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

Geochemistry Monitoring in the Kamojang Vapor-dominated Geothermal Field from 2010 to 2013

Firmansyah, W. Sujarmaitanto, H. Mulyanto, Hartanto, D. B. and Wicaksono, T

PT. Pertamina Geothermal Energy

Skyline Building 15th Floor Jl. MH. Thamrin no. 9 Jakarta 10340 Indonesia,

wahyu_firm@pertamina.com

Keywords: Geochemistry, Superheat, Injection and Monitoring

ABSTRACT

During more than 30 years of steam and energy production for Indonesia, the monitoring activity at the Kamojang geothermal field has successfully been done by both the reservoir and geochemistry departments to maintain steam production. In the last three years (2010 to 2013), geochemistry monitoring has been done by monitoring the pressure, temperature, production, and chemistry of noncondensable gas (NCG) and condensate liquids for each production well. Moreover, the condensate injection rate and tracer injection at the KMJ-21 injection well has likewise been monitored as part of a comprehensive study.

The NCG trend for 2010 and 2013 are unlikely to change with high values in the southern area, southeast, and the east-southeast. In well KMJ-75, the NCG declined, which could be an indication of condensate injection breakthrough since the condensate injection rate was increased. The tracer injection study also showed that the injected condensate had a connection with a well which was located in same cluster with KMJ-75.

The temperature, pressure, and wells production trend for 2010 and 2013 are also unlikely to change with high values in the southeast area. The wells on the west-southwest area have the highest superheat value because the exploitation process is longer compared to the wells on the east-southeast area. The lack of condensate injection in that area might cause a decrease in pressure and an increase superheat in the wells.

1. INTRODUCTION

The Kamojang geothermal area (KMJ), located in the western portion of Java island in Indonesia, is about 40 km from Bandung City (Figure 1). At present, it has an installed capacity of 200 MWe from four power units and is connected to the Java-Bali transmission line (Pertamina, 2010). On July 2015, an additional 35 MW unit will be commissioned for a total of 235 MWe.

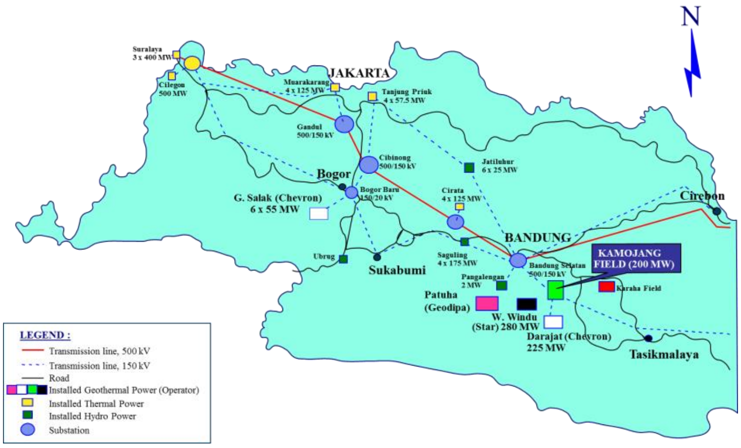


Figure 1: Kamojang and another west java geothermal area map

KMJ is located at the Rakutak Guntur volcanic sequence, the product of quaternary volcanic activity series (Figure 2). The sequence indicates the evolution of younger volcanic activity towards the northeast (Pertamina, 1995). In those volcanic series, the two important faults are the Kendang fault and the Citepus fault. Moreover, Kamojang is located in the Pangkalan depression fault that forms a sort of cover that is ideal for the formation of dry steam geothermal systems. As expected, the formation of a vapor-dominated geothermal system begins with a specific geological setting where there is a permeable reservoir and an impermeable recharge area.

Surface thermal manifestations can be found as acidic hot (>70^oC) pools, fumaroles, mud pools and altered grounds in Kawah Berecek and Kawah Manuk, acidic hot springs in the Ciwalirang River and Kawah Hujann, and, a neutral spring in Citepus. The acidic hot springs contain mainly sulfate (~300 ppm), with some chloride (< 5ppm). The neutral hot spring manifestation is mainly composed of bicarbonates. Fumaroles gases are mainly CO_2 (~ 90% volume) with limited amounts of H_2S, CH_4, H_2, N_2, and NH_3.

