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Geochemical Re-Assessment of Mt. Balut Geothermal Prospect, Sarangani, Davao Del Sur: An Update

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ABSTRACT

Surface exploration surveys were conducted in Balut Island geothermal prospect in 2013 as part of the Department of Energy (DoE) project "Detailed Assessment of Selected Low Enthalpy Geothermal Areas in the Philippines". The primary objective of the abovementioned project is to accelerate the development of low to medium enthalpy geothermal resource areas (90^0C to 150^0C) in the Philippines mainly for power generation. Secondary project objectives included: (1) the assessment and realization of the economic feasibility of small scale geothermal power projects for local power needs, and (2) the preparation of a comprehensive data package that will showcase this type of geothermal resource for future private investor participation.

Hot springs and hydrothermally-altered grounds are found in four barangays located on the west and northwest apron of the Balut island volcano namely, Lipol, Gomtago, Tinina and Batuganding. The hot springs have discharge temperatures ranging from 38-75^0C. The waters from Barangay Lipol are the hottest and the most acidic with field pH of 2. Those from Barangays Tinina and Batuganding are warm with neutral to near neutral pH. The chloride levels of the waters are low, ranging from 123-279 ppm; HCO_3 range from nil to 606 ppm while sulfate levels range from 26-564 ppm. The higher temperature waters have higher chloride and sulfate levels than the warm waters which are bicarbonate rich. The large altered region of Tacol Solfatara, named after the Tacol Collapse Structure in Barangay Gomtago, is characterized by a very dry, hot, gassy, and intensely altered ground.

All thermal springs have high Cl and SO_4 content although the previous and present report has not found a representative hot spring of reservoir fluids. Tolentino, et. al. (2014a) further investigated to explain the source of high temperature, Cl and acidity of the thermal springs by cross-plotting the SO_4 vs. pH and Cl vs. Mg. In the report, it is confirmed that an increase in temperature shows an increase in SO_4 content and pH. The positive correlation indicates that the springs are actually steam heated. The result of the Cl vs Mg on the other hand shows that the spring waters are a product of mixing and dilution of seawater and groundwater, thus are all shallow in origin. To explain the source of high temperature, it is then inferred the existence of a gas cap underneath that supplies heat and H_2S to the thermal springs. Reservoir temperature on the other hand is estimated to range from 175-200^0C based on gas geothermometry.

1. INTRODUCTION

The Philippines-Department of Energy conducted follow up reconnaissance geochemical surveys of the thermal areas in Balut Island, Saranggani Province of Davao del Sur, in line with the locally funded project "Detailed Assessment of the Selected Low Enthalpy Geothermal Resources in the Philippines".

The Balut Island was initially surveyed in by Balmes (1998 and 2000) as part of the locally funded project entitled "National Inventory of Geothermal Resources of the Philippines" wherein patches of altered ground, hot and warm springs occurring in brgys. Lipol, Bato Ganding and Tinina were noted. Another survey was conducted by Del Rosario et al (2012), and was able to confirm the said sites and an additional three (3) springs, which were not reported in the previous survey, were sampled.

2. LOCATION AND ACCESSIBILITY

Balut Island is located about 14 km off the southern coast of Batulaki Peninsula in the southern tip of Mindanao Island across Sarangani Strait. It is part of the 5^{th} class municipality of Sarangani in Davao del Sur Province. Covering an approximate area of six thousand eight hundred one (6,801) hectares, the island rises to about 1,800 m (5,900 ft) from the seabed with the highest elevation of 863 m (2,831 ft) above sea level occupied by Balut Volcano, also known as Sanguil. The base diameter of the volcano is about 8 km. It is the westernmost island of the Sarangani Island group and is larger, higher, and better cultivated than Sarangani Island.

The island can be reached from Manila by commercial flights to General Santos City in Sarangani Province and thence by direct commercial ferryboat.

