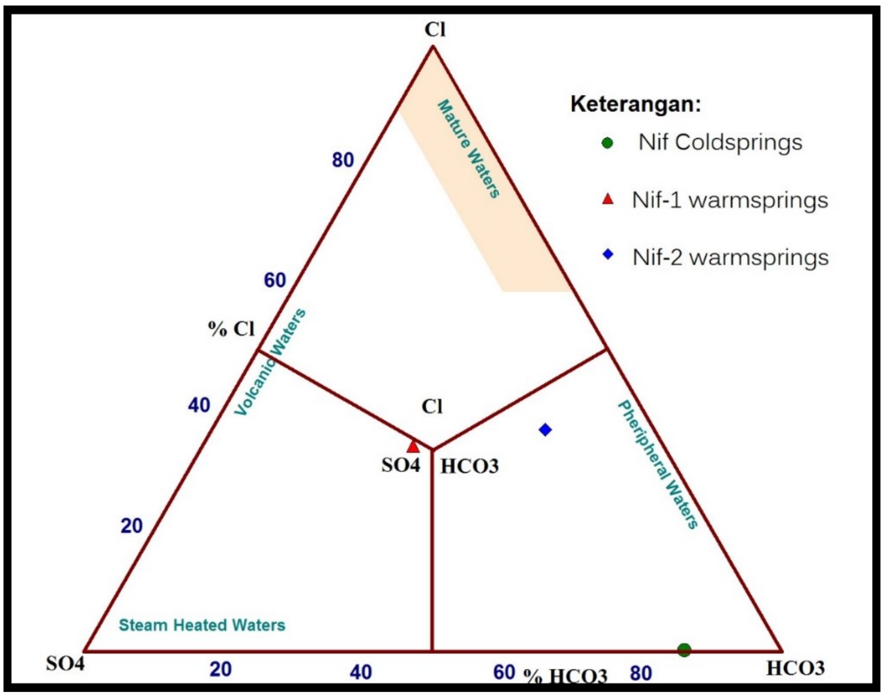

Figure 8: Cl-SO_4-HCO_3 Ternary Diagram

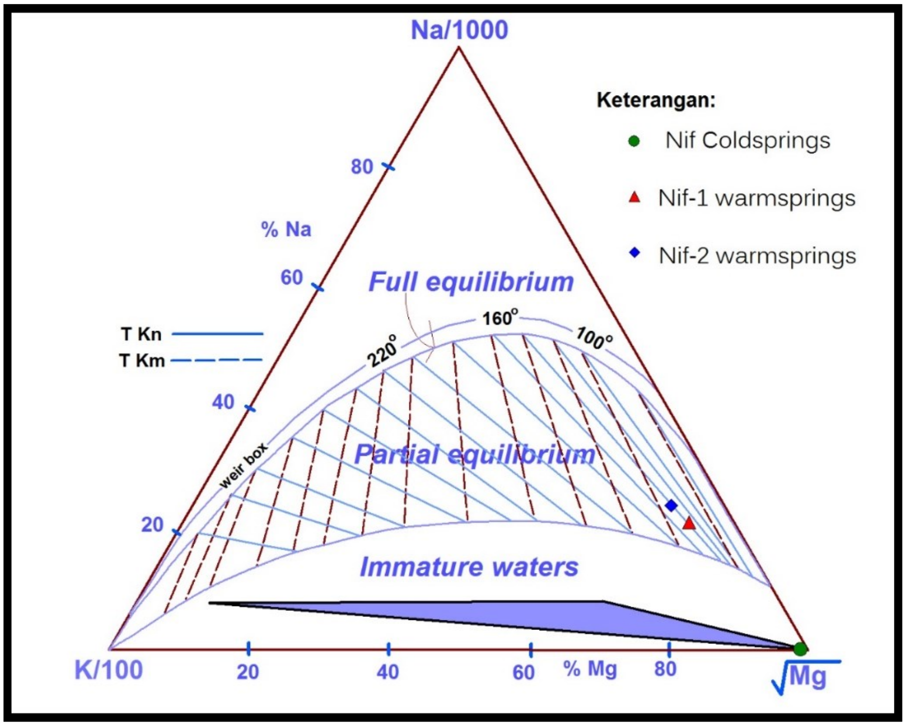

Figure 9: Na-K-Mg Ternary Diagram

5.2 Isotope

In general, geothermal fluids will undergo the process of adding the oxygen-18 isotope from water origin, in this case is meteoric water (Craig, 1963 in Nicholson, 1993). The data is plotted into the diagram relationship between oxygen-18 isotope ($\delta^{18}O$) versus deuterium ($\delta^{2}H$) and compared with the line of Indonesia's local meteoric water (BAFI-BATAN, 1984 in Sidauruk et al, 2000). It shows that Nif warm springs are relative away from the meteoric water line (adding the oxygen-18 isotope from water origin) and could be concluded that there are the mixing process and representing the reservoir fluid of Niff geothermal system. While deuterium isotope changes will not occur because rocks generally have a concentration low hydrogen. Seeing the characteristics of the geothermal manifestation on the surface, the warm springs of Nif is geothermal fluid water from deep waters. It can be seen that the water-rock intensity is very significant.

