Jurnal Perspektif Pembiayaan dan Pembangunan Daerah Vol. 5. No.3, January – March 2018 ISSN: 2338-4603 (print); 2355-8520 (online)

The geothermal potentials for electric development in Maluku Province

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Abstract.
The characteristic of small to medium size islands is the limited amount of natural resources for electric generation. Presently the needs of energy in Maluku Province are supplied by the diesel generation units. The electricity distributes through an isolated grid system of each island. There are 10 separate systems in Maluku Province, namely Ambon, Namlea, Tual, Saumlaki, Mako, Piru, Bula, Masohi, Dobo and Langgur. From the geothermal point of view this condition is suitable because the nature of the generation is small to medium and the locations are dispersed. The geological condition of Maluku Province is conducive for the formation of geothermal resources. The advanced utilization of geothermal energy in Maluku Province is in Tulehu located about 8 kilometers NE of Ambon. It is expected that 60 MW electric will be produced at the first stage in 2019. A total of 100 MW resources were estimated. Other places of geothermal potentials are Lauke and Tawen both located in Ambon Island with the potentials of 25 MW respectively. In Oma Haruku, Saparua and Nusa Laut the geothermal potentials were estimated to be 25 MW each. The total amount of geothermal energy in Maluku Province is thus, 225 MW which will contribute significantly to the needs of projected 184 MW in the year 2025.

Keywords: *Maluku Province, geothermal energy, suitable, dispersed, conducive*

INTRODUCTION

The increasing needs for electricity

The electricity demands in Maluku Province is constantly increasing in line with the progressing development and the number of population. Annual electricity demands increase about 7.1% in respon to the economic growth of 2.9% and population of 2.4% (Jarman 2012). Presently electricity supply comes out from diesel generation units numbering to 42 which distribute in many islands. There are ten seperate electricity distribution grid systems in each island, namely Ambon, Namlea, Tual, Saumlaki, Mako, Piru, Bula, Masohi, Dobo and Langgur.

The electrification in Maluku Province is 54%, in which the villages have been 82.1% covered. The waiting list for the request of electricity outnumbered to be 1.2 MW (PLN Website, 2015). These figures indicate that the demand for electricity is still high, particularly to cover the whole province which at peresent only almost half of the area.

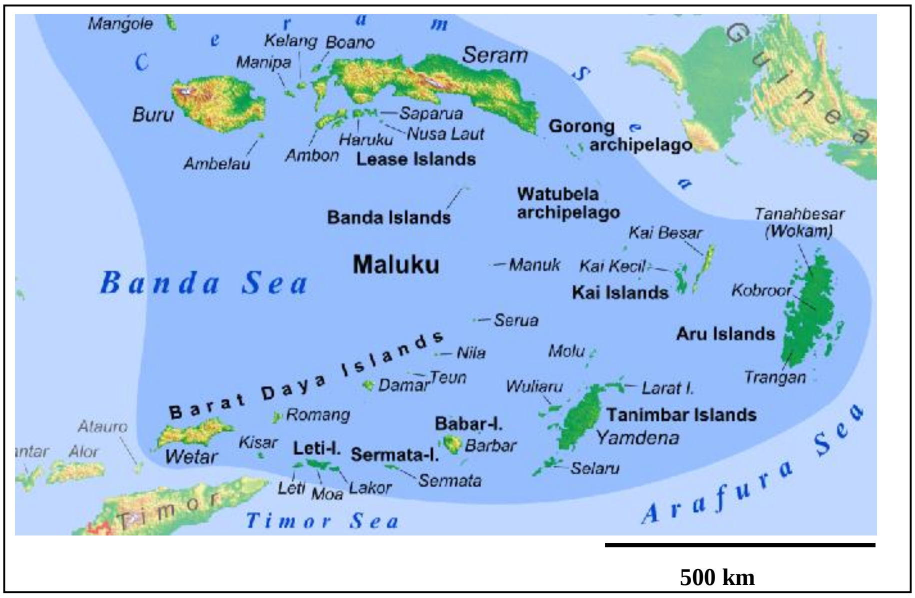
The characteristic of small and medium size islands is lack of energy resources in particular the hydropower which is quite natural because of the size of the island. However other alternative energy might be available, among others solar and wind energy and the ocean thermal energy conversion (OTEC). The technology of the the first two are readily operationally marketed. Solar panels are suitable and handy for isolated area. Small island with limited number of population might enjoy the benefit of solar energy. However all those energy resources need an intesive maintenance, which local people might always unable to offer.