Sea travel normally takes about 6 hours depending on the cargo load of the boat and sea condition. Travel time period is from midnight to dawn to accommodate goods and merchandise coming from either ports of origin. There are also outrigger pumpboats that are available for hire either at General Santos City or Glan, Sarangani. The town of Glan can be reached by public land transport from General Santos City in about 2 hours. Another possible access route is to travel further by land from General Santos City thru Glan to the southern tip of Davao del Sur (i.e. Batulaki Peninsula) and then hire a pumpboat for about an hour journey to the island across Sarangani Strait. The island has a very a poor road network and access to different places is normally by hiking and horseback or motorbike riding along tracks and trails.

Figure 1

The climate on the island is generally characterized by even rainfall distribution throughout the year. Tropical cyclone, normally spawned in the West Pacific, seldom passes in this part of Mindanao. There are, however, erratic weather disturbances occasionally experienced in the area brought by the inter-tropical convergence zone (ITCZ) over the region. Vegetation is dominated by coconut trees with secondary patches of other trees, shrubs, and vines. Industry is dominated by harvesting coconuts for copra production. Copra products are regularly shipped to General Santos City for oil processing. The fishing industry is not well developed due to the absence of ice-making and refrigeration facilities in the island brought about by scarcity of power supply.

3. PREVIOUS STUDIES

The reported earliest survey work in Balut Island was done by a field investigation team of PHIVOLCS (Sabit et al, 1995). This was in response to a request of the Disaster Coordinating Council of Region 12 (RDCC XII) filed on February 14, 1995 to investigate the reported increase in streaming and lava emission from the crater of Balut Volcano. The survey activities consisted of: (a) reconnaissance field investigations, (b) seismic observations, and (c) collection of rock and water samples.

The field study revealed no indication of any volcanic unrest. Sulfur vents in highly altered grounds were observed at the upper western slope of Balut Volcano which is the reported center of activity. Recorded temperatures range from 95-96^{0}C. A kilometer southwest of this location but situated at a lower elevation is a hot spring named Palabuno Hot Spring. It has a temperature of 42^{0}C, a neutral pH, conductivity of -49 mv, and flowrate of about 0.5 liters per second. At the south-southwest basal slope of Balut Volcano in Sitio Cayupi, Barangay Lipol, a small thermally altered ground hosts a small vent that emits steam and sulfur gas. The temperature at the opening of the vent was 95.5^{0}C. On January 17, 1996, PHIVOLCS sent again a Quick Response Team (QRT) to address a request from Davao del Sur Gov. Rogelio Llanos thru the regional Office of Civil Defense (OCD, Region 11) to investigate alleged explosions and subsequent crater formation at the southwestern seashore of Balut Island in Barangay Tagen, Sarangani town (Catane et al, 1996). The residents claimed that an explosion pit as large as an oil drum formed in the inter-tidal zone due to successive explosions on 4, 7 and 8 January 1996. This was verified by the team and found the phenomenon was not due to renewed magmatic activity. About 30 meters away to the northwest of the alleged explosion pit were small and weak bubbling and steaming vents known to the locals as Dapulan thermal area. The steaming and bubbling activities however cease during periods of high tide as the rising seawater drowns the thermal activity. Measurements taken in the mud pit show a temperature of 82.5^{0}C with a pH of 7.4.

In 1997, the DOE-Geothermal Division conducted a reconnaissance geological and geochemical survey under its project “National Inventory of Geothermal Resources”. The surveys were undertaken in the thermal areas found in Barangays Lipol, Batuganding and Tinina. The work done was the subject of the internal geological and geochemical reports written by Malapitan (1997) and Balmes (1998), respectively. The geochemical work was also the subject of Balmes’ paper that was presented during the World Geothermal Congress (WGC) in 2000 in Kyushu-Tohoku, Japan. Rock samples were collected for petrographic analysis and sampling of thermal and non-thermal waters was done to characterize the chemistry of the source of the hot spring waters. Gas sampling activity was not undertaken. Successive follow up works were completed by the DOE-Geothermal Division in 2011 and 2012.

