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Potency of Non Volcanic Hosted Geothermal Resources in Sulawesi-Indonesia

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ABSTRACT

Indonesia is blessed with abundant geothermal resources (27.7 GWe) that allow the country to lead the world with the the largest geothermal energy potential. About 96% (26.5 GWe) of the total Indonesian geothermal potencial is derived from a volcanic environment, while 4% (1.2 GWe) came from non volcanic environment., such as in Bangka, Kalimantan, Sulawesi (except N.Sulawesi and Gorontalo), and Irianjaya. Sulawesi has 46 promising locations in its geothermal field with a geothermal energy potential of 2134 MWe, unfortunately none of them have been developed as a geothermal power supply. Over the course of five years, the Geological Agency of Indonesia did an integrated study (geology, geochemistry and geophysical) in several areas of non volcanic geothermal propects in Sulawesi, such as Merana, Pulu-Pakuli, Parara, Masepe and Mangolo. We concluded that the geothermal systems in the area are anticipated to merge from varieties of tectonic phenomena such intrusive rocks (plutonics? and or concealed volcanic intrusive body?), which is associated with the NW-SE trending fault (Palu-Koro). The surface temperature varies from 40 – 90^{o}C while the sub surface temperature ranges from 136 – 225^{o}C. The potential of each non volcanic geothermal prospect is relatively small (10 – 80 MWe) compared to volcanic ones (up to 600 MWe), so small scale geothermal plants using binary system are considered more suitble for developing a non volcanic hosted geothermal prospect in Sulawesi Indonesia.

1. INTRODUCTION

Geologically, Indonesian Archipelago lies at the intersection of the Eurasian, Indian-Australian and Pacific plates. This tectonic conditon leads to magmatic and volcanic processes to form a volcanic belt stretching from Sumatra, in the west, to Maluku, in the east of Indonesia. In the beginning of 2009, about 258 geothermal area has ben inventoried by Geological Agency-Center for Geological Resources of Indonesia, inwhich 80% (or 203 locations) occured in volcanic environment and 20% (or 55 areas) is associated to non volcanic zone, such as Sulawesi, 50 areas (central, south and south-east Sulawesi), Kalimantan and Irian Jaya, 3 and 2 locations, respectively, (Figure 1). This paper is an overview of the distribution and the potency of non-volcanic geothermal resources in Sulawesi, after five years of investigation and to support government plan such to stable power supply and to develop rural electrification program, especially in Eastern part of Indonesia for expansion of the infrastructure to promote the development of remote islands.

2. CLASSIFICATION OF GEOTHERMAL ENERGY POTENTIAL

The classification of geothermal energy potential in Indonesia has been established based on the level of confidence as a result of integrated scientific survey works (surface and subsurface) and economical-technological considerations. The two general categories are defined as Resource and Reserve that are further subdivided as shown bellow, (BSN, 1999), see also Table 1.

1. Resource (Reconnaissance Resource) consists of two classes, i.e.:
   - Speculative Resource
   - Hypothetical Resource
2. Reserve (Identified Resource) consists of three classes, i.e.:
   - Possible Reserve
   - Probable Reserve
   - Proven Reserve

Table 1: The relationship between potential classification and investigation stage.

Classification	Investigation Stage
Speculative resource	Preliminary investigation
Hypothetical resource	Advance preliminary investigation
Possuble reserves	Detailed investigation
Probable reserves	Expl. Drilling and pre-feasibility studt
Proven reserves	Deliniation drilling, reservoir simulation and Feasibility study

3. GEOTHERMAL POTENCIAL IN SULAWESI

Geologically, Sulawesi that is located at the western end of active pacific plates, lies at the collosion zone of the Eurasian, Indian-Australian and Pacific plates. Tectonically Sulawesi is divided into 2 tectonic belts, namely west and east tectonic belts. West tectonic belt consists of south and North arms and Central part of Sulawesi., whilst the East tectonic belt consist of South East and East arms (Figure 2). This tectonic condition leads to magmatic and volcanic processes to form non volcanic hosted geothermal areas and volcanic geothermal fields (north arm) in Sulawesi.