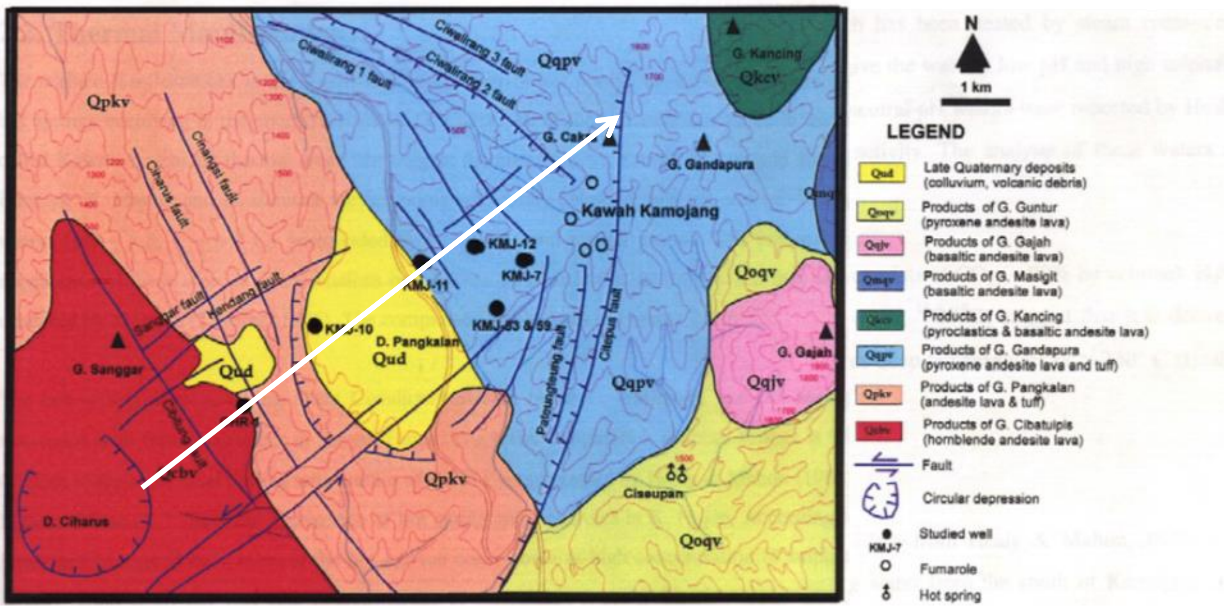
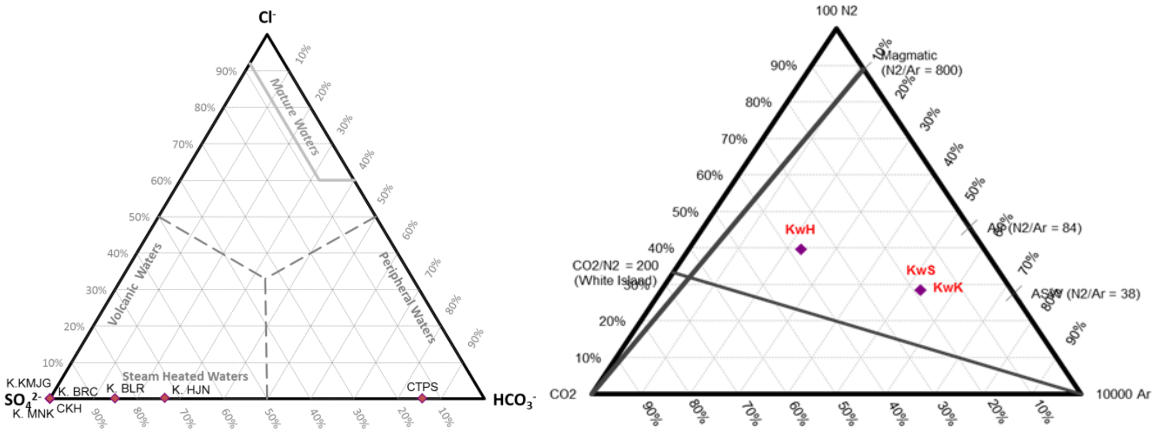


Figure 2: Regional Geology Map of Kamojang (Pertamina, 1995). The white line indicates the direction of the cross-section model of hydrothermal Kamojang.