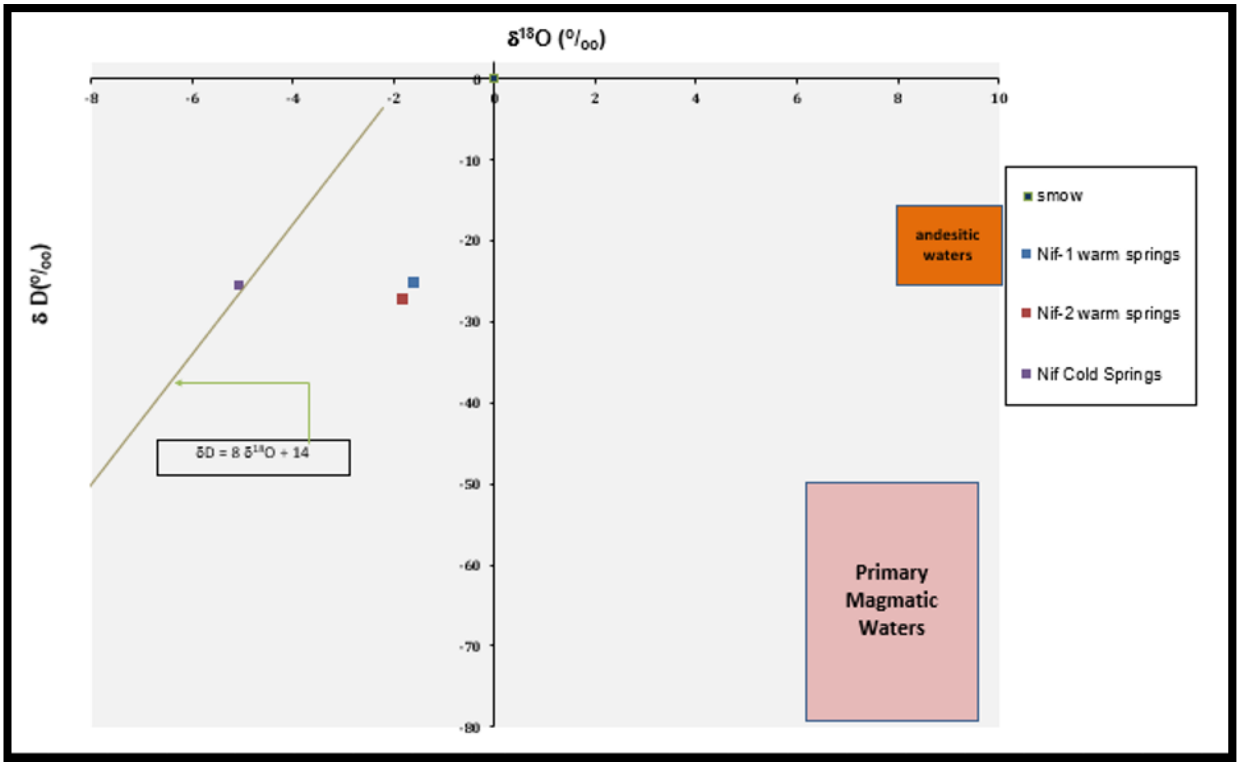

Figure 10: Water Isotopes Diagram

5.3 Geothermometry

Estimating reservoir temperature is the main objective in the chemical characteristics of hotsprings. Some of the approaches used to determine a geothermometer can be through the concentration of solutes in water, isotopes, or with a gas geothermometer. The solute geothermometer is based on fluid-mineral equilibrium that depends on temperature with several assumptions (Ellis, 1979; Fournier, 1977; Fournier et al, 1974; Truesdell, 1976; and White, 1970, in Nicholson, 1993). In other words, the reaction must be fast enough to maintain the conditions equilibrium that has occurred in the reservoir.