Geothermal energy potencials in Sulawesi is mostly in resources statues. North arm of Sulawesi that is located in Quaternary volcanic belt has larger geothermal potential compare to the other arms. However, these arms have more geothermal areas, for example central part has 15 areas, (Figure 3), south and south east arms have 17 and 13 areas, respectively, (Figure 4 and 5). Unfortunately the total resources is relatively small (1299 MWe) compare to the north arm (875 MWe) or in the other word 41% of total geothermal resources in Sulawesi is located in the North arm (Quarternary volcanic belt) of Sulawesi. Tabel 2 show the distribution and potency of geothermal resources in Sulawesi (except north arm of Sulawesi).

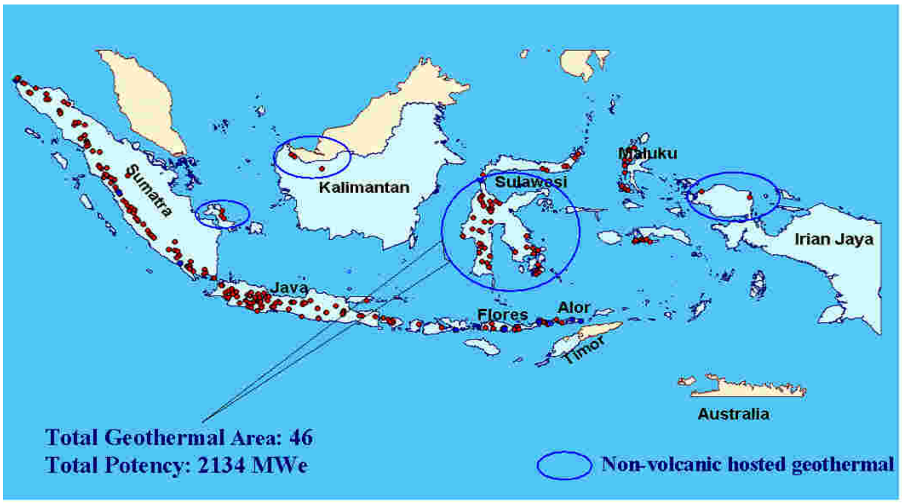

Figure 1: Potency of Non-volcanic Geothermal area in Sulawesi.

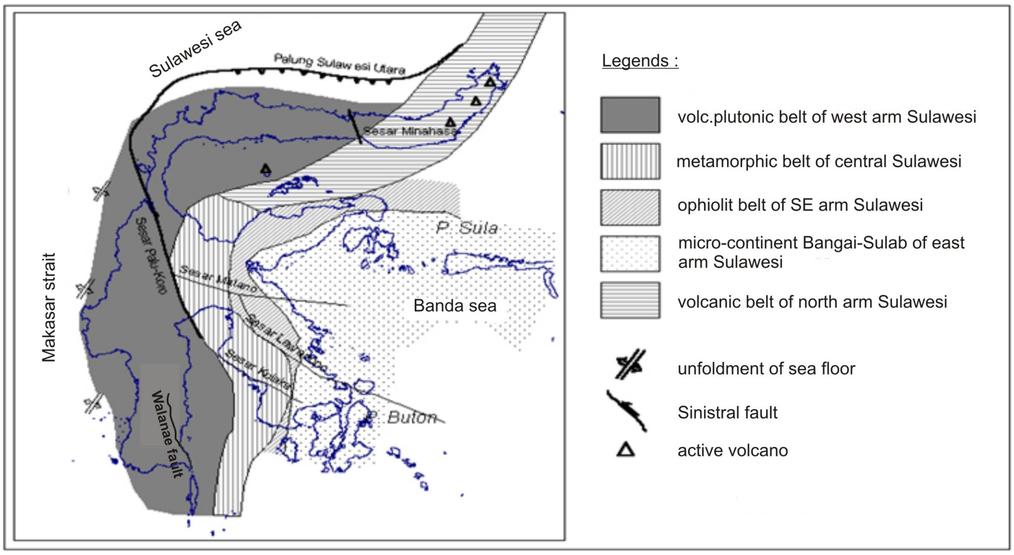

Figure 2: Tectonic map and regional structure of Sulawesi (Hamilton, 1979, 1989; Katili 1978, 1989; Bagja, M., 1995).