In August 2011, the Geothermal Energy Management Division (GEMD) and the Geoscientific Research and Fuel Testing Laboratory Division (GRFTLD) of the DOE conducted initial socioeconomic survey and reconnaissance geochemical survey of the different thermal areas. The surveys were conducted in line with the objectives of the locally funded project, "Detailed Assessment of Selected Low Enthalpy Geothermal Areas in the Philippines". In conjunction with this, standard courtesy calls were made to the municipal and barangay officials to introduce the project and its objectives. The specific technical objective of the survey is to confirm the 1997 findings. In addition to the hot and warm springs located in the three (3) barangays that were reported and sampled in the 1997 survey, the team was able to investigate and sample additional three (3) new hot springs from different locations in the same barangays. Another possible hot spring in Barangay Lipol, which according to barangay officials is boiling and bubbling loudly, was not sampled by the team due to time constraint. An altered ground in Sitio Pandaring, Barangay Tinina was also investigated and sampled.

The 1997 and 2011 surveys revealed that some thermal manifestations such as solfatara and hot springs are qualified for gas sampling in their next survey campaign. The same divisions of the DOE undertook a follow-up survey on the island in July 2012. Additional water and gas samples were collected from the thermal areas that include the reported solfataras and hot springs found in four (4) barangays namely, Lipol, Konel, Gomtago and Tagen. The reported sub-tidal hot spring in Barangay Tagen however was not sampled due to bad weather condition brought by Typhoon Gener. The previously documented hot spring in Barangay Lipol was also visited and sampled for gas analysis. Gas samples were also taken from the solfataras along the northwest slope of Mt. Balut. Although there are no visible gas vents in the solfatara site, a closer inspection of the intensely altered ground showed sulfur crystallization where steaming activity is considered minimal. A total of 3 gas samples from 2 sampling sites were collected. The team also sampled a cold spring in Barangay Konel for baseline values. The results of the gas analyses done on the three samples, however, did not show up in the reports that detailed these new findings.

To resolve some of the inconsistencies in the results gathered from all the previous studies, DOE recommended undertaking a more comprehensive program to document all known and still unreported thermal features on the island. The proposed works include: (1) remote sensing to determine the faults, lineaments and structural features in the island; (2) semidetailed to detailed geological mapping to identify faults, determine the extent of lithological units, alteration zones, and to understand the volcanic history of Balut Island; (3) thorough documentation of all thermal manifestations and additional geochemical sampling for water and gas chemistry and isotopic study; and (4) deeper probing by geophysical survey to obtain a better understanding of the depth and extent of the anticipated geothermal resource. A volcanic geohazard assessment to evaluate the risk to further exploration and development in the area was also proposed by the workers.

4. GEOCHEMISTRY

According to Baltasar, et al (2013), there is an impressive array of thermal features in Balut Island prospect found in the northwest, south and east sides of the island (Figure 2). These manifestations range from solfataras in Gumtago, to acidic hot springs at Cayupi and Tambulos, to warm neutral-pH springs. The acidic springs are devoid of HCO_3, and are either high in Cl (Cayupi at 4,200ppm based on 2012 chemistry, and disregarding 2013 chemistry analysis) or mixed SO_4-Cl waters (Tambulos) (Figure 3). Although the warm springs are HCO_3-dominant, there is significant Cl content of 100-600ppm and SO_4 of 20-80ppm. Clearly there is a Cl source for the thermal springs in Balut prospect.

