Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Geothermometer, Geoindicator and Isotope Monitoring in Lahendong Wells during 2010-2012

Azka G., Suryanto S. and Yani A.

Pertamina Geothermal Energy Lahendong

Bandung Institute of Technology, Geothermal Engineering, Jl. Tamansari 64, West Java, Indonesia 40132

ghilmanazka@students.itb.ac.id

Keywords: Lahendong, Geothermometer, Geoindicator, Isotopes

ABSTRACT

Pertamina Geothermal Energy (PGE) Lahendong area has been developed since 2001. Since then, scientific research were always performed to obtain reservoir's performance information. Hence, geochemical monitoring is essential to maintain and improve production. In this paper geochemical monitoring was performed to gain subsurface and well behaviour during production. Data from PGE well were processed to Geothermometer, geoindicator, isotpe and entalphy to monitor changes within the reservoir. Well LHD-X show significant change from chloride to chloride sulphate water. Boiling occured then mixing with meteoric water in well LHD-X2. Well LHD-X3 showed Chloride and entalphy decline indicating water meteoric and injection influx. writer recommends to perform tracer test intensively for injection well to provide hidrogeological pattern. MEQ investigation can also provide data to confirm the event in wells.

1. INTRODUCTION

Lahendong is a geothermal field located at Tomohon, North Sulawesi province in Indonesia (fig. 1) . The field has been developed by PT Pertamina Geothermal Energy (PGE) since 2001. Total generated capacity till 2002 is 80 MWe and to mantain this capacity, monitoring such as geology, geochemistry and geophysics are needed.

Geochemistry monitoring using chemical parameter to interpretate fluid changes is commonly used in geothermal. But this monitoring cannot stand alone, the monitoring result must be compared with geological monitoring. Some methods conventionally used in geochemistry are geothermomter, geoindicator and isotopes. In this paper those three methods are used to understand changes in reservoir. Hopefuly, if changes can be predicted then it will be helpful for the next development.

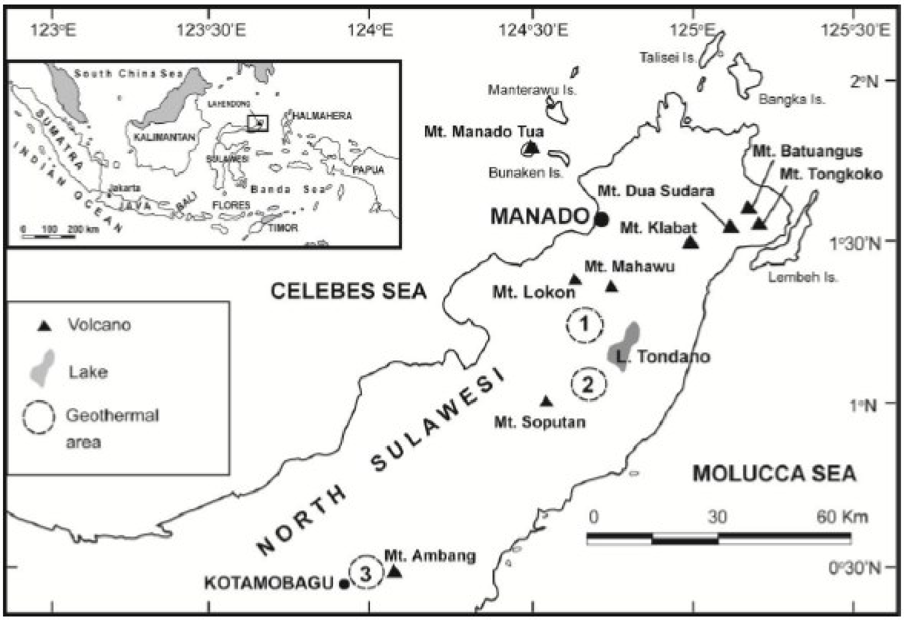


Figure 1: Map location of PGE geothermal field in North Sulawesi: Lahendong (1), Tompaso (2) and Kotamobagu (3) (Utami, P. 2011)

