SLIMHOLE DRILLING: MARICABAN ISLAND (TINGLOY) LOW-ENTHALPY GEOTHERMAL PROSPECT

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Keywords: *Philippines, Low-Enthalpy, Slimhole, Drilling*

ABSTRACT

The Maricaban Island (Tingloy) geothermal prospect was one of the three candidate areas for the Department of Energy's (DOE) locally-funded project: "Detailed Resource Assessment of Selected Low-Enthalpy Geothermal Areas in the Philippines", implemented from January 2011 to June 2015. The result of the integrated resource assessment for the area suggests a Cl-rich reservoir based on the chemistry of the thermal springs. To further investigate the occurrence of the reservoir, two slimholes with an accumulated depth of 1,500 m was drilled in the area using tractor mounted core drilling rig. The data collected from the two slimholes shows a steeply dipping sedimentary rock formation overlaying the probable reservoir. From the two slimholes, hot water has flowed at an approximate rate of 1 L/s while there was no flow but a standing column of water was encountered at the second well. In a short period of time the slimhole drilling was completed due to the prevalent lithology of these sedimentary units. The highest recorded temperature for both slimhole ranges from 130-136 °C.

1. INTRODUCTION

The slimhole drilling activity is part of DOE's locally funded-project "Detailed Resource Assessment of Selected Low-Enthalpy Areas in the Philippines" implemented from January 2011 to June 2015. The total project cost was PhP 30M for a two slimhole with an accumulated depth of 1,500m. The mode of implementation is by contract-out, wherein the winning bidder will implement the work program designed by DOE. Diamond Drilling Corp. of the Philippines (DDCP) won the bidding for the contract-out services with the lowest budget of PhP 26M. DDCP utilized a Boart Longyear drilling rig capable of reaching 1,200m. The drilling aims at further characterizing the prospect by collecting core samples, measuring the temperature and pressure profile; and collecting downhole water samples if encountered at depth. The objective of this paper is to present the results of the slimhole drilling, from operational side to data gathering and the significance of the slimhole drilling in the early stages of geothermal exploration.

The slimhole drilling was carried-out in Maricaban Island (Tingloy) geothermal prospect after studies in the area lead to the conclusion that it may host a low enthalpy geothermal prospect (Halcon R. M. 2015a).

The Maricaban Island (Figure 1) is accessible from Manila, via a combination of land and sea travel from South Luzon expressway (SLEX) and Southern Tagalog Access Road (STAR) expressway to Batangas City and Calumpan Peninsula and thence to Maricaban Island across the narrow Maricaban straight. The journey takes a total of 4-5 hours depending on the mode of transport. There are two commercial ports on the Calumpan peninsula, one in Talaga, Mabini along the eastern side and another in Anilao, Mabini on the western coast.

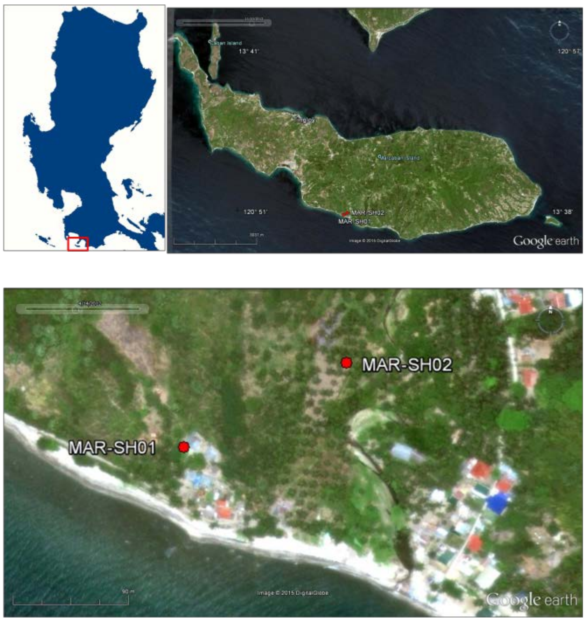

Figure 1: Location map of the Maricaban Island geothermal prospect relative to Luzon Island (top left).