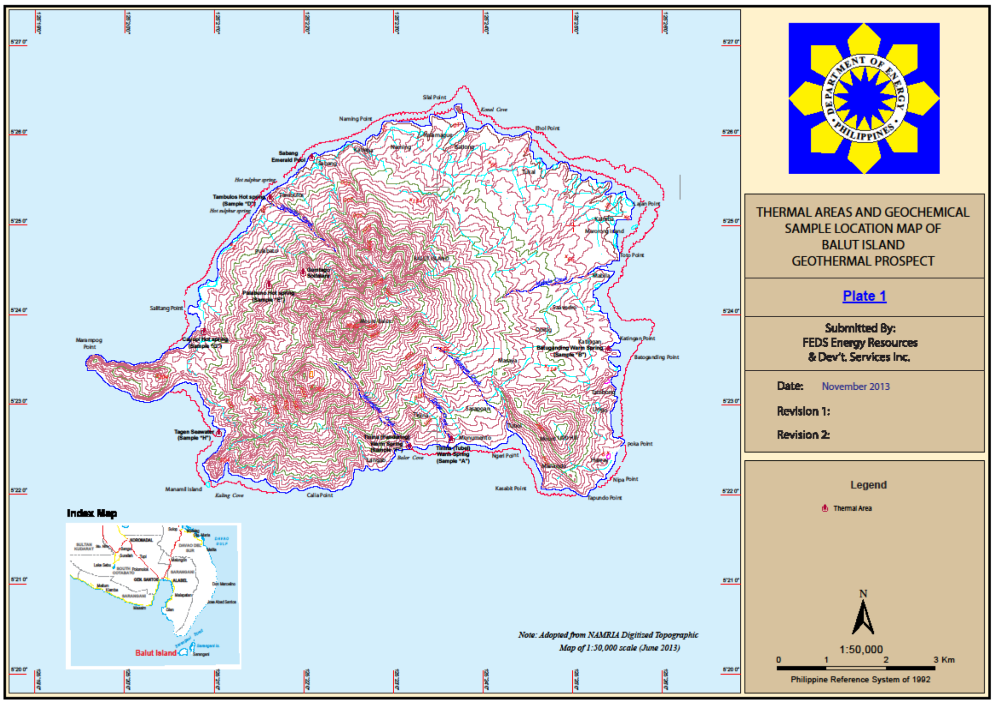

Figure 2. Thermal area location map, Balut prospect

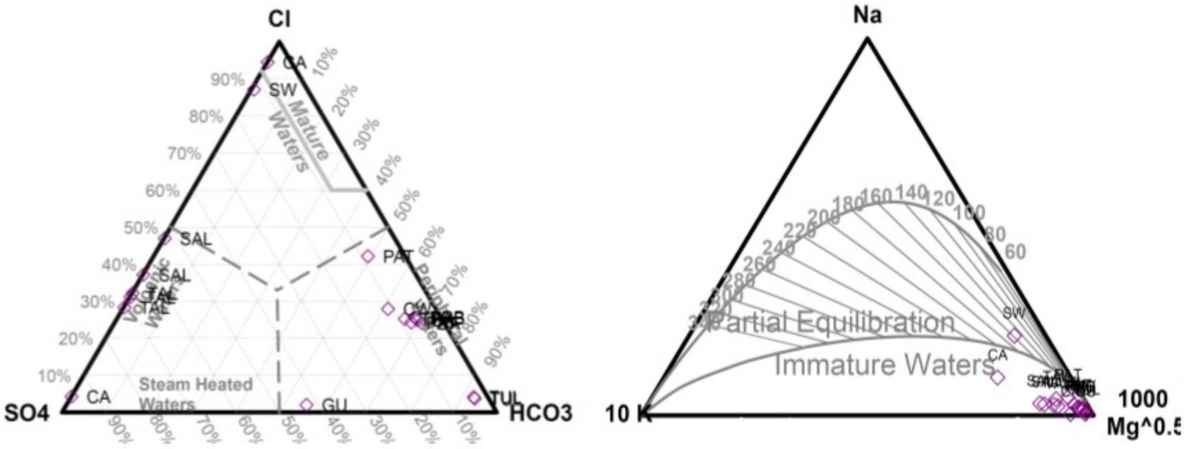

Figure 3

4.1 The role of SO_4

SO_4 appears to be a critical component of the thermal springs in the Balut prospect, providing insights on processes within the hydrothermal system. Figure 4 shows that spring temperature increases with increasing SO_4 content in the water (see dashed arrow; disregarding the seawater cluster at upper left corner). The positive correlation between SO_4 and temperature indicate that the springs are actually "steam-heated" waters. Steam heating is not so obvious because the waters are not purely meteoric in origin (i.e., low Cl, low Mg, others indicative of shallow groundwater), but are significantly mineralized.