2. GEOTHERMAL SYSTEM OF LAHENDONG

Based on well characteristic, Lahendong consist of 2 geothermal system: north and south. North Lahendong is related to the activity of lake linow vulcanism. Otherwise, the south is related to mount Lengkoan and Kasuratan. Both of the system are high temperature system (>225 ^{o}C) and none of them are vapor dominated. Although north have high pressure well, but the type of reservoir is water dominated (entalphy <1500 kJ/kg). The south have more complex reservoir than north, there is one well proven to be vapour but other wells in the same pad tend to have lower enthalphy so the south is two phase reservoir. The natural discharge are controlled by Linow caldera, NW-SE, and NE-SW major structure. Recharge zone of the system is in the lower elevation of Lahendong like SE of mount Kasuratan and big caldera feature on northeast of lake Linow.

3. TYPES OF WATER

Plotting for well water types were performed and displayed on fig.2. On water plotting, almost all of the fluids are chloride water indicating that fluid come directly from the reservoir. The only fluid that shifted to chloride-bicarbonate is LHD-X5.From 2010 to 2012, types of water didn't change significantly but there is one well need to be concerned. The change come from LHD-X well. In 2011, LHD-X was in mature water zone but in 2012, LHD-X shifted to sulphate water. This change can be caused by anynthing and will be discussed in next section.

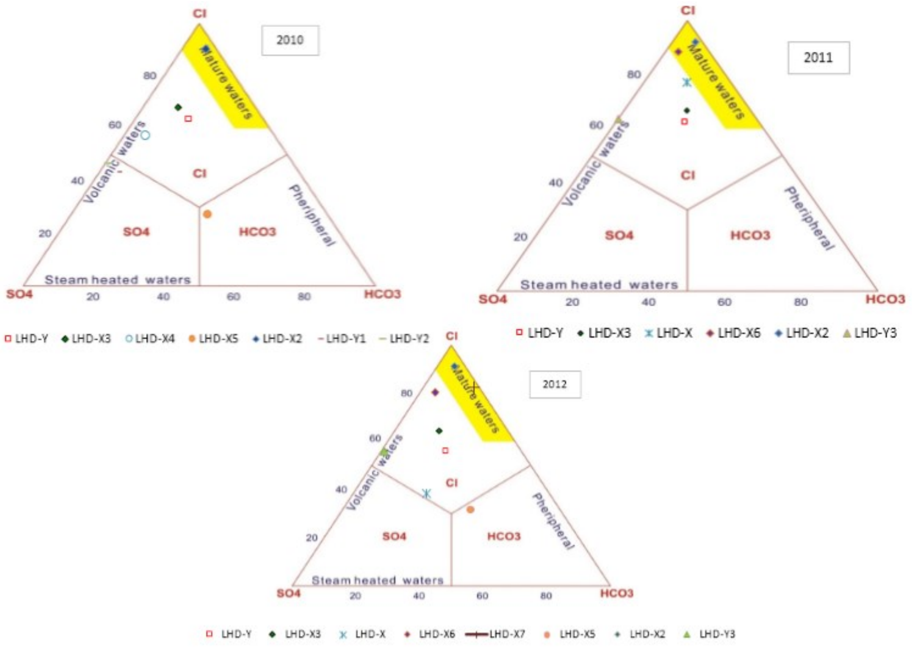


Figure 2 : Plotting Cl-SO_4- HCO_3 for some wells in 2010-2012

4. GEOTHERMOMETER

Geothermometer calculation and geoindicator result are displayed on fig 3. Plotting Na-K-Mg showed that all well sample are inside the partial equilibrium. Temperature result from conventional geothermometer (Na-K, Na-K-Ca, SiO_2) vary from 210 to 350 ^{O}C. Lowest temperature come from LHD-X6 in april 2012. Temperature decrease may be caused by mixing with cooler water such as injection or meteoric. In the other hand, increasing temperature happened due to boiling process causing elevated concentration of element. Increasing temperature may also be caused by magma intrusion but the pH of the fluid would be acid and the pressure and entalphy will increase significantly. So new intrusion was not possible to happen during 2010-2012.