2. METHODOLOGY

2.1 Summary of operations

Before the drilling proper commences, permitting works involving clearances from the environment Department and local government were secured. Afterwards, site preparation for the location of drilling equipments and support ancillaries were also done. See figure 2.

Well 1, Maricaban Slimhole - 01 (MARSH01) has a total depth of 500 m and well 2 - MARSH02 has a total depth of 1000 m. Generally, drilling for the two wells follows the same methodology:

1. Triconebit (8") drilling up to 39m.

2. Drilling up to 150.80m using PQ size core drilling barrel assembly for MARSH01 while up to 305m for MARSH02.

3. Drilling from 150.80m to TD using HQ size drilling barrel assembly for MARSH01 and from 305m to 632m for MARSH02.

4. Drilling from 787m to TD using NQ size drilling barrel assembly for MARSH02.

Cement grouting is done up to 39m and BOP installation was carried-out afterwards. The following casing sizes are used for the project in table 1 and figure 3 for the well design:

Table 1: Casing size guide used for the project.

Drilling Rods	Depth (meters)	Size (Inches)
PQ	350- 400	$4\frac{1}{2}$
HQ	600 – 700	$3\frac{1}{2}$
NQ	1000 - and above	$2\frac{7}{8}$

After the conductor casing, collection of core samples was carried out with a full core recovery. Temperature and pressure profiling was also conducted using a PT memory type tool while for the collection of water samples, a rig part downhole sampler was used.

Generally, drilling of the two slimholes was completed with no significant problems encountered. The average Rate of penetration (ROP) recorded for the drilling ranges from 30-60m per day, attributing its speed to the lithology of the area, which is an intercalating sedimentary unit. A total of 15 days was needed to complete MARSH01 while 48 days for MARSH02. Total loss zone was encountered at depths 419m and 646m for MARSH01 and MARSH02 respectively. The average drilling cost per meter is PhP17,334 or US$385.20 (US$1=PhP45). Breakdown of the costing is shown in table 2. Well testing was not conducted as it was not part of the work program as well as it is beyond the projects' budget.

2.2 Description of equipment used

2.2.1 Drilling rig

The drill rig used for this activity was a LF90D-6 Cylinder Cummins Engine Boart Longyear tractor mounted with a hydraulic, telescopic, 6m pull mast, capable of reaching a depth of 1,200m (NQ size). It is remotely controlled to move to the desired site. Pumps for water and mud were available at the site. These are FMC535 pumps with 16HP engines.

2.2.2 Pressure and Temperature (PT) tool and Downhole sampler

DDCP hired the services of Scientific Drilling Inc. (SDI) to measure the temperature and pressure profile of the well. The PT instrument is a memory type tool, capable of measuring the pressure and temperature of the well every 2 seconds. After reaching the TD, the tool is pulled-up and data is downloaded. The external diameter of the instrument is 45mm which enables logging in slimline investigation wells and it is capable of operating at 315°C and up to 200 bar pressure.

For the collection of downhole water sample, the rig downhole assembly is fitted with a downhole water sampler capable of collecting approximately 15 liters of samples. Water collection is through a flap valve on the bottom of the downhole water sampler.

2.3 Core logging

Premier Geoexcel Inc. handled the core logging activity of the project. Core logging involves several steps to ensure good recording of samples: 1) cleaning the core to wash off contaminants, 2) Provide thick marks to mark structures, 3) Core photography prior to logging for a baseline sample, 4) Logging intervals to reconstruct the drill cores and marking of geological structures, 5) Detailed logging involves recording of essential information and providing of geologic codes and symbols, 6) Sampling intervals are marked in the corebox and last 7) Photo documentation for drill cores are done for archiving purposes. Core samples is collected in boxes and stored in a dry place for safekeeping and easy retrieval when needed. The core samples, totaling to 380 boxes is currently stored in Energy Data Centre of the Philippines (EDCP) for archiving and use in the future.