In this particular case, the islands in Maluku province has the advantage of the potentials geothermal resources, for the following reasons: a) The island are located along the volcanic belt extending from the South to the North; b) The belt covers almost the entire Province; c) The dispersed location of the geothermal potentials optimized the distribution grid. The present isolated and separated grid is most suitable for geothermal energy in Maluku Province.

The dispersed location of the islands

Maluku Province consists of small and medium size island. The administration was established in 1999 when the proper Maluku Province was developed into two provinces namely North Maluku and Maluku. The proper Maluku Province was established in 1959. The biggest Island in Maluku Province is Seram with the length of about 500 kilometer while the width is about 100 kilometer. Next to Seram is Buru with elliptic shape with the length of 175 kilometer and width of 150 kilometers. Topographically these two islands are mountainous, therefore the micro hydropower might be possible to produce (Figure 1).

The other big size island is Aru Island with the 250 kilometers long and 100 kilometer wide. Finally the included in the big size island is Tanimbar Island measuring about 150 km long and 50 kilometers wide. These two islands are flat because it is built by the uplifted coral reef.



Graph 1. Maluku Province consists of big and small islands.

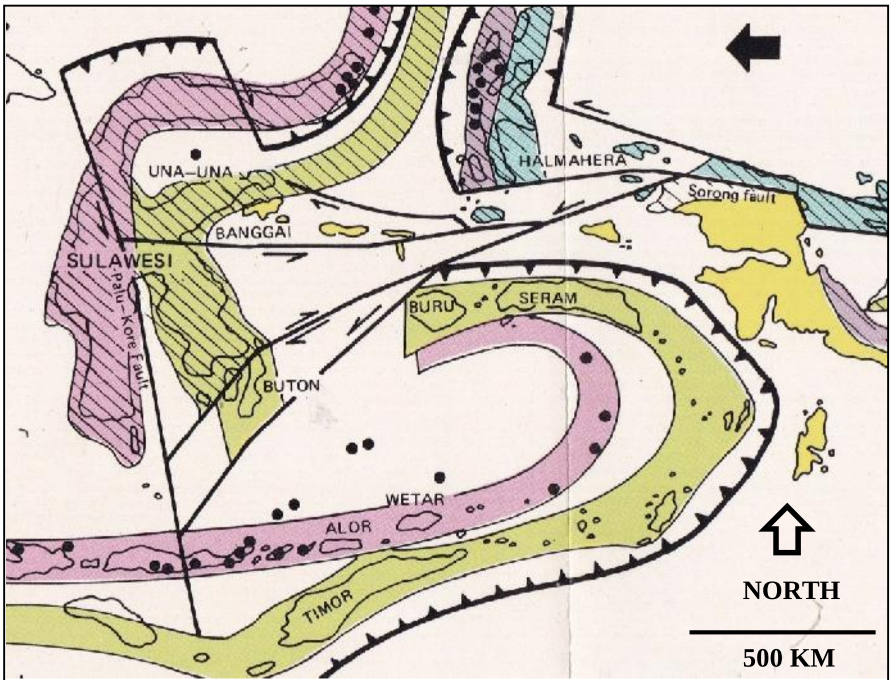
Note: The territory of the Province is indicated by deep blue color
Source: website Maluku Province.

Kai Island consisting of two groups namely Kai Kecil and Kai Besar. Kai Besar has a particular long and thin shape with the longest axis of about 125 kilometer while the width is around 20 kilometers. This particular shape reflects the island was tectonically pressed forming a hilly East side of the island. This characteristic is completely different with Kai Kecil which consists of several island, all are topographically flat. The tectonic setting in Kai Island explain suc a diferences.