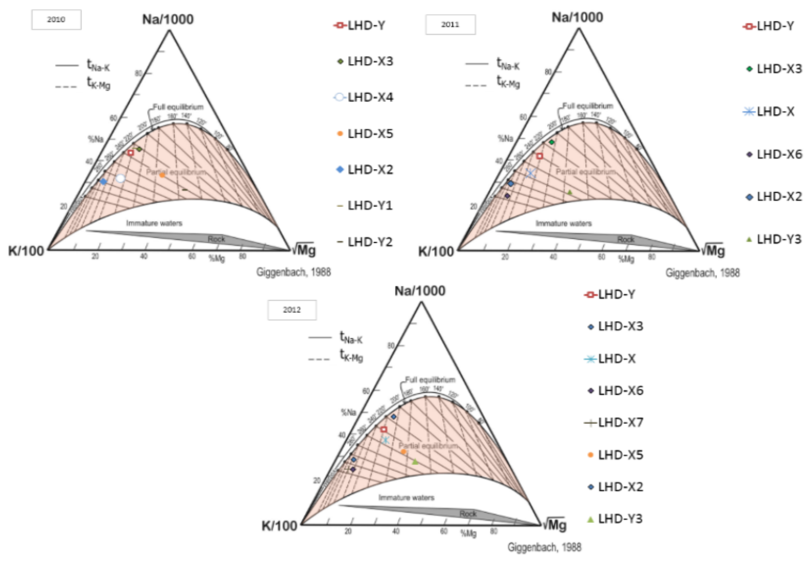


Figure 3: Geothermometer Na-K-Mg result for Lahendong well during 2010-2012

5. GEOINDICATOR

Ion balance can indicate if the fluid directly come from reservoir or not. If the ion balance result is less than 5% then the sample is reservoir fluid. If not, then there has to be second process affecting the fluid before come out to the surface or well. In table 1 , only LHD-X5 which has ion balance more than 5%. LHD-X5 is located in the boundary of the system causing meteoric fluid mixed with the reservoir fluid in LHD-X5.Geoindicator Na/K and HCO_3/SO_4 can be used to predict upflow and outflow zone. All the well from 2010 to 2012 tend to have Na/K ratio less than 15 and relatively low ratio of HCO_3/SO_4. These values indicating that all wells are from the upflow.

Table 1 Geoindicator

Year	Well	ion balance	Na/K	HCO_3/SO_4	NH_4/B
2010	LHD-Y	1.9	10.1	0.6	0.06
	LHD-X3	3.8	11.7	0.4	0.04
	LHD-X4	1.6	6.1	0.1	0.14
	LHD-X5	13.3	9.6	1.1	0.02
	LHD-X2	2.3	5.1	1.4	0.06
	LHD-Y1	1.5	11.4	0.1	0.01
	LHD-Y2	4.0	9.4	0.0	0.08
2011	LHD-Y	3.0	9.8	0.8	0.07
	LHD-X3	4.2	13.4	0.4	0.05
	LHD-X	4.8	8.1	0.4	0.05
	LHD-X6	2.1	3.8	0.3	0.04
	LHD-X2	0.9	4.8	2.2	0.03
	LHD-Y3	1.6	7.3	0.0	0.12
2012	LHD-Y	0.4	9.7	0.8	0.08
	LHD-X3	2.6	13.1	0.6	0.06
	LHD-X	2.1	8.3	0.6	0.07
	LHD-X6	0.1	3.8	0.2	0.05
	LHD-X7	1.3	3.7	5.2	0.10
	LHD-X5	7.3	8.1	1.4	0.01
	LHD-X2	0.7	4.6	1.1	0.06
	LHD-Y3	2.9	7.5	0.0	0.13

Geoindicator Cl-Li-B (fig 4) can be used to understand hydrogeology of the reservoir. If the south and the north sample have similar ratio of Cl-Li-B then both come from the same reservoir. Data plotting in pic showed that some well may have the same source of reservoir but in fact LHD-X2 and LHD-Y2 are remote and might have different geological setting in regional. Hence, the Cl-Li-B plot result cannot be used to interpretate hydrological system of Lahendong.