2.4 Pressure and Temperature logging

A surface test of the PT equipment is conducted prior to measuring the pressure and temperature profile of the well. Likewise, it requires well quenching to acceptable temperatures for instrument and personnel safety purposes. Afterward, the tool is fitted to the downhole assembly tool of the rig and ran throughout the well until it reached the bottomhole and vice versa. The whole process takes approximately 45 mins. The well was cased all throughout the PT survey to ensure instrument safety. The initial pressure and temperature profile is viewed while the raw data in text format can be easily transferred to excel format for plotting and further processing. The end result is a PT profile of the well plotted against the boiling point per depth curve.

2.4 Well water sampling

Water samples collected from the downhole sampler are transferred on air-free, raw sample, filtered and acidified bottles. These bottles are properly labeled indicating date of sampling and the type of sample. These samples will be further analyzed to determine its chemistry and origin.

3. RESULTS OF THE DRILLING

3.1 Brief geologic data

Maricaban Island lies at the junction of the north-northwest trending Pleistocene-Quaternary volcanic chain making up the West Luzon volcanic arc and the NW-SW trending Macolod Corridor. The arc formation was caused by the subduction of the South China Sea oceanic crust along the east-facing Manila trench. This chain starts with Mt. Pinatubo in the north and proceeds southward through Bataan Province and Batangas Province, thence to Mindoro Island where the chain continues with the volcanic centers Mt. Naujan, Mt. Montelago, Mt. Pola and Mt. Dumali. It is predominantly underlain by young Tertiary clastic sediments and carbonates while this sedimentary sequence appears to be underlain and overlain by two slightly distinct volcanic sequences. Active volcanism in the region is exemplified by periodic activities in Taal Volcano. Thus, the eventual transfer of strain associated with the microplate collision in Mindoro may have resulted in the extensive NE-SW rifting within the Macolod Corridor.

There are seven (7) rock formations mapped in the area. These are as follows, from oldest to youngest: 1) Gamao-Pisa Metavolcanics / Older Volcanics, 2) Burihar-Pinagcrusan-Sedimentary Series, 3) Gamao Creek Intrusive Porphyry, 4) Mt. Magasauang Bato Agglomerate, 5) Hulo Sediments, 6) Pliocene to Quaternary(?) Tuff, and 7) Quaternary Alluvium (Tolentino 2014a).

From (Bayon 2014), the result of the integrated geoscientific evaluation indicates that there is an active geothermal system existing in Maricaban Island. The andesitic magma chamber underneath Maricaban Island was recharged with fresh deep-seated somatic melt triggering the youngest volcanic activity that emplaced both andesite lava and basalt in largely submarine eruptions with a young sub-crustal magmatic heat source that have undergone at least two magmatic emplacements in the Quaternary age.

The postulated geothermal resource region is set in a tectonically stressed terrain that gave rise to intense fracturing and faulting of the crust in the area where a geothermal reservoir has been anticipated to develop. This system is postulated to be fed by seawater. An estimate of the deep fluid temperature was not made because of seawater contamination which renders the use of solute geothermometry inapplicable.

Based on the appearance of the thermal features and the lack of surface manifestations the geothermal system is believed to be small and of low temperature. The geometry and location of the system at the subsurface was also not delineated by the resistivity survey due to the seawater contamination.

The results of the core drilling samples have confirmed the two stratigraphic units in the area. These are Burihar-Pinagcrusan-Sedimentary Series (Plio-Pleistocene) and the Older Volcanics (Miocene). The common exhibited lithology is sandtone-mudstone sedimentary sequence. In MARSH01 laminated sandstone is observed dipping 15-20° with respect to long core axis. On the other hand, MARSH02 displayed a sandstone-mudstone sequence with minor intercepts of conglomerate and andesite porphyry.