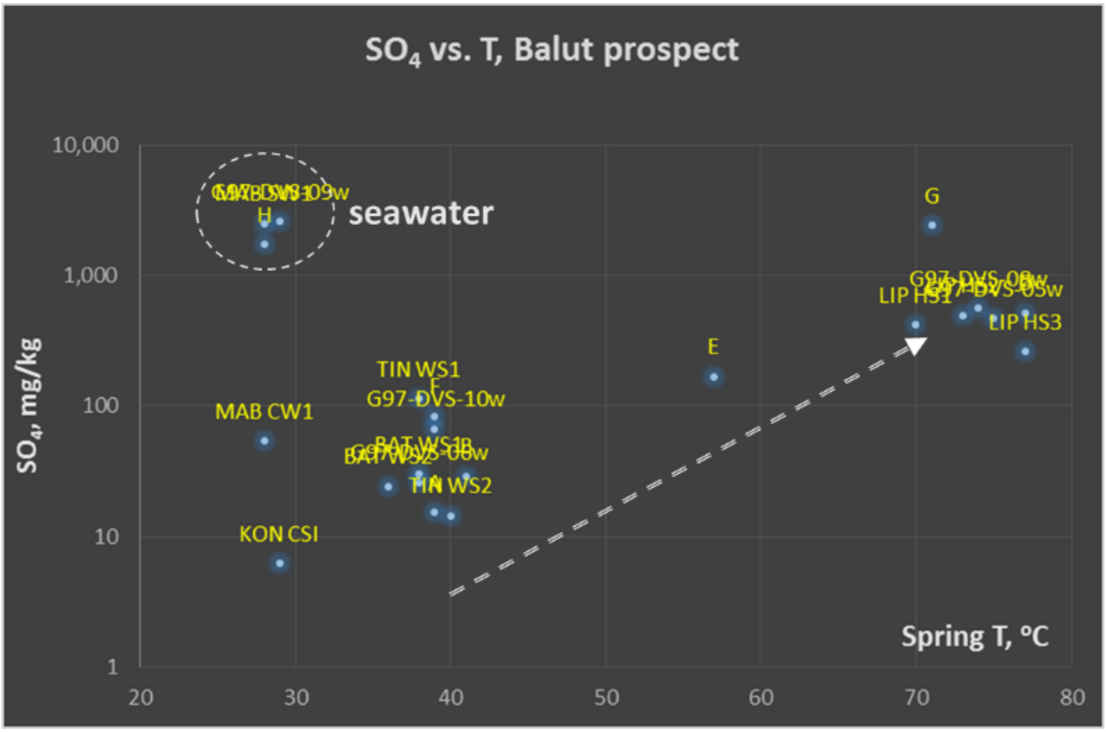

Figure 4. SO_4 vs T cross plot

In addition, SO_4 also controls the acidity of the springs. A simple cross plot of SO_4 vs. pH (Figure 5) shows 3 distinct groups of waters – high SO_4 / high pH, high SO_4 / low pH, and low SO_4 / high pH. The first cluster represents the seawater samples collected in the prospect over the years, and the third cluster characterizes most of the warm springs. Cluster 2, on the other hand, correspond to the high temperature springs in the prospect. There is an apparent negative shift in pH (from high or neutral to low or acidic) with increasing SO_4 content, strongly suggesting that the pH buffer for the thermal waters is SO_4 (a similar exercise was done with Cl and pH, but there is no significant contrast in Cl values to imply that Cl also contributes to fluid pH). Sulfate acidity in hydrothermal systems is often inferred to be caused by near surface oxidation of H_2S gas.