All manifestation in the Nif-Bula tend to have a neutral pH and is in a partial zone equilibrium so that it can be considered in the calculation of the geothermometer. In this area, it is estimated that there are 2 (two) warm springs: Nif-1 and Nif-2 which have a tendency to pH neutral to alkaline so that it can be considered in the geothermometer calculation. In the Nif geothermal system, the reservoir temperature calculation uses the results of analysis Nif-1 and Nif-2 by considering the following: type on the manifestation of Nif in the middle zone of chloride-sulfate-bicarbonate, located in the zone in partial equilibrium, isotope values reflect the interaction of water and rocks very significant which is an indication of the origin of deep waters, indicating Nif fluids is reflecting the reservoir fluid of the Bula geothermal system. Reservoir temperature calculations relating to the Nif-Bula geothermal system are listed in Table 3. The results of the calculation of reservoir temperature around 155°C Na-K (Giggenbach).

Table 3: Consideration of temperature Reservoir in Nif-Bula Geothermal Areas, Maluku.

Name	Quartz cond	Quartz adiabatic	Na-K-Ca Mg corr	Na/K Fournier	Na/K Truesdell	Na/K (Giggenbach)	K/Mg (Giggenbach)
Warm springs of Nif-1	85	88	86	133	88	153	93
Warm springs of Nif-2	91	93	86	136	91	155	99

5.4 The General Early Interpretation

Hochstein, M. and Browne, P. (2000) explain that each of the geothermal systems is dynamic phenomenon. Its surface manifestations are often beautiful and are expressions of transfer of heat energy visible from beneath the surface. Every manifestation comes from the system special. Most of the warm water discharge (ie, <40°C) comes from Fracture zone systems hosted by sedimentary or metamorphic rocks. The heat flow pattern in an area can affect a favorable heat source for geothermal system. Surface hot springs extract heat from the depths. Bula Basin has an approximate heat flow of >80 mWm^2 compared to other regions. So, territory it may have a good to moderate heat source.

Hochstein, M. and Browne, P. (2000) explain that the deep-reaching heat-sweep systems can also develop in terrain with rather flat topography if fluids ascend via a deep, highly permeable (>100 millidarcy) fracture zone in a brittle crust of high heat flux (>70 mW/m^2). Such high fluxes often occur where thick gran- ites provide radiogenic heat (see Fig. 8). Fracture zones near the surface may be ‘‘narrow’’ (<100 m) or ‘‘wide’’ (>200 m). A good example of the former is the Fuzhou prospeci in southern China; the San Kamphaeng prosp ect in northern Thailand is an example of a wide fracture system. Another dozen or so fracture zone-sweep systems occur in northern Thailand (e.g., Fang) and a few within the coastal strip of southern China (e.g., Zhangzhou). The dominant manifestations of all these systems are hot springs, and occasional hot pools, both with minor encrustations of sinter and travertine; alteration of the surrounding rocks is rare. Conduction contributes to the heat transfer, which commonly lies between 3 and 10 MW. Prospects with indicated high Na/K equilibrium temperatures (some greater than 225 °C) can also be misinterpreted as being ‘‘high-temperature systems,’’ although their low heat outputs and isotopic signatures (no significant oxygen-18 isotope shift) show them to have intermediate-temperature reservoirs.

In the area of the Bula basin, geothermal features on the surface are identified in the form of warm springs, namely in Nif (manifestation temperatures ranging from 44-49°C) which is located close to the Bula oil field. Thus, in the Bula area is not a 'blind geothermal system' because there are springs emerging warm, so that it has the potential for geothermal energy which can be further analyzed the size of the source geothermal power with a more complete method. The types in the Nif manifestations in the middle zone of the chloride-sulphate-bicarbonate, are located in the zone of partial equilibrium, isotope values reflect the interaction of water and very significant rocks which are indicative of origin deep waters, indicating water Warm Nif is the fluid that reflects the reservoir fluid of the Bula and geothermal systems is an indication of the upflow area in the low terrain system. Reservoir temperature calculation results about 155°C Na-K (Giggenbach). The type of Nif-Bula system still unknown wether it is a fractures sytem, a heat sweep system, in this case there must be additional geophysical data to determine the subsurface dimensions of Nif-Bula geothermal system.

6. CONCLUSION

Surface geothermal appearance in the eastern part of Bula-Seram is identified at Nif hamlet, there are two manifestations of warm springs identified, namely: The Nif-1 and Nif-2 with a manifestation temperature ranging from 44-49°C, appears in limestone lithology. Type of the manifestation of Nif are in the middle zone of chloride-sulphate-bicarbonate, is in a partial equilibrium zone. The reservoir temperature is estimated to be around 155 °C (Geothermometer Giggenbach Na-K), including the moderate temperature system. To find out the geothermal resources in this area, it is necessary to do other methods such as geology, geochemistry, and geophysics in more detail. So, Nif-Bula warm springs as a part of East Indonesia has mature medium temperature geothermal systems that will be challenging to develop for local people mostly and to develop small scale geothermal power plant or to develop the geothermal direct use industry.

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