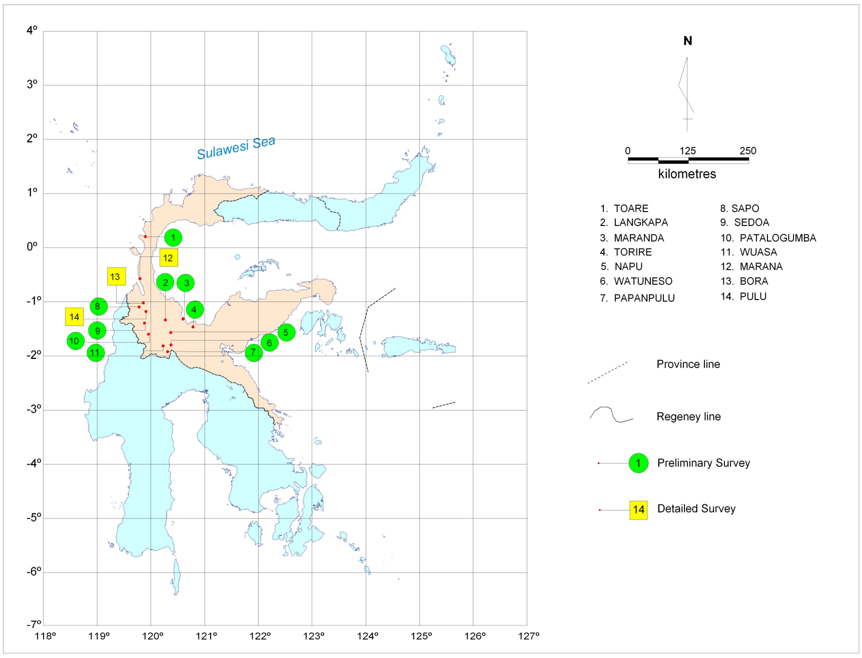

Figure 3: Geothermal area in central part of Sulawesi (modified from PMG).

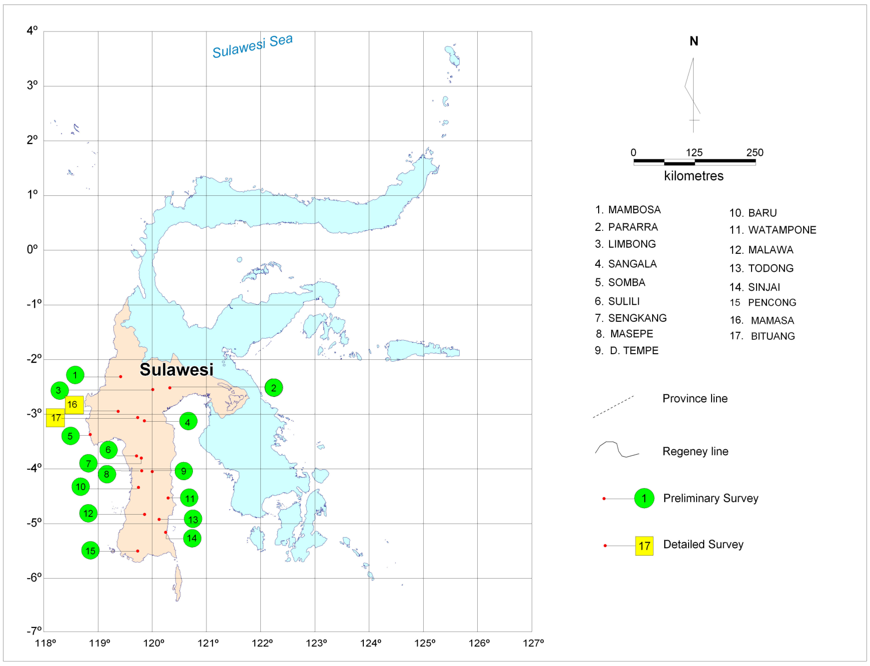

Figure 4: Geothermal area in south arm of Sulawesi (modified from PMG).