What the data sets suggest is the possible presence of a "gas cap" at shallow depths in the vicinity of Cayupi to Sabang Emerald Pool. A "gas cap" rather than mere gas leaks is invoked because of the >3km aerial distance between Cayupi and Sabang springs, both affected by the gas phenomenon. This near-surface "gas cap" heats up the subsurface waters that feed the high temperature springs discharging in the western coastline of the island. The "gas cap" also infuses H_2S which is oxidized by subsurface water, giving rise to the acid SO_4 character of the western springs. With the available data todate, there is no evidence of direct magmatic input into the Balut hydrothermal system (i.e., Cl as pH buffer, produced by magmatic HCl gas making its way to near surface levels), and the acidity issue raised early on in this study does not seem to be a major constraint to further exploration and possibly eventual development.

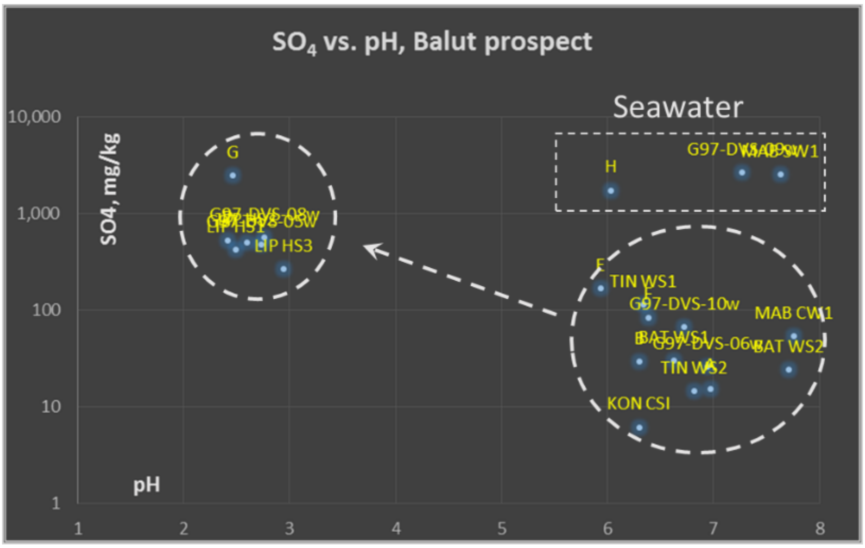

Figure 5. SO4 vs. pH cross plot

4.2 The origin of Cl and Mg

As mentioned previously, all thermal waters in the prospect exhibit Cl contents that are significantly higher than local groundwater. It is therefore an important exercise to try and determine the source of Cl in the fluids, mainly because Cl is the principal chemical component of hydrothermal systems in andesitic terrains. Below (Figure 6) is a semi-log cross plot of Cl vs Mg of all Balut island data, and the graph clearly indicates a positive relationship between the 2 chemical components. More importantly, the graph exhibits a mixing and dilution relationship between seawater and shallow groundwater end-members (dashed white line in figure), for the chemical species Cl and Mg. It thus appears that Cl in the spring waters in the prospect are derived from varying degrees of mixtures of seawater and shallow groundwater. Furthermore, Mg also appears to be derived from the same process and the same end-members. This further supports the theory that spring acidity is of shallow origin, with very little water-rock interaction occurring from the point where the spring waters become acidic, to the surface. If acidity was deep seated, significant water-rock interaction would have occurred and provided a Mg source (i.e., rock) separate from seawater-groundwater mixing, and the points would not have fallen nicely along the dilution line inferred in the plot.