GEOLOGIC SETTING

General geology

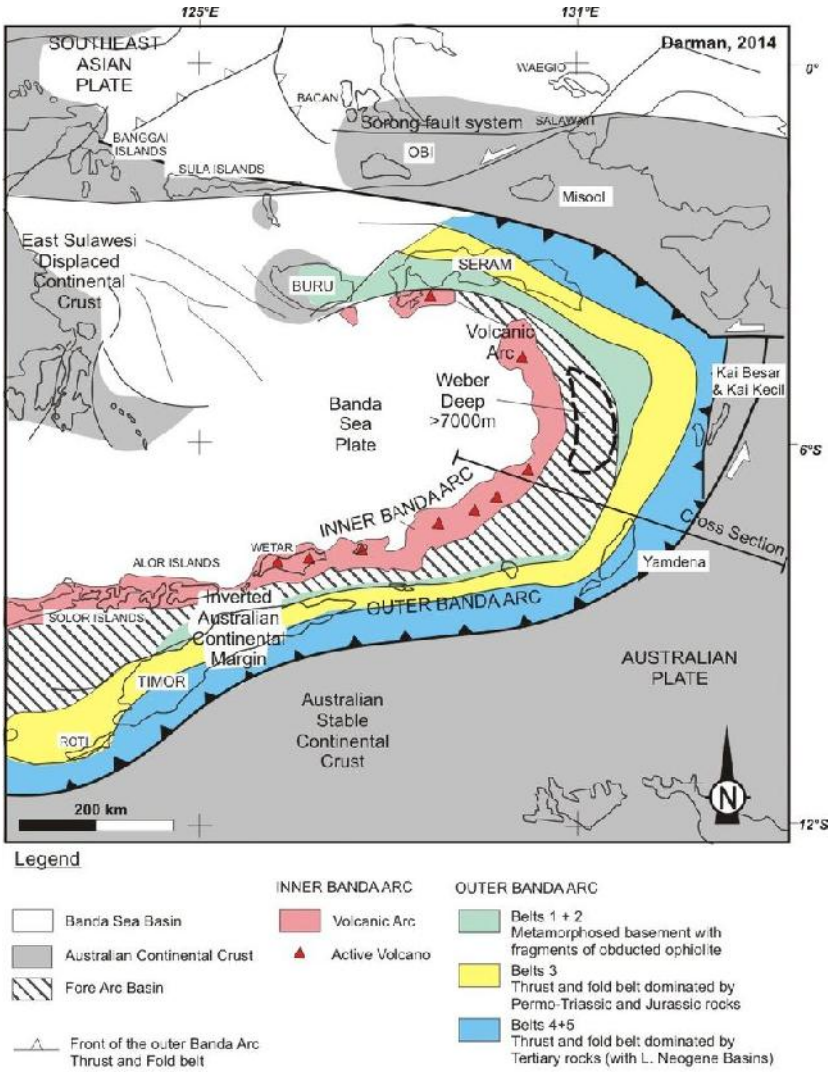
Maluku Province occupies a unique position in the Indonesian geological structure. The volcanic belt bends to the North forming a curvilinear. The volcanoes are located along the line extending from the south to the North. To the East of the line the area consists of stable continental crust of Sahul shelf where Aru Islands is located. To the West the row is paired with the deep sea of Banda Basin. The extraordinary depth of more than 7,000 meters locates in this basin known as Weber Deep.



Legend:
Purple is the volcanic arc with old volcanoes in hachured area, greenish yellow Tertiary subduction zone with old rock assemblages in hachured area, blue represents Late Tertiary subduction zone

Graph 2. The unique geological structure of Maluku Province with curving volcanic arc flanked by deep sea.(Source: Katili, 1985).

Darman et al. (2012) divided the structural element of Maluku into six units (Graph 3): 1) The Australian continental unit represented by Sahul Shelf; 2) Dynamic belt with thrusting and folding; 3) The Mesozoic thrusting and foldings; 4) The metamorphosed continental rocks mixed with obducted ophiolite fragments; 5) The row of volcanoes; 6) The volcanic arc flanked by deep sea.



Graph 3. The tectonic setting and geologic condition of Maluku Province and its surroundings prepared by Darman, 2014, based on Smet's work, 1999.

Those structural elements can be simplified into four groups identifying their position and in the light of plate tectonics as follows: 1) The trapped oceanic plate of Banda Sea; 2) The magmatic belt represented by a row of volcanoes or the Inner Banda Arc; 3) The squeezed Mesozoic and Tertiary sediments with metamorphosed continental basement rocks and fragments of obducted ophiolite; 4) The stable continental plate of Sahul Shelf.

The position of the tectonic sequence seems to inverted, namely the oceanic plate of Banda Sea is obducted below the continental arc. This position resulted in the uplifting of the mixed materials of Mesozoic, Tertiary, metamorphosed continental basement and the fragments of ophiolites. In the normal situation the assemblage might represent the melange where mixed of rocks are deposited in the flank of the subduction trough or in this case the deep sea of Weber. Because of this abnormality, Darman (2012) introduced the term "inverted Australian continental margin."

Volcanic arc of Maluku

In terms of geothermal potentials, the Volcano Islands which were formed by the volcanic activities are very conducive. The topography of the island resembles the cone of a volcano, except Wetar Island where composite volcano was formed. The locations of volcanoes in Maluku Province are the continuation of the row of volcanoes in Java and Nusa Tenggara West and East. Therefore the row is known as Sunda-Banda volcanic arc.