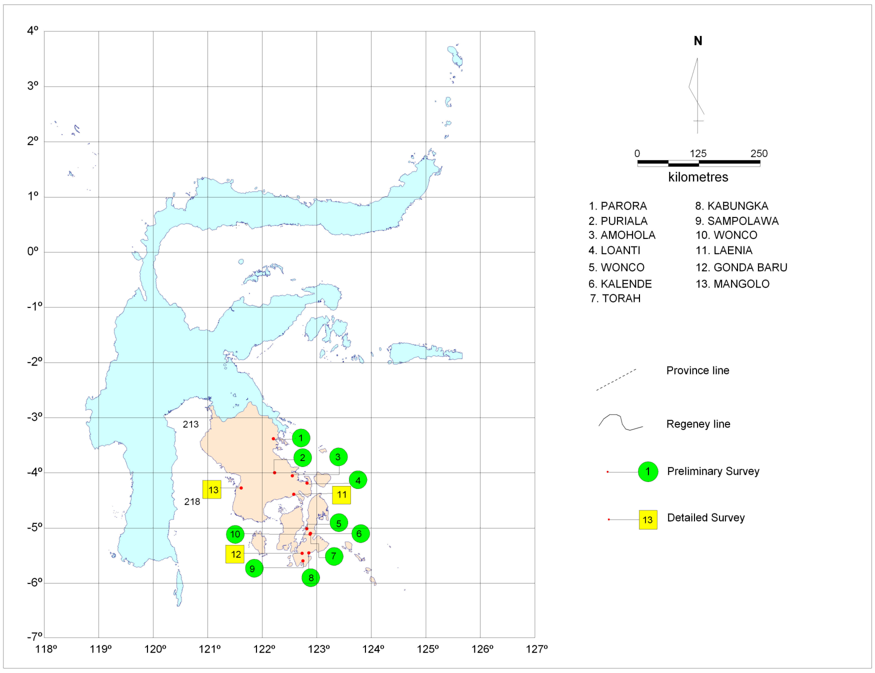

Figure 5: Geothermal area in SE arm of Sulawesi (modified from PMG).

4. SUMMARY OF 5 YEARS GEOTHERMAL INTEGRATED SURVEY IN SULAWESI

During the past 5 years, Indonesian Geological Agency-Centre for Geological Resources has carried out integrated geothermal studies (geology, geochemical and geophysical) in several areas of Sulawesi, such as Merana, and Pulu-Pakuli, (Central Sulawesi); Parara and Maseppe (South arm of Sulawesi), and Mangolo in SE arm of Sulawesi. Below we summarized the result of an integrated survey in several prospect areas.

4.1 Merana Geothermal Prospect

The survey area is situated in Marana area, Donggala regency-Central Sulawesi. The thermal feature is hot waters with temperature range between 50 and 94^{o}C, (Figure 6). The hot waters belong to a bicarbonate water type. Morphological units of the area can be divided into high to low undulating hills and alluvial plain morphology with a height range of 200 up to 1500 meters above sea level.

The rock units of Marana geothermal area consists of Green schist rocks unit (TrS), Gneiss granite rock unit (Trg), Granite rock unit (Tg), Sedimentary rock unit (QTs), Limestone rock unit (Qgp) and Alluvium (Qal). The manifestation is controlled by the NE-SW trending Masaingi fault. The geophysical data indicate the geothermal system is covered by low to medium resistivity zones indicating hot fluid reservoirs located at deep narrow zones along fault zones. The subsurface geothermal temperatures are estimated between 154°C to 237°C. The total prospect area is about 6 km^2, and the estimated geothermal potential is about 40 MW.