Majority of the calcite±gypsum occurred as fracture fill with minute veinlets and selvages. Mineralization of fine to cubic pyrite occurred as specks, clots and for dissemination with slight oxidation on other intervals. Common structures in the drill cores are microfaults, sheared zone and slicken sides. Microfaults are isolated within the sandstone-mudstone intercalations.

Furthermore, the mineral assemblages that would correspond to the alteration zones in a hydrothermal system is not observed in these depths. Minor epidote and smectite is sparsely distributed while chloritization becomes pervasive at depth. Figure 4 shows the general lithology of the wells.

3.2 Pressure and Temperature profile

MARSH01 is a discharging well with an approximate flowrate of 1 L/s. This is the stable flow since the initial opening of the well encountered geysering that enabled the water to reach the top mast of the rig (6m).

Figure 5 shows the PT profile of MARSH01. The survey was run twice, PT measurement up and down. Running-in temperature survey revealed a steady rising temperature inside the well while pulling-out temperature has displayed a stable temperature profile. A slight lowering of the temperature while going up may be explained by heat loss to the surrounding formation. The maximum recorded temperature of the well is 130°C taken at around 394m deep. This temperature continues to 420m while the temperature lowers by 4°C going to bottomhole. Judging by the temperature profile beginning in this segment and the running-in and pulling-out, the stable temperature of the well may be 126°C. A hydrostatic pressure profile meanwhile is displayed by the well because of the linear increase of pressure with depth. Correlating this PT profile with the drilling operations, the high temperature recorded coincides with the loss circulation zone reported at the same depth. Looking at this profile, it is interpreted that this zone 394-420m may be the location of a feedzone that supplies the stable flowrate of the well. This feedzone is obviously structurally controlled as the immediate surrounding is fracture dominated.

The PT profile of MARSH02 is shown in figure 6. The same PT survey was carried-out just like in MARSH01 but unlike MARSH01, this well did not discharge hot water. Upon review of the PT profile, it shows a gradual increase in temperature, consistent throughout the running-in and pulling-out survey. This profile exhibits a static water column in the well, with the water level beginning at a depth 150m. The maximum recorded temperature for this well is 136C, taken at depths 650m and 990m, that might represent the feedzone. This proposed feedzone is also supported by drilling results as this depth is the portion of a reported loss circulation zone. It is interesting to note however, that the despite the high temperature recorded, the well was not able to discharge. This could be due to the flowrate is not enough to push the static column of water or that the feedzone is obstructed, restricting fluid flow. The correlation with MARSH01 is not yet established upon publication of this paper.

3.3 Geochemistry of downhole samples

Both wells encountered hot water at depth where MARSH01 flows out with an approximate rate of 1L/s. Water sampling was done at bottomhole and surface for MARSH01 while bottomhole sampling only was done in MARSH02. These samples are compared to nearby hand-pump wells and existing dataset of the thermal springs.

Complete analysis of the water samples shows a Cl-rich chemistry comparable to seawater. The Cl content of MARSH01 is approximately 15,500ppm while for MARSH02 is 750ppm. This analysis was expected considering its proximity to the shoreline. However, the Cl content of MARSH02 may be considered diluted because of the well quenching prior the downhole survey. In (2015a), the source of the thermal springs is considered to be a “reworked seawater” as compared to the chemistry of pure seawater. The seawater undergoes alteration as it seeps into the island gets heated and inducing water-rock and water-water interaction.

4.0 DISCUSSION AND CONCLUSION

The conduct of the slimhole drilling activities has yielded additional geological information on the geothermal prospect. In particular, it has proven the presence of the two stratigraphic formations such as Burihar-Pinagcrusan-Sedimentary Series and the Older Volcanics with a relative thickness of the overlaying sedimentary units that is observed within the whole island. In a short period of time the slimhole drilling was completed due to the prevalent lithology of these sedimentary units.

The result of the core samples shows lack of hydrothermal alteration mineral assemblages that is used to determine a geothermal system. The absence of these minerals may be attributed to a shallow drilling depth and might be observed at a deeper level.