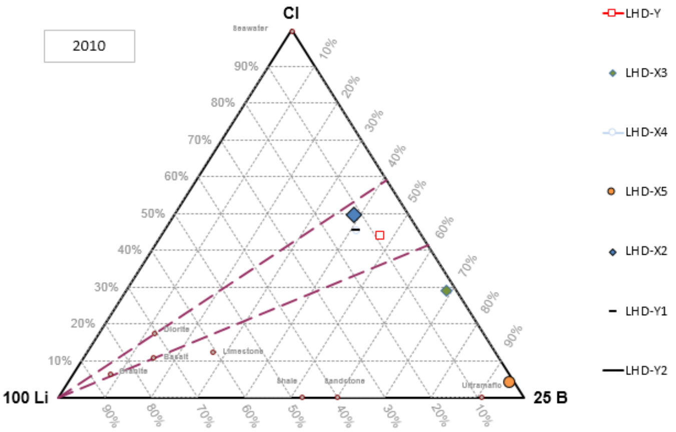


Figure 4: Plotting lahendong wells in 2010 on Cl-B-Li diagram

Geoindicator related to boron (B) such as NH_4/B can indicate steam heating or sediment basement. During 2010-2012 ratio NH_4/B remain low indicating no steam heating near the surface.

6. CHLORIDE-ENTHALPY AND ISOTOPES

Entalphy-chloride curve from 6 wells are displayed fig 5. Well LHD-Y is water dominated, entalphy and chloride decrease caused by mixing process with meteoric water. Mixing process also happened with LHD-Y3 which located relatively close with LHD-Y. Increasing chloride in LHD-Y3 showing that there is injection water infiltrate the well but entalphy decrease here is more influenced by the meteoric because in fact pressure drop happened and affect the meteoric to infiltrate. Isotope ploting (appendix A) of the two wells also proven that in 2010-2012 oxygen isotope shifting closer to the Global Meteoric Water Line (GBWL) means that there is mixing process with meteoric water.

In well LHD-X2 during april-sept 2012, chloride and silica concentration increased. If the increase happen due to injection mixing then silica concentration wont increase. From isotope plot, LHD-X2 shifted to heavier oxygen isotope. Those change indicating boiling process but the process didn't happen in september 2012 because oxygen isotope of well LHD-X2 shifted to GBWL indicating mixing process.

In water type plotting, well LHD-X changed from chloride to sulphate-chloride water. Chloride decreased significantly, meanwhile sulphate concentration increased. Sulphate increase could occur due to mixing with condensate. Isotope plotting showed significant oxygen shifting to GBWL during the change. The significant change may happened due to big amount mixing with meteoric water caused by pressure drop in reservoir. This well need to be monitored intensively to study the change because this change could acidified the fluid then damage well casing.