4.2 Pulu-Pakuli Geothermal Prospect

Pulu-Pakuli prospect lies in Pulu-Pakuli village of Donggala regency, Central Sulawesi. The thermal feature is hot water with temperatures between 80 and 90°C (Figure 7), normal pH and of the bicarbonate type. The area is composed of green schist (Trs), granite geneis (Trgn), phiylite (Km), granite (Tgr), collovium (Qcl) and alluvium deposits (Qa). The surface manifestation is controlled by NE-SW Pulu and Pakuli faults. Low resistivity value of <25 Ωm and high Hg anomaly occurred in the west Pakuli hot water with the total prospect area of 4.6 km^2. The subsurface geothermal temperatures (SiO_2, Conductive cooling) are estimated between 124°C to 180°C. The estimated geothermal potential is about 40 MWe.

Figure 6: Hot water geothermal manifestation in Merana, found in sedimentary rocks.

4.3 Parara Prospect

Parara prospect lies in Sabbang district, Regency of North Luwu, South Sulawesi. Like the other areas the thermal feature is hot water with the surface temperature varies between 40.5 – 96.5°C, pH normal, and chloride-bicarbonate type. Subsurface temperature ranges vary between 103.28 – 125.91°C and as such is classified as intermediate enthalpy. Stratigraphically, the area is covered by metamorphic rocks (phyllite, schist and gneiss), intrusive rock (granite, granodiorite) and alluvium. The area lies relatively closed to Palu-Koro fault that trending NW-SE, the structure is considered control the Parara hot water. The total prospect area is about 5 km^2, and the estimated geothermal potential is 8 – 21 MWe.

4.4 Maseppe Prospect

Maseppe prospect area is located in Sidendreng-Rappang Regency, South Sulawesi. Stratigraphically the area is composed by sedimentary rocks of Walanae Formation (Tms), consists of sandstone, clay stone, and limestone; volcanic rocks of Tertiary-Quaternary age, (lava and pyroclastic); lava dome of Plio-Plestocen age; lake deposit and alluvium, (Qal). Geothermal manifestations consist of hot water, travertine, and altered rocks. The manifestations are controlled by Alakuang and Maseppe faults that are trending relatively N-S. Surface temperature of hot water is 68°C, pH normal, and the hot water belongs to chloride-bicarbonate type. The sub surface geothermal temperature in average is 198°C, (SiO2 Conductive cooling). Heat source is considered to be intrusive rocks that are associated with lava dome. The total prospective area is about 10 km^2, and the estimated geothermal potential is 80 MWe.

(a)

(b)

Figure 7: Pulu (a) -Pakuli (b) hot waters.

4.5 Mangolo Prospect

The prospect area lies in Kolaka regency, SE Sulawesi. The area is predominantly covered by metamorphic rocks such as (young-old) gneiss, schist, lime stone and alluvium. Geological structures evolved into a progressively metamorphic sequence is characterized by structure segment lineament, which influenced by the growth of Palu – Mekongga tectonic belts that related to Verbeek and Moliowo Mountain developments in the southeastern arm of Sulawesi Island.

Thermal surface manifestations in the Mangolo area are of hot springs (Figure 8), travertine and gas bubbles that occur along Besar River through fissures in metamorphic limestone and voids on river terraces. The temperature varies between 40 – 50 °C, pH normal, and bicarbonate type. The sub surface temperature is about 170°C (Na – K – Ca).