In Maluku Province the row begins with Wetar in South and followed by Romang, Damar, Teon, Nila, Serua, Manuk, Banda Api, Nusa Laut, Saparua, Haruku and finally Ambon. It extends about 1.600 kilometer long and about 60 kilometer wide. Although parts of the arc are submarine there are at least nine volcanoes located in the island which are potential for geothermal development.

Both the edges of the volcanic arc compose of old volcanic rocks of Lower Pleistocene in age, and getting younger to the center. Banda Api volcano is the youngest compared to Teon, Nila Serua and Manuk. The same case hapens with Damar and Romang. Wetar Island very particular because it locate at the junction, where the arc splits to the North following Banda arc and right forward to the East following the line of Leti, Sermata, Babar which finally joins Tanimbar Island.

Many authors called this line as the outer Banda Arc which differs significantly from the the Inner Banda Arc. There is no volcanic activity in the outer arc, which is in contrary to the Inner Arc where active volcanoes are located. Although the topography of volcano Island is less than 500 meters the root of the volcano from the sea floor might locate about 3.000 to 4.000 meters. The real height of the volcanoes thus, is about 3.500 to 4.500 meters or higher than Kerinci, the highest volcano in Indonesia.

The volcanic arc of Maluku is the source of heat to generate steam in geothermal system. In the old volcanoes such those in the line of Nusa Laut, Saparua, Haruku and Ambon the heat is produced by retreating magma front. This type of heat is quite conducive to yield geothermal energy. Therefore this group of volcanoes are all the first priority of the geothermal potentials to develop.

Unique geological condition

The geologic setting outlined above demonstrates the unique and complicated geology of Maluku. There are many other publications concerning Banda, the most comprehensive is the Proceedings of Banda Arc Transect published by the Geological Survey of Indonesia (1982). This very particular area has long been the interesting research subject and perhaps will be the case in the future. Nevertheless, for the purpose of economic mineral evaluation the following summary is outlined: 1) Volcanic arc represented by active and inactive volcanoes is potential for geothermal resources and the formation of base metals among others gold and silver; 2) The squeezed Mesozoic and Tertiary sediments mixed with the basement and ophiolite fragments are perhaps the location for oil exploration. Seepages are found among others in Bula, Seram Island, where this assemblage crops out. However the degree of success might be rather low because of the intensive folding and faulting; 3) The continental crust of Sahul shelf promises the potential gas resources. The mechanism of sag basin in the continental flat form has proven to be productive among others in Bonaparte basins North of Australia. The North margin of the Sahul shelf in the common boundary with Papua might be the most potentials for oil and gas. This area is intensively explored taking into account the handicaps of limited data available.

The importance of geologic condition in Maluku Province lays on the very unique characteristics which draws attention from the scientific community as also exhibited by the floran and fauna in the Past. The Weber deep and the curving shape of the subduction zone remains the mystery to reveal in the future. The area so far is categorized as frontier, due to the scarcity of the available exploration data. This particular situation however might be the challenge and opportunity.

The occurrence of gold in Gunung Botak, Buru Island indicates that in addition to the hydrocarbon potentials, the metamorphic rocks might also contain base metal. The deposits most likely originated from the magmatic activity during the Mesozoic time of Triasic and Jurassic ages. The Gunung Botak gold might have been reworked or in place as in situ. The same case happens in Bombana South East Sulawesi, which remains the mystery. This particular situation might generate the challenge to reveal more deposits in the future.

The old volcanic rock of Plio-Pleistocene age has proven to be potentials for gold deposition such as in Wetar Island. Similarly it occurs in many locations in North Maluku province, among others in Gesowong and Bacan. More deposit to explore in the future.

THE GEOTHERMAL POTENTIALS

Method of estimate

As already outlined above the volcanic belt of Maluku Province is potentials for geothermal energy. It is more significant because the nature of the scale of the dispersed location of the resources. The volcanic belt containing heat resources extend about 1.600 kilometers with about 60 kilometers wide. Although parts of the belt lay under sea water, the location in the island might be promising. The scarcity of data might be the first handicap. However this might also the impact of the economic scale of the demands in the small island.

The study by Japanese experts (Geological Agency, 2007) suggested classifying the degree of economic scale into three categories namely A, B and C. The last category, where the demand is very limited, is recommended to be developed by the government regardless the economic feasibility. They further suggested to apply the subsidy scheme for such geothermal development, taking into account the low interest of the company due to uneconomic feasibility.