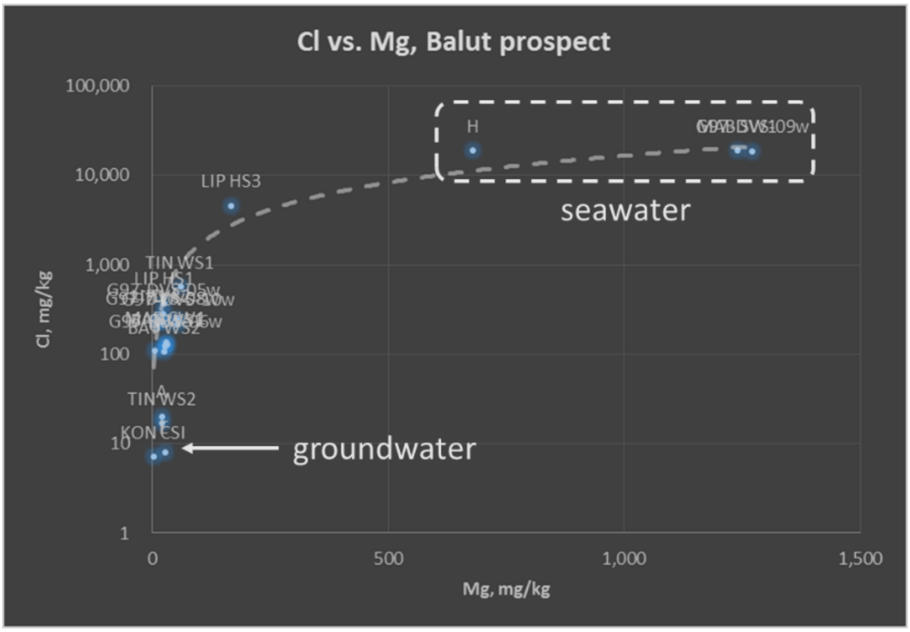

Figure 6. Cl vs. Mg cross plot

There is currently no indication of a deep Cl source for the springs, although this is by no means a firm conclusion that there is no deep, Cl-rich reservoir in the prospect. What the data analyses imply is merely that spring water sources in Balut are shallow, and no representative of the deep fluid has emerged at the surface. The inferred presence of a shallow “gas cap” however, presumes that a deeper liquid reservoir exists beneath the gas zone, which supply gases and steam to the “gas cap” above it. The extent of the gas cap, or at least the extent of its effects on the thermal manifestations, covers Cayupi hot spring, Sabang Emerald Pool, and Gumtago solfatara. Based on the appearance of Gumtago Solfatara, the postulated "gas cap" may not be as large as in other geothermal areas around the world, as the level of gas activity at Gumtago can be classified as weak.

4.3 Geothermometry

Since all thermal waters are secondary and products of mixing and dilution processes, no temperature estimate of the deep reservoir can be estimated using solute geothermometry. From the lone gas data set of Tambulos solfatara, the estimated deep fluid temperatures ranges from 175°C (H2S/H2 geothermometer), 180°C (D'Amore & Panichi) to 202°C (CO2/H2 geothermometer); the difference in temperature estimates is due to the different gas equilibrium reactions the geothermometers are anchored on. Although gas dynamics (i.e., deep seated, or resulting from boiling, mixing, dilution processes, etc.) in the prospect are unknown given only 1 dataset available, gas geothermometry is the only basis for estimating the minimum deep fluid temperatures at this point. The estimated minimum deep fluid temperature range in Balut prospect is therefore 175-200°C.

5. CONCLUSION

The Balut Island geothermal resource is believed to be the high enthalpy hydrothermal system rather than the low enthalpy type. Thus, recommended future works for this prospect should be patterned after conventional exploration activities for high enthalpy geothermal systems. The prospect should therefore be made to compete with the presently available high enthalpy geothermal prospects of the Philippines. There is laudable merit to pursue advanced exploration surveys and activities in Balut prospect to better and fully characterize its geothermal resource.