The PT profile on the other hand has shown an average temperature gradient of .095°C/m in the area. Although it was expected that MARSH01 will encounter hot water, as compared to MARSH02 it is even more surprising that MARSH02 even registered the highest recorded temperature of 136°C.While, considering the chemistry of the downhole samples, particularly that of the MARSH02 and assuming that it is not diluted, the origin of the downhole sample may have a temperature in the range of 165C. However, given the present case, this temperature assumption remains to be proven by deep exploratory drilling.

It has been demonstrated in other case histories (Finger 2000) that slimhole drilling is an excellent method in further investigating a geothermal area prior the more high risk deep geothermal drilling. For this geothermal prospect, although it has not proven conclusively the presence of the geothermal resource, the geologic data it has collected will aid in future well site targeting and well design. The PT survey has estimated that the geothermal prospect may indeed be a low enthalpy geothermal resource while downhole sampling shows that hot water may still be encountered somewhere in the middle of the Island. The collected data will be further evaluated and integrated with the existing reports.

In conclusion, slimhole drilling is an attractive way of further collecting additional data in investigating the geothermal potential of the area for a relatively lower cost as compared to deep exploratory wells.

5.0 RECOMMENDATION

Slimhole drilling has demonstrated its potential to be a useful tool in investigating geothermal fields in the Philippines as it will significantly lower the risks involved as compared to deep exploratory drilling. With the wealth of data and information generated under this locally-funded project, the Maricaban Island geothermal prospect is recommended to be offered for public bidding under the Open and Competitive Selection Process in the future.

Nevertheless, to fully evaluate the geothermal potential of the area, it is recommended that additional geophysical surveys such as MT and Gravity are to be carried-out. These two surveys will map the extent of the conductive layer.

ACKNOWLEDGEMENT

The authors would like to thank their colleagues in the Geothermal Energy Management Division for the useful comments and inputs; the authors would likewise extend their appreciation to the management of Renewable Energy Management Bureau headed by Director Mario C. Marasigan and to the Department of Energy for the support and for allowing the publication of this paper; and lastly to DDCP and partners for the sharing of technical expertise during the implementation of the project.

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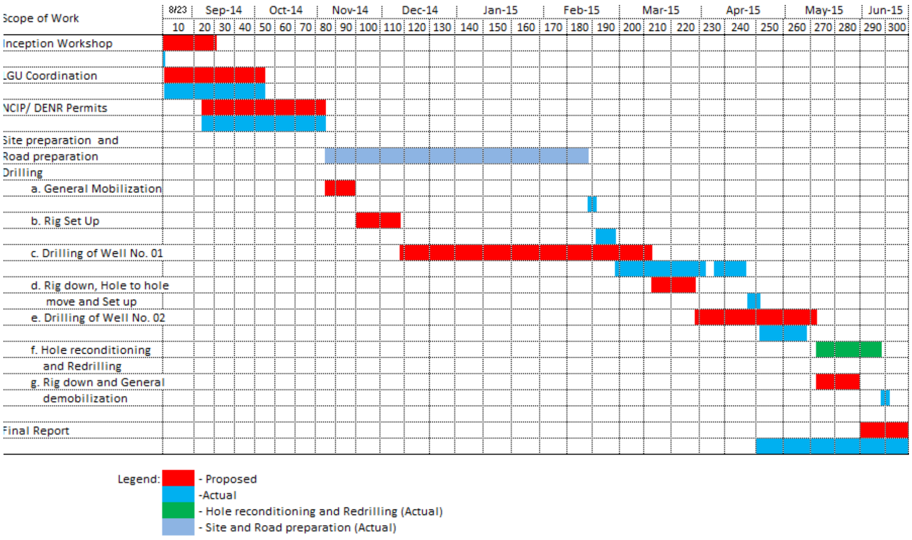