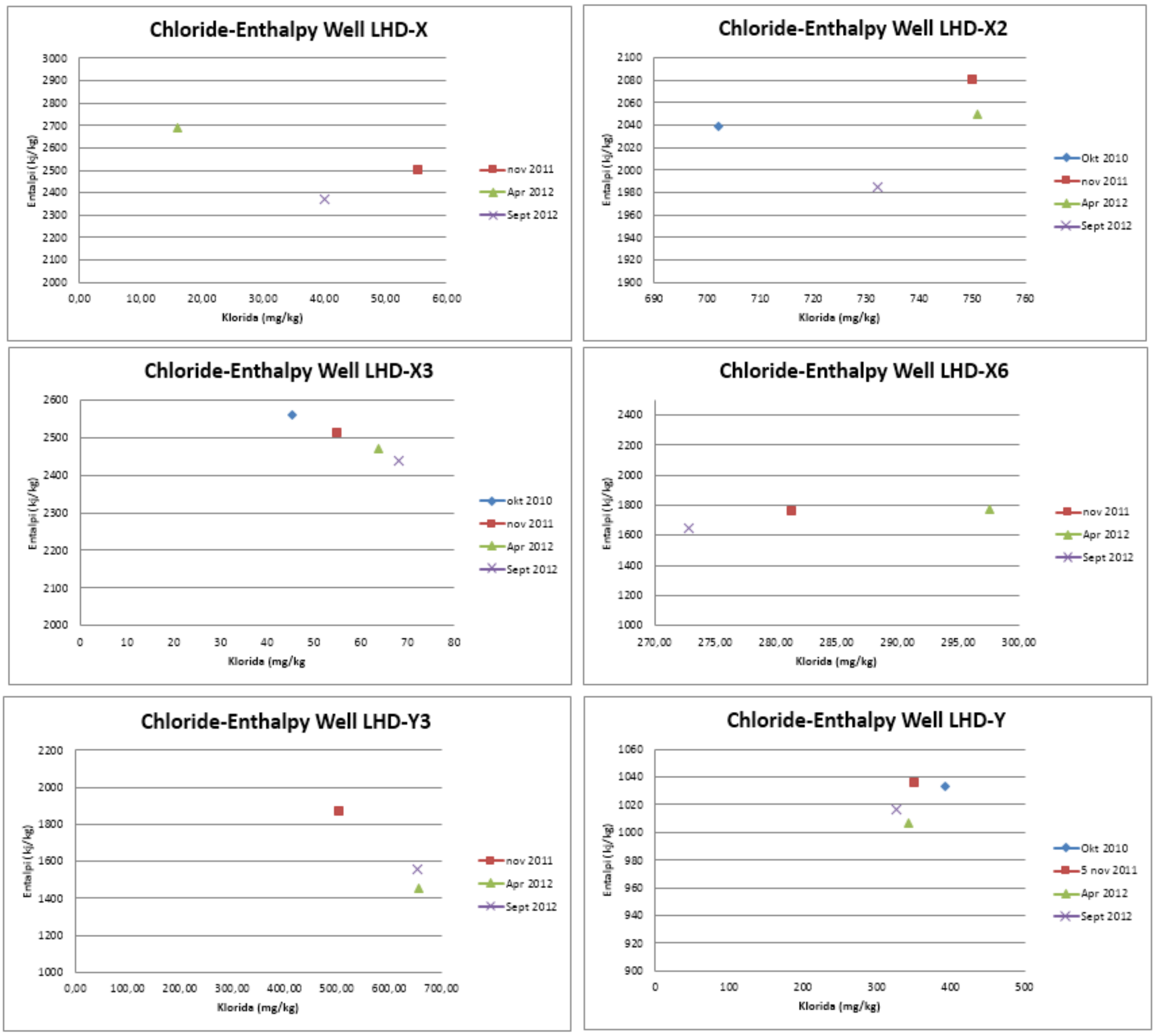


Figure 5: Chloride-Entalphy curve for six wells in lahendong

6. CONLCLUSION

Plotting trilinier diagram Cl-SO4-HCO3 showed only LHD-X changed. LHD-X changed from chloride to sulphate water due to mixing with condensate water. From geoindicator Na/K and HCO3/SO4 during 2010-2012, all well are from the upflow. Temperature increase showed by geothermometer occured due to concentration change caused by boiling and mixing, this occured in LHD-X2. During april to august 2012, LHD-X2 had boiling process then mixing in september 2012 indicated by elevated dissolved concentration then decline in september 2012. Entalphy-chloride's LHD-X3 curve shows decrease wih time. the decrease followed by increased chloride concentration indicating injection and meteoric water mixed with reservoir fluid.