5. CONCLUSION

All prospective areas that lie relatively close to Palu-Koro fault (except for S.E Sulawesi prospect) show hot water as geothermal manifestation, and the temperature range varies between 40 – 90°C. The hot water has neutral pH and chloride-bicarbonate water type. In general, the survey result indicates that the geothermal system in the area seems to merge from varieties of tectonic phenomena such as intrusive rocks (plutonics and or concealed volcanic intrusive body?), which are associated with a NW-SE trending fault (Palu-Koro). The sub surface temperatures range from 136 – 225°C. The potential of each non-volcanic hosted geothermal prospect is relatively small, less than 100 MWe, so small scale geothermal plants using binary systems are considered more suitable for developing of non volcanic hosted geothermal prospects in Sulawesi Indonesia, in order to support the government plan for expansion of the infrastructures and to promote the development of remote islands.

Figure 8a: Hot water in Goa-Mangolo.

Figure 8b: Hot water in Bumi-Perkemahan-Mangolo.

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Table 2: The distribution and potency of geothermal resources in Sulawesi, (modified from PMG).

No	Field name	Regency	Coordinate		T.surface. (^{0}C)	T. Geot/ T.Res. (^{0}C)	area Km^2	Thick. Reserv (Km)	Potency (MWe)					Installed Capacity	Expl.statue/Not
									Resource (MWe)		Reserve (MWe)				
			Long	Lat					Specul.	Hipotetis	Possible	Probable	Proven		
1	MARAN DA	Poso	120.6050	-1.3209	40-110	-	5	-	25	-	-	-	-	-	GL
2	SAPO	Donggala	119.8590	-1.2425	51	-	5	-	25	-	-	-	-	-	GL
3	LANGKAPA	Poso	120.2770	-1.3386	52	-	5	-	25	-	-	-	-	-	GL
4	NAPU	Poso	120.2660	-1.3760	55	-	5	-	25	-	-	-	-	-	GL
5	TORIRE	Poso	120.1960	-1.6625	38	-	5	-	25	-	-	-	-	-	GL
6	TOARE	Donggala	120.8020	-1.4475	44	-	5	-	25	-	-	-	-	-	GL
7	PATALOGUMBA	Donggala	119.8980	0.2052	52	-	5	-	25	-	-	-	-	-	GL
8	MARAWA	Donggala	119.8460	-0.1218	-	-	5	-	25	-	-	-	-	-	GL,GK,GF, PMG
9	BORA	Donggala	119.8660	-1.0227	81	225	1.2	1	-	-	8	-	-	-	GL,GK,GF, PLN
10	PULU	Donggala	119.8610	-1.0650	75	-	5	-	-	-	58	-	-	-	GL,GF,GK
11	SEDOA	Donggala	119.8890	-1.3982	38	-	5	-	25	-	-	-	-	-	GL,GK,GF, PMG
12	WUASA	Poso	120.2480	-1.4422	-	-	5	-	25	-	-	-	-	-	GL
13	WATUNESO	Poso	120.3960	-1.7996	-	-	5	-	25	-	-	-	-	-	GL
14	PAPANPULU	Poso	120.4020	-1.5802	34.5	-	5	-	25	-	-	-	-	-	GL
15	TAMBU	Donggala													GL,GK,GF, PMG
Total Geothermal Potency of Central Sulawesi = 366 MWe									**300**		**66**				
No	Field name	Regency	Coordinate		T.surface. (^{0}C)	T. Geot/ T.Res. (^{0}C)	area Km^2	Thick. Reserv (Km)	Potency (MWe)					Installed Capacity	Expl.statue/Not