The A and B categories might interest for the company because the large demands of electricity regardless the remote location and low demand of the electricity for domestic use. The Jailolo geothermal potentials in Halmahera Island, North Maluku for instance would be developed under feasible economic scale because a large mining company PT Aneka Tambang needs the electricity for the nickel smelter located in Weda Bay, East Halmahera. The situation amplifies the advantage in line with the Mining Law no 4 promulgated in 1999, which stipulates the compulsory processing of raw mineral to export. The feasibility depends upon a lot of circumstances that may develop in the future. The geothermal potentials in Maluku Province therefore remain important to explore regardless the economic scale.

In the estimation of the size of the reserve, there are five levels of the accuracy, namely speculative resource, hypothetic resource, probable reserve, possible reserve and proven reserve (Table 1). The classification is based on advance of the exploration. The estimation of speculative resource or the lowest rank was calculated from the surface manifestation. The surface temperature and chemical composition may lead to the determination of the subsurface temperature. The SiO_2 indicates the temperature up to

250^0 Celsius or lower. Giggenbach and Fournier methods were applied to measure the characteristic represented by Na-K and Na-K-Ca-Mg.

Tabel 1. The standard classification of resources in exploration stage applied in Indonesia

General Estimate	More detailed estimate	Degree of accuracy*	Exploration data*
Resources	Speculative	Very low (< 10%)	Surface manifestation
	Hypothetic	Low (± 20%)	Geochemical exploration
Reserve	Probable	Medium low (± 40%)	Geophysical survey
	Possible	Medium high(± 60%)	Shallow drilling, heat flow
	Proven	High accuracy (> 90%)	Test drilling

* Modified by the authors based on the national standard developed by Geological Survey of Indonesia

The lowest degree of estimation accuracy is the speculative resource, whilst the most accuracy is proven reserve. The sufficient data both from the surface and underground will push the status of the accuracy from speculative to proven. The following Table 2 is the estimation of geothermal potentials in Maluku Province compiled from various sources particularly from the data provided by Directorate General of Electricity and Renewable Energy, Ministry of Energy and Mineral Resources (2004).

Indicators for the geothermal resources

The most important indication of geothermal resources is the present of surface manifestation, related to the heat. Two types of heat sources are known namely the volcano origin and the deep hot rocks origin. In Maluku Province apparently the most important indication is the volcano. The row of volcanoes along the volcanic arc of Maluku is the emminent source of heat. The question is whether such heat energy can be transferred into steam that might push the generator to produce electricity.

Some requirements are needed to accumulate the geothermal energy, namely: a) The heat source, in Maluku Province is the volcanoes; b) The stage of the volcano must be in dying phase or the volcano is old, preferably of Pliocene to Lower Pleistocene. This phenomenon is usually presented by the deeply eroded shape of the volcanic body. In many cases the cone shape has already disappear. The manifestation in the form of mofet, solfatar or fumarole; c) The volcano should have the alteration between permeable and impermeable rocks, which is usual in strato volcanoes such as those in Maluku Province. The requirement is needed to provide space for steam to accumulate; d) The healthy hydrologic system, meaning that the meteoric water should be sufficient to refill the underground water kept in the volcanic body. This particular requirement relates very much with the rate of rainfall and the vegetation.

Based on the indicators as outlined above the geothermal potential in Maluku Province is concentrated on the presence of volcanoes. The volcanoes are located along the volcanic belt of Maluku with the length of 1.600 meter and the width of around 60 kilometers. This figure demonstrates the high potentials of geothermal energy in around 96.000 kilometers square.

Unfortunately a large part of the volcanic row is submerged. However the portion above the sea water surface manifested by volcano islands are potentials for the electric development to fulfill the the needs of the inhabitants. The community type development therefore might take the benefit of the isolated small island with a small scale geothermal development. Based on the requirement pointed above, the following table shows the list of geothermal prospects in Maluku Province (Table 2).