Tracer test need to be performed to confirm mixing and boiling process in reservoir. Geopysical monitoring such as gravity and MEQ are needed to understand fluid properties and changes after more than 10 years utilization. This result must be compared with geological interpretation.

REFERENCES

Giggenbach, W.F. 1984. Mass transfer in hydrothermal alteration system – A conceptual approach. Geochim. et Cosmochim. Acta. v. 48. pp. 2693 – 2711.

Hochstein, M.P., Sudarman, S, 2008, History of geothermal in Indonesia from 1970 to 2000, Geothermics 37, 220-266.

Lee, K.C. 1996. Classifications of Geothermal Resources - An Engineering Approach. 21 Workshop on Geothermal Reservoir Engineering Stanford. SGP-TR-151.

Karingithi, C. 2009. Chemical Geothermometers For Geothermal Exploration. Kenya. UNU-GTP.

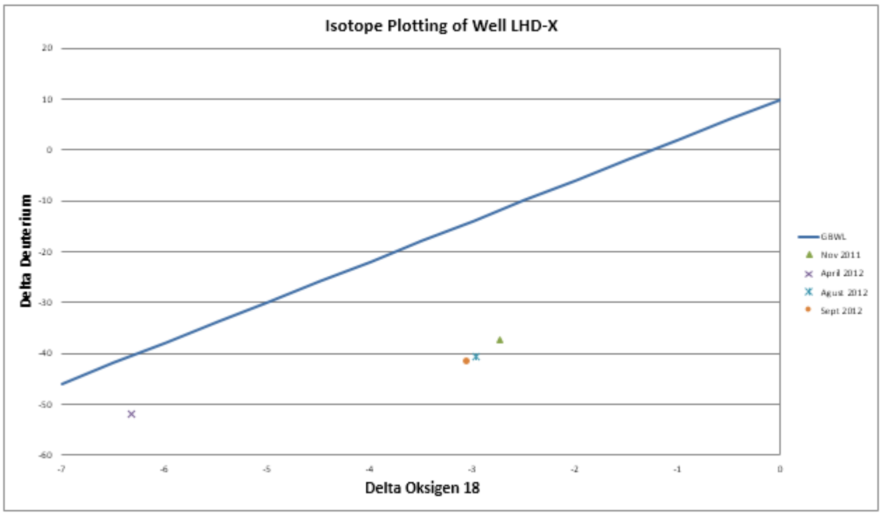
Nicholson, K. 1993. Geothermal Fluids. A Text Book. The Robert Gordon University: Scotland.

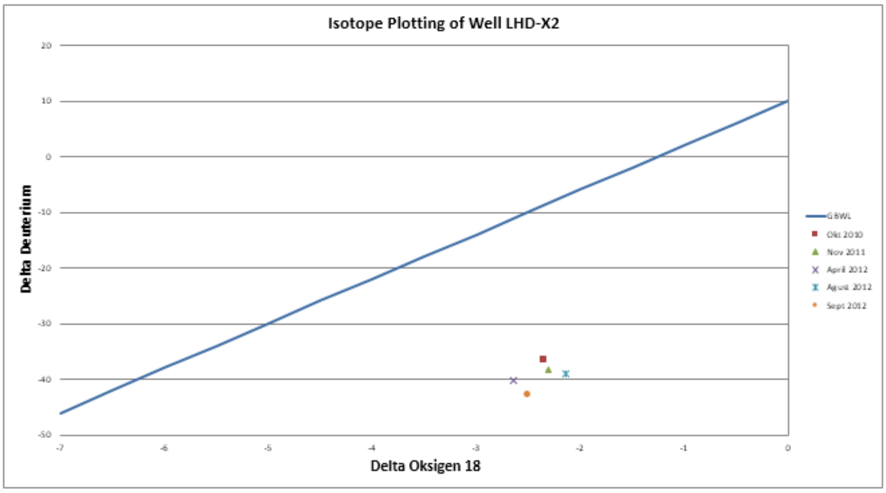
Soemodipoero, K.1982. Borehole Geology of Well LH2 in Lahendong High Temperature Area North Sulawesi Indonesia. UNU Geothermal Training Programme. National Energy Authority. Iceland