									Resource (MWe)		Reserve (MWe)				
			Long	Lat					Speculativ	Hipotetis	Possible	Probable	Proven		
16	L U W U	Luwu Utara	120.0170	-2.5507	83-96.5	119	5	-	25	-	-	-	-	-	GL,GK,GF-PMG
17	PARARA	Luwu Utara	120.3300	-2.5176	40-80	103-126	5	1	-	-	30	-	-	-	GL,GK,GF-PMG
18	MAMBOSA	Mamuju	119.4240	-2.3142	40	-	5	-	25	-	-	-	-	-	GL
19	SOMBA	Majene	118.8650	-3.3737	40	71	5	-	25	-	-	-	-	-	GL
20	MAMASA	olewali Mamas	119.3770	-2.9481	42-57	124	4	1	-	-	2	-	-	-	GL,GK,GF
21	BITUANG	Tanatoraja	119.7370	-3.0616	96-98	136 - 175	10	1	-	-	17	-	-	-	GL,GK,GF, Pertamina
22	SANGALA	Tanatoraja	119.8610	-3.1231	37	-	5	-	25	-	-	-	-	-	GL
23	SENGKANG	ndereng Rappa	119.8040	-3.8044	37	70	5	-	25	-	-	-	-	-	GL
24	SULILI	Pinrang	119.7190	-3.7653	56	112	5	-	25	-	-	-	-	-	GL
25	MALAWA	Pangkajene	119.8640	-4.8322	-	112	5	-	25	-	-	-	-	-	GL
26	BARU	Baru	119.7520	-4.3400	30-38	70	5	-	25	-	-	-	-	-	GL
27	WATAMPONE	Bone	120.3010	-4.5326	56	61	5	-	25	-	-	-	-	-	GL
28	TODONG	Bone	120.1350	-4.9252	56	83	5	-	25	-	-	-	-	-	GL
29	SINJAI	Sinjai	120.2540	-5.1616	42-66	-	5	-	25	-	-	-	-	-	GL,GK,GF-PMG
30	MASEPE	ndereng Rappa	119.8120	-4.0342	65-70	116	5	-	25	-	-	-	-	-	GL
31	D. TEMPE	Wajo	120.0070	-4.0501	37-47	100	5	-	25	-	-	-	-	-	GL
32	PENCONG	Gowa													-
33	BANGKOA	Gowa													-
Total Geothermal Potency of Soth Sulawesin = 374 MWe									**325**		**49**				
No	Field name	Regency	Coordinate		T.surface. (^{0}C)	T. Geot/ T.Res. (^{0}C)	area Km^2	Thick. Reserv (Km)	Potency (MWe)					Installed Capacity	Expl.statue/Not
									Resource (MWe)		Reserve (MWe)				
			Long	Lat					Speculativ	Hipotetis	Possible	Probable	Proven		
34	MANGOLO	Kolaka	121.6190	-4.2767	46-64	175	5	-	-	-	14	-	-	-	GL,GK,GF
35	PARORA	Kendari	122.2090	-3.3840	-	-	5	-	25	-	-	-	-	-	GL
36	PURIALA	Kendari	122.2340	-4.0006	45	-	5	-	25	-	-	-	-	-	GL
37	AMOHOLA	Kendari	122.5590	-4.0550	47	-	5	-	25	-	-	-	-	-	GL
38	LOANTI	Kendari	122.8250	-4.1864	40-50	-	5	-	25	-	-	-	-	-	GL
39	LAENIA	Kendari	122.5830	-4.3919	60-95	250	6	1	-	-	36	-	-	-	GL,GK,GF / PLN
40	TORAH	Buton	122.8910	-5.0986	41	-	5	-	25	-	-	-	-	-	GL
41	KALENDE	Buton	122.8910	-5.0986	49	-	5	-	25	-	-	-	-	-	GL
42	KANALE	Buton	122.8840	-5.1118	65-67	-	5	-	25	-	-	-	-	-	GL
43	WONCO	Buton	122.9070	-4.9837	49	-	5	-	25	-	-	-	-	-	GL
44	GONDA BARU	Buton	122.7350	-5.4589	33-36	98	5	1	-	-	1	-	-	-	GL, GK, GF
45	ABUNGKA - WENIN	Buton	122.8590	-5.4533	38-40	-	5	-	25	-	-	-	-	-	GL
46	KAONGKE ONGKEA	Buton	122.7420	-5.4747	37	-	5	-	25	-	-	-	-	-	GL
Total Geothermal Potency of SE Sulawesi = 301 MWe									**250**		**51**				