Table 2. Geothermal potentials in Maluku Province (compiled from various references)

No	Location	Island	Estimated Electric Energy		Type of Estimation	
			Low	Optimistic	Low	Optimistic
1	Larike	Ambon	25 MW	125 MW	Hypothetic	Probable
2	Taweri	Ambon	25 MW	125 MW	Hypothetic	Probable
3	Tulehu	Ambon	100 MW	150 MW	**Proven**	**Proven**
4	Oma Haruku	Haruku	25 MW	125 MW	Speculative	Probable
5	Saparua	Saparua Island	25 MW	125 MW	Speculative	Probable
6	Nusa Laut	Nusa Laut	25 MW	125 MW	Speculative	Probable
7	Waeapo	Buru Islands	N.A.	N. A.	Speculative	Probable
8	Batabuel	Buru Island	N.A.	N.A.	Speculative	Probable
9	Lonthor	Banda Island	N.A.	N.A.	Speculative	Hypothetic
10	Rozengain	Banda Islands	N.A.	N. A.	Speculative	Hypothetic
10	Wetar Island	Wetar Island	N.A.	N.A.	Speculative	Hypothetic
11	Wetar Volcano	Off Wetar Island	N.A.	N.A.	Hypothetic	Hypothetic
12	Romang	Romang Island	N.A.	N.A.	Hypothetic	Hypothetic
13	Damer	Damar Island	N.A.	N.A.	Hypothetic	Possible
14	Wurlali	Damar Island	N.A.	N.A.	Hypothetic	Possible
15	Serawarna	Teon Island	N.A.	N.A.	Hypothetic	Probable
16	Lawarkawra	Nila Island	N.A.	N.A.	Hypothetic	Probable
17	Legatala	Serua Island	Hot spring 45^0 C	N.A.	Hypothetic	Probable

N.A. Not available, suggested to be surveyed

THE ASSESSMENT ON INDIVIDUAL POTENTIALS AND PROSPECTS

List of volcanoes and geothermal assessment in Maluku Province

The source of heat in the geothermal system of Maluku Province apparently derives from the volcano. Magma chamber radiates the heat to the body of the volcano and its surrounding. If enough ground water, the hot spring usually occurs. In absence of ground water, other manifestation such as mofet and solfatar might take place. Hot spring in Kali village in Damar Island indicates the prospect of geothermal energy in this island. Wurlali located in Damar Island is likely to be the source of heat.

The most active volcano in volcanic arc of Maluku is Banda Api. The volcanic arc therefore quite frequently named Banda Arc. In Pre-historic time Banda Api volcano erupted violently resulted in the formation of a submarine caldera (Matahelumual, 1988). The present Banda Api grows in the ancient caldera (somma) as the regeneration of Ancient Banda. The altitude of the cone is 658 meters above sea level. The real height from the sea floor might exceed 3.800 meters.

The north edge of the roe is in Ambon area consisting of volcanoes in Nusa Laut, Saparua, Haruku and Ambon. There are several centers of activities, mostly are dying. The volcanoes in these islands might have the age of Pliocene or Lower Pleistocene. The other edge of the arc is identifies by Wetar Island, supposed to be the beginning of the belt splitting the Sunda Arc into volcanic and non-volcanic arc. Kisar Island is the initial island of non volcanic. The arc is therefore young in the middle and olding to both edges. The list of volcanoes and its characteristics is presented in Table 3 and some of them are featured in Graph 4.

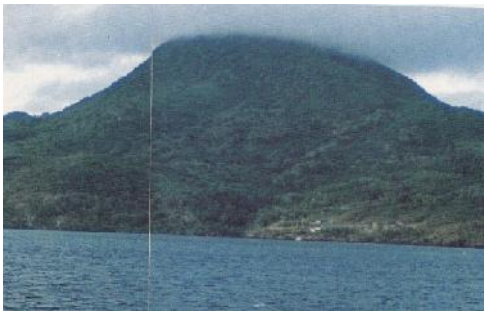
From the list of Table 3 it may come to the conclusion that some of the volcanoes show the indication of the geothermal potentials. The old volcanoes are feasible for the accumulation of geothermal potentials. However various handicaps are to be anticipated; a) The economic feasibiliity due to the low number of population; b) The area of danger in case the volcano eruption that cover almost the whole island. In the past the inhabitants experienced the total evacuation to other island; c) The isolated location.