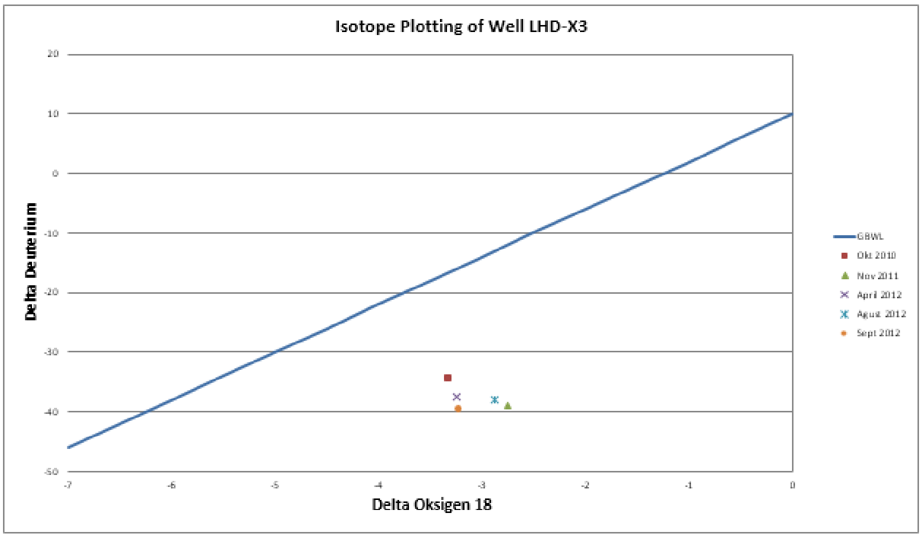
Suryantoro, S. Laporan Survey Manifestasi Lahendong-Tompaso. PT Pertamina Geothermal Energy (PGE). 2012.

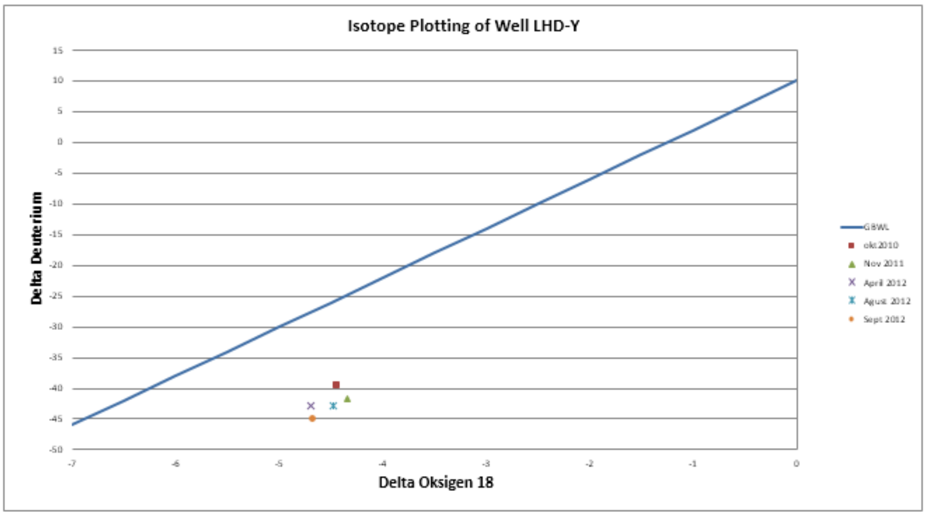
Utami, P. 2011. Hydrothermal Alteration and the evolution of the Lahendong System, North Sulawesi, Indonesia. Master of Thesis