Figure 2: Schedule of works for the slimhole drilling

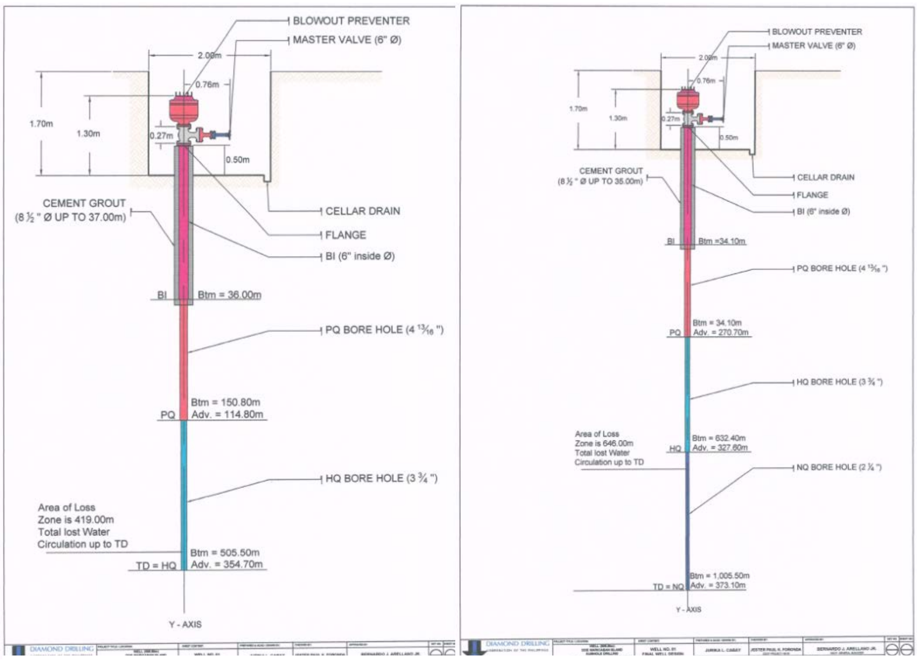

Figure 3: Well design for MARSH01 (left) and MARSH02 (right).

Table 2: Breakdown of expenses incurred for the slimhole drilling.

			Operating cost
Labor			
	Salaries and Wages		
	Benefits (SSS, Pag-ibig, Philhealth)		
	Sub-Total		**5,348,526**
Supplies			
	Tubings and casings	TRICON	364,374
		PQ	920,512
		HQ -	1,186,314
		NQ -	475,270
	Drilling Parts		4,023,000
	Drilling Supplies		1,350,900
	Diamond Bits		584,140
	Motor Fuel & Oil		369,000
	Muds and Additives		442,403
	BOP		1,500,000
		Sub-Total	**11,215,913**
Overhead			
	Depreciation		1,497,163
	Repairs & Maintenance		100,000
	Insurance & Bond		300,000
	Office Supplies		120,000
	Miscellaneous-site preparation/clean up and restorations		2,746,748
	General Mobilization/demobilization & hole to hole transfer		4,672,500
		Sub-total	**9,436,411**
Direct Contract Cost			**26,000,850**
	Cost per meter		17,334