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Sample No	Thermal Area/Sitio	Barangay	Source	Date	Temp C	pH	Li	Na	K	Rb	Cs	Ca	Mg	Fe	Cl	SO4	HCO3	SiO2	B
KONC CS1	Pang	Konel	del Rosario et al (2012)	25-Jul-2012	29	6.30	ND	7.66	3.08	ND	<0.25	9.31	3.7	<0.20	7.08	6.17	63.20	52.10	0.12
B	Batoganding	Batoganding	This report	10-Aug-2013	41	6.30	<0.05	111	12.1	NA	NA	36.0	27.6	ND	125	29.1	347	154	0.60
G97-DVS-06w	Batoganding	Batoganding	del Rosario et al (2012)	1997	38	6.94	<.05	118	11.9	<.05	ND	41	28.6	NA	123	26	362	116	0.28
BAT WS2	Patuwa	Batoganding	del Rosario et al (2012)	Aug 2011	36	7.71	<0.05	85.90	10.30	0.05	<0.20	37.20	25.30	0.76	107	24.30	289	105	0.91
BAT WS1	Proper	Batoganding	del Rosario et al (2012)	Aug 2011	38	6.63	<0.05	99.8	12.30	<0.05	ND	59.30	32.1	<0.20	128	30.20	339	111	1.36
MAB CW1	Poblacion	Bgy Mabila	del Rosario et al (2012)	Aug 2011	28	7.76	ND	104	7.42	ND	ND	52.60	29.10	<0.20	136	53.7	297	53.7	2.26
E	Palabuno	Gumtago/Gomtago	This report	11-Aug-2013	57	5.95	ND	23.0	8.71	NA	NA	68.9	26.8	ND	8.04	168	217	159	0.60
LIP HS3	Kayupi	Lipol	del Rosario et al (2012)	Aug 2011	77	2.94	1.20	1,770	284	0.87	0.33	579	167	3.29	4,570	263	NA	224	66
G	Kayupi/Cayupi	Lipol	This report	13-Aug-2013	71	2.46	ND	11.6	13.4	NA	NA	2.56	6.7	96.4	110	2,440	0	297	4.01
G97-DVS-05w	Sabang	Lipol	del Rosario et al (2012)	1997	75	2.73	0.20	164	52	0.22	<.0.2	69.4	23.5	NA	279	471	NA	230	14.3
G97-DVS-09w	Sabang	Lipol	del Rosario et al (2012)	1997	29	7.27	0.08	10,500	344	0.06	<0.20	379	1,270	NA	18,600	2,620	122	0.80	4.28
LIP HS1	Sabang	Lipol	del Rosario et al (2012)	Aug 2011	70	2.49	0.24	189	60.5	0.24	<0.20	80.7	26	0.23	373	420	NA	202	36.7
D	Tambulos	Lipol	This report	11-Aug-2013	77	2.42	0.19	117	30.1	NA	NA	20.1	13.3	3.05	236	520	0	264	12.4
G97-DVS-08w	Tambulos	Lipol	del Rosario et al (2012)	1997	74	2.76	0.17	124	33.6	0.18	<0.20	101	20.9	NA	224	564	NA	224	14.4
LIP HS2	Tambulos	Lipol	del Rosario et al (2012)	Aug 2011	73	2.6	0.17	214	30.2	0.17	<0.20	87.40	19.3	1.49	236	496	NA	218	12.90
MAB SW1	Seawater, Pier	Mabila	del Rosario et al (2012)	Aug 2011	28	7.63	0.11	10,700	409	0.07	ND	508	1,240	0.25	18,800	2,510	117	2.67	5.60
H	Seawater	Tagen	This report	13-Aug-2013	28	6.03	2.38	9,830	759	NA	NA	1,380	679	13.9	18,800	1,730	108	217	41.9
G97-DVS-10w	Pandaring	Tinina	del Rosario et al (2012)	1997	39	6.72	<.05	159	19.2	0.05	ND	111	54.1	NA	216	66.9	606	134	0.37
TIN WS1	Pandaring	Tinina	del Rosario et al (2012)	Aug 2011	38	6.34	<0.05	409	27.60	<0.05	<0.20	88.50	60.20	ND	563	114	658	116	0.74
TIN WS2	Tubal	Tinina	del Rosario et al (2012)	Aug 2011	40	6.82	<0.05	44.30	5.69	<0.05	<0.20	73.90	21.90	0.75	16.90	14.50	421	91.80	0.51
A	Tubal/Tubel	Tinina	This report	12-Aug-2013	39	6.97	ND	42.8	5.65	NA	NA	73.0	21.0	ND	20.1	15.4	446	138	0.45
F	Unknown Sitio	Tinina	This report	12-Aug-2013	39	6.39	<0.05	216	22.6	NA	NA	79.0	52.4	ND	249	84.0	652	169	0.80