Table 3. Name of active and ancient volcanoes and the geothermal assessment in Maluku Province*

No	Name of Volcano	Island	Characteristics	Geothermal Assessment
1	Banda Api (+641 m)	Banda	Active, mainly lava	Ancient hot spring in Rozengain, hypothetically Lonthor Island suitable for accumulation of steam, populated
2	Manuk	Manuk I	Repose period	No geothermal indication
3	Legatala (+641 m)	Serua	Inactive since 1921	Solfatar 99^0, fumarole 85^0C, hot springs in North and South Coast 45^0C
4	Lawarkawra (+781 m)	Nila	Active, dome, hot avalanche	Inactive solfatar in the coastal area, alteration zones, old volcano
5	Serawerna (+655 m)	Teon	Crater opens to the North, active	Fumarole and solfatar in the top 80^0-110^0 C. Dangerous to develop
6	Wurlali (+686 m)	Damar	Active, fumarole and solfatar, 90^0 C, sulphur was mined, two craters	Ancient crater of Damar (Damer), the location of Wurlali is suitable for geothermal potentials, hot spring in Kali village
7	Wetar Volcano (+282 m)	240 km N of Wetar Island	Solfatar, isolated, diameter 1 km, total area 0.8 km^2	Not potential for geothermal development, small, isolated
8	Old volcanoes	Wetar	Ancient volcanoes	Topographically two ancient volcanoes were identified
9	Saparua	Saparua	Ancient volcano	Prospective, Hypothetic
10	Larike	Ambon	Ancient volcano	Prospective, Hypothetic
11	Taweri	Ambon	Ancient volcano	Prospective, Hypothetic
12	Tulehu	Ambon	Ancient volcano	**Proven, retreating magma, 100 MW**
13	Oma Haruku	Haruku	Ancient volcano	Prospective, Hypothetic
14	Nusa Laut	Nusa Laut	Ancient volcano	Prospective, Hypothetic

*Compiled from various sources mainly from Geological Survey of Indonesia (1988, 1991)



Figures 4. Active volcanoes in Maluku Province. Clockwise direction: Serawarna (Teon), Wurlali (Damar Island), Lawarkarwa (Nila) and erupting Banda Api (Banda). Source: Volcanological Survey, ellijar travelhunt.wordpress.com)

In many cases the demand is economically feasible, among others the Island of Banda, where the city of Banda Neira is located. This island was the center of business in the 17 century. The luxurious government buildings and the strong forts are the evidences that me be observed to-day.

The Tulehu prospect (soon will be called Tulehu Field)

Tulehu Geothermal Prospect is the most advance electric development harvesting geothermal energy. Tulehu geothermal prospect is located about 8 kilometers NE of the Provincial capital ciity, where the electric consumption is rather high (Figure 5).

The Tulehu prospect at present has entered the development stage after a considerable time of lap since the exploration survey. The development is underway and hopefully soon the Tulehu Prospect will become Tulehu Geothermal Field. The detailed exploration study carried out by joint Japanese-Indonesian Team (Nasution et al., 2012) revealed the proven energy of 100 MW electric equivalent. This estimation was based on a comprehensive survey applying various method and finally a test well with the depth of 930 meters was drilled. The drilling gave the validation of the interpreted surface geology, geochemical thermometry, 1D-3D MT-TDEM combination, stable isotop and shallow gradient thermal drilling. Based on exploration standard the methods used in this survey has already meet the requirement to conclude the proven reserve.

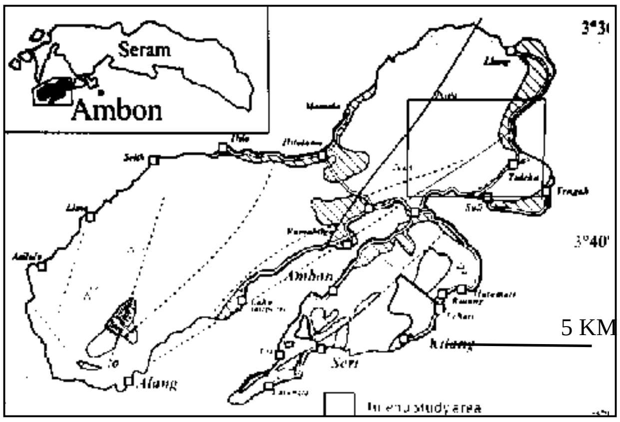


Figure 5. The location of Tulehu Geothermal Prospect denoted by quadrangle) about 8 kilometer NE of Ambon. Two other prospects in Ambon Island are Taweri and Larike about 12 Km and 16 Km NW of Ambon respoectively (Source: Nasution, et. al., 2015).

The combined data as the final interpretation of Tualehu Prospect shows the accumulation of steam at the depth of about 800 meters with the temperature of 250^0 C or high enthalpy steam reserve. The energy estimation concludes 100 MW electric equivalent. At a low estimation the exploitable energy might amount to 40 MW. The alteration of smactite-illite, chlorite clay and pyrophyllite confirms the cap rock at the depth of 800 meters. The heat source comes from the retreating intrusion most likely the oldest stage of Late Tertiary to Early Quaternary Age.