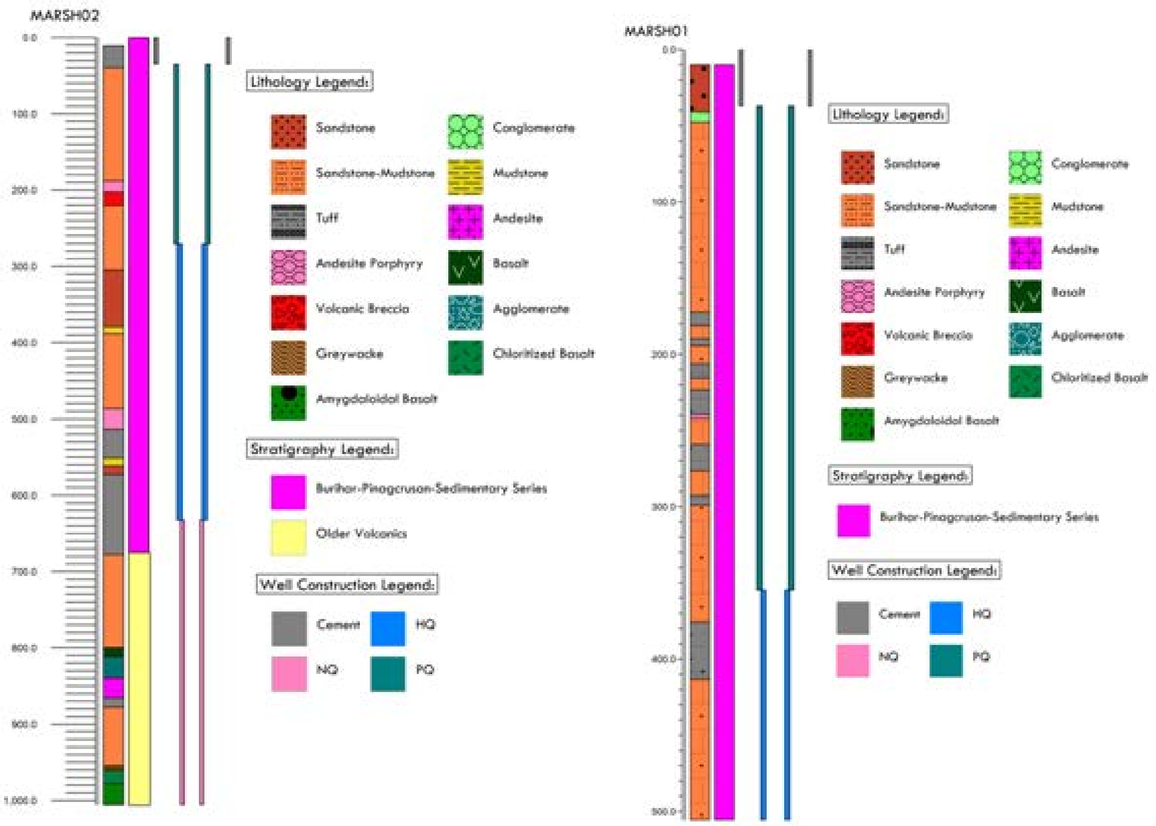

Figure 4: Well profile of both wells showing the lithology and stratigraphy. Both wells encountered the thick sedimentary sequence that overlays the Island.