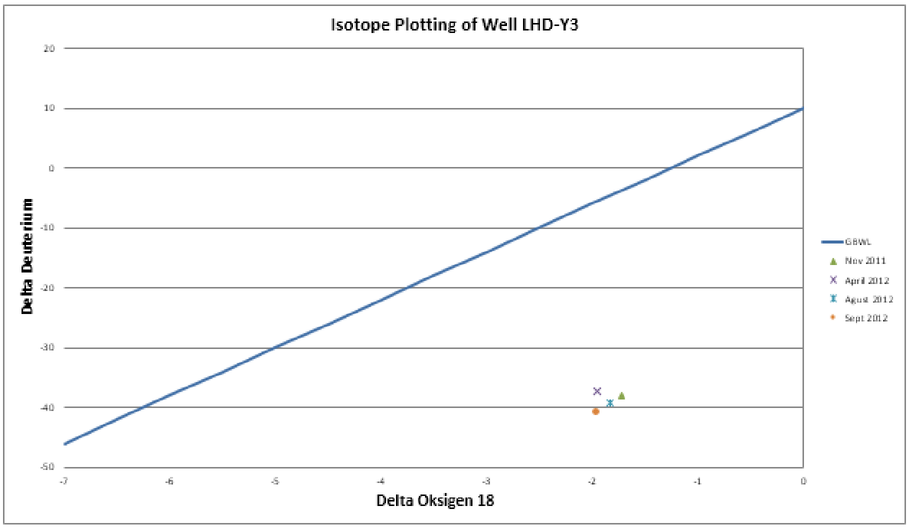
APPENDIX A PLOTTING ISOTOPES

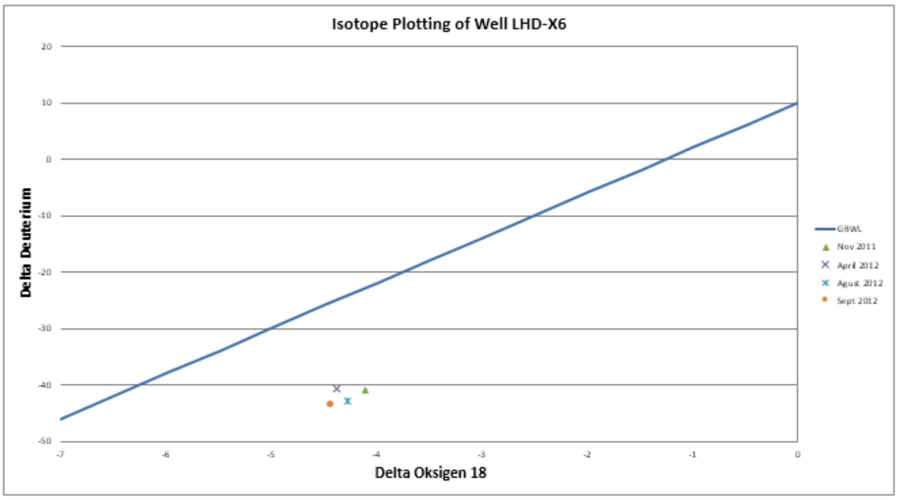





Isotope Plotting of Well LHD-X3
Delta Deuterium
Delta Oksigen 18
GBWL
Okt 2010
Nov 2011
April 2012
Agust 2012
Sept 2012


Isotope Plotting of Well LHD-Y
Delta Deuterium
Delta Oksigen 18
GBWL
okt 2010
Nov 2011
April 2012
Agust 2012
Sept 2012


Isotope Plotting of Well LHD-Y3
Delta Deuterium
Delta Oksigen 18
GBWL
Nov 2011
April 2012
Agust 2012
Sept 2012


Isotope Plotting of Well LHD-X6
Delta Deuterium
Delta Oksigen 18
20
10
0
-10
-20
-30
-40
-50
-7
-6
-5
-4
-3
-2
-1
0
GBWL
Nov 2011
April 2012
Agust 2012
Sept 2012