Based on the stable isotope analysis water might have come from the sea water intrusion combined with meteoric water. The surface manifestation indicating the geothermal energy was identified from the hot spring distributed along the fault lines in NE and NW direction. The model shows two intrusions, namely Tulehu and Eriwakang (Figure 6) . The Tulehu manifestation appears to be more prospective.

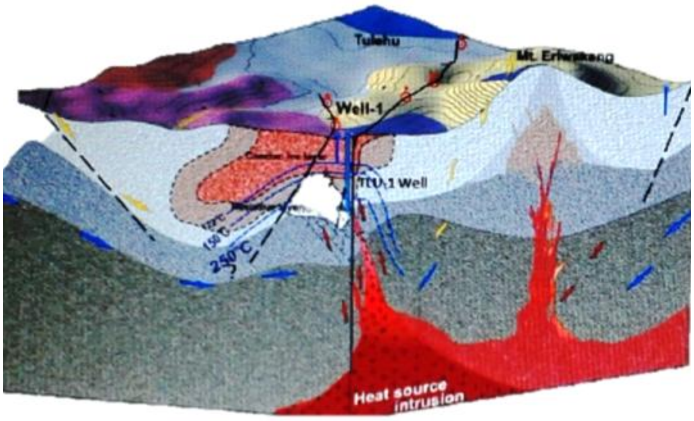


Figure 6. Geothermal model of Tulehu Prospect, showing two sources of heat and the water supply. The steam is located at the depth about 600 meters (Source: Nasution et al., 2015)

From the model of Tulehu Geothermal Prospect it appears that another heat source is present to the North East of Tulehu. This condition provides the other prospect for the future. The optimistic resources of 125 MW might increase to be dibble or about 250 MW. The conventional estimation by Japanese expert gave the figure of 40 MW at the lowest. The production of a generator unit of 30 MW therefore is quite feasible.

Due to the strategic location close to Ambon this prospect economically is viable. Furthermore the distribution grid is readily available. The demonstration effect of the successful Tulehu prospect might trigger the development of other geothermal potentials in Ambon Iowland, namely Taweri and Larike. Optimistic estimate shows respectively the potentials of 125 MW with minimum of 25 MW.

The geothermal resources in Ambon Island in total amount to around 500 MW. The supply is far above the present demand. The available electricity might trigger various kind of marine and agro industries. Taking into account the short distance from the giant copper mining in Papua, it is expected that the company will be interested to build the smelter in Ambon. The marine facilities in Ambon island has long been ideal for sea transportation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The exponential demands of electricity in Maluku Province is immense with annual increase of 7.1% as the result of economic growth of 2.9% and the population rate of 2.4; To overcome the electricity demands, there are a variety of energy resources in Maluku Province, namely hydropower in Seram and Buru, Ocean Thermal Energy Conversion (OTEC) provided by the sea water, wind, solar and geothermal energy; Geothermal energy seems to be most feasible due to a large number of old and young volcanoes that provide heat for the generation of steam to produce electricity; The potentials of about 225 MW have already been estimated, 100 MW of which is categorized proven in Tulehu prospect and hopefully will soon produce the first stage of electricity; The volcanic belt of Nusa Laut, Saparua, Haruku and Ambon harbors ancient volcanoes with the geothermal prospects in 6 locations which is very strategically located around the Provincial capital city of Ambon; The other island with old and young volcano might also produce the geothermal energy based on the preliminary observation on the presence of hot springs such as that in Damar Island; The dispersed location of the geothermal potentials is the advantage for the Islands Province in minimizing the distribution grid.

Recommendations

The government should provide the incentive for development of geothermal energy in the Islands Province, taking into account the negative economic feasibility due to the limited number of population and thus the demands; The incentive might be in the form of exploration and feasibility study which will reduce the risk in the geothermal development. Hopefully the scheme will draw the interest of investors;

ACKNOWLEDGMENT

The authors wish to express their gratitude to the Provincial Government of Maluku for the Cooperation between the Government and Padjadjaran University. The cooperation resulted in the assignment of the students to further their knowledge in Faculty of Geological Engineering in the anticipation of the Masela Gas Project to build in Maluku. The authors are also grateful to the Maluku Corner of Padjadjaran University, for the opportunity to present this review paper in the Workshop. Finally the acknowledgment goes to the Rector of Padjadjaran University for the provision of funding under ALG Program for the preparation of this review paper as part of the comparative study on the Islands Province which is the research object of the ALG in Riau Province.

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