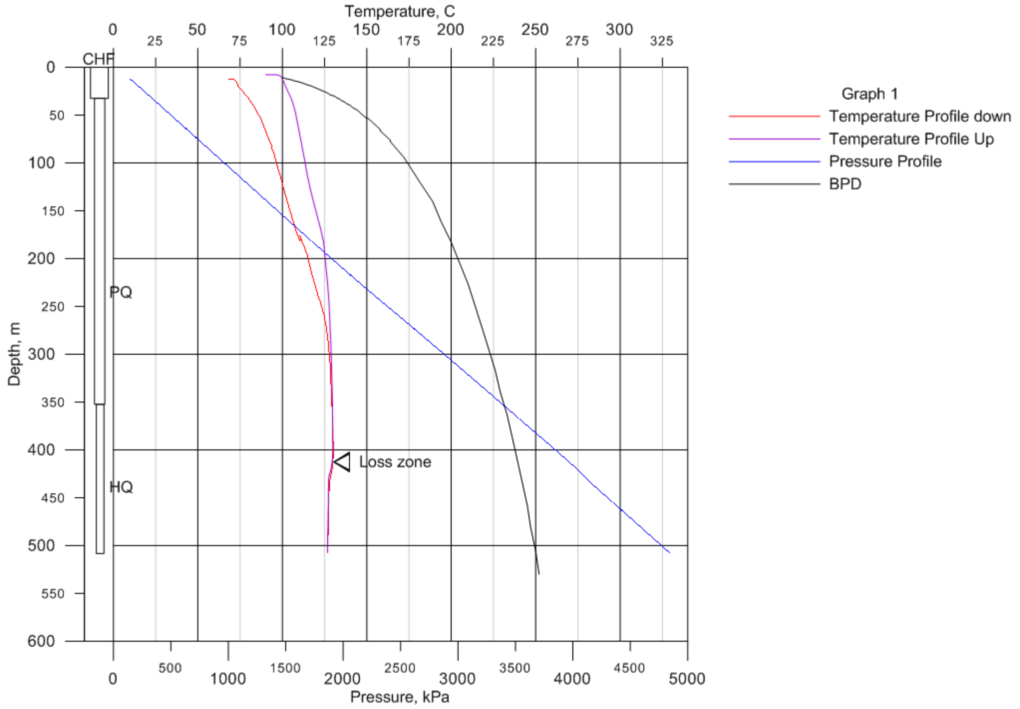

Figure 5: Pressure and Temperature profile of MARSH01, showing the increase and eventual stable temperature of the fluid as it flows out the well. Possible location of feedzone is at 420m that is also the location of the reported loss circulation zone during drilling.

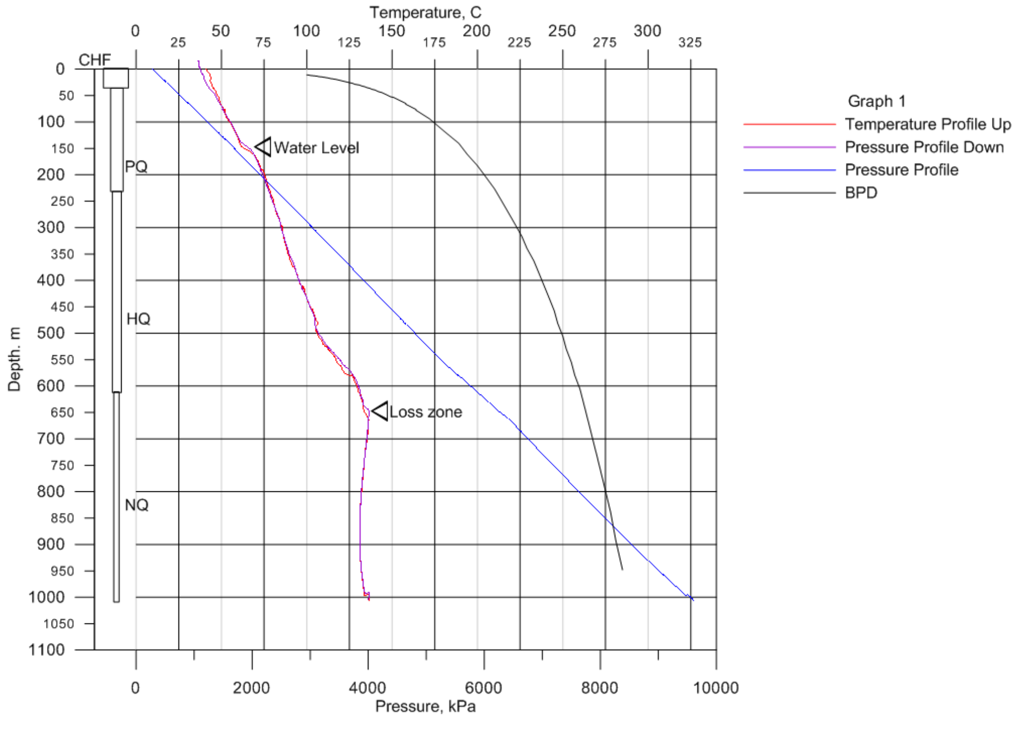

Figure 6: Pressure and Temperature profile of MARSH02 showing a relatively gradual increase and unchanged temperature during running-in and pulling-out survey. Possible feedzone is located at around 650m.