(a) **(b)**

Figure 3: SO_4-HCO_3-Cl modified from Giggenbach, 1991 (a) and CO_2-Ar-N_2 modified from Giggenbach, 1992 (b) ternary diagrams

The thermal waters are categorized as steam heated waters, except Citepus, from the SO_4-HCO_3-Cl ternary diagram (Figure 3a) of Giggenbach (1991). The CO_2-Ar-N_2 ternary diagram (Figure 3b) from Giggenbach (1991) as plotted using the Powell and Cumming (2010) spreadsheet shows that the gas manifestations form a mature and high enthalpy geothermal system.

Figure 4 shows the conceptual model of the Kamojang hydrothermal system model adopted from Utami and Browne (1998). At the margins, meteoric water enters the reservoir to form high-temperature steam. At depth, liquid convection occurs with steam forming at the top. This steam is condensed upon contact with the atmospheric pressure environment, to form a condensate layer, which is associated with acid alteration in the altered grounds.

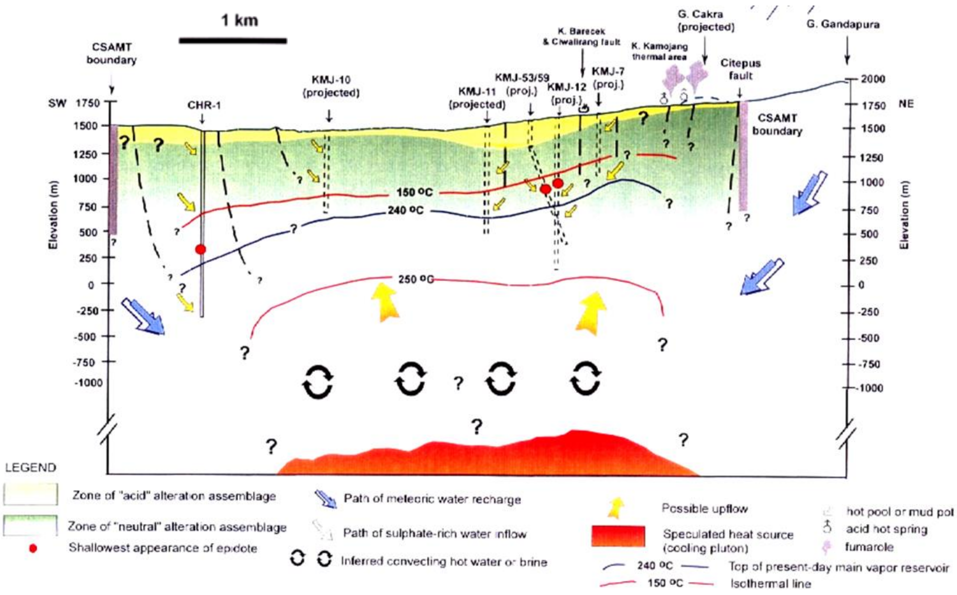


Figure 4: Reservoir structure and hydrology of Kamojang geothermal field (Utami and Browne, 1998).

At present, Kamojang wells produce dry to superheated steam. The enthalpy of the fluid is around 2800 kJ/kg, with pressures of 30-34 bars and temperatures of 235-250 °C. The capacity of the wells varies from 20 to 110 tons/hour of steam. From 2010 to 2013, eight wells were used for the disposal of condensate from the power plants. The reinjection strategy is to use four wells but if steam production rate is found to decrease, reinjection will be transferred to other wells that are near the declining area. This strategy has been successful in minimizing productivity decline (Suryadarma et al, 2010).

2. DISCUSSION

This paper will review the monitoring activities in Kamojang from 2010 to 2013. The monitoring parameters that are discussed in this paper are noncondensable gases, pressure, temperature, boron, steam production, and tracer tests with connectivity. These are plotted at the main feed zone of the wells. Contours based on the data distribution are plotted. These are discussed further in the following sections.

2.1 Noncondensable Gas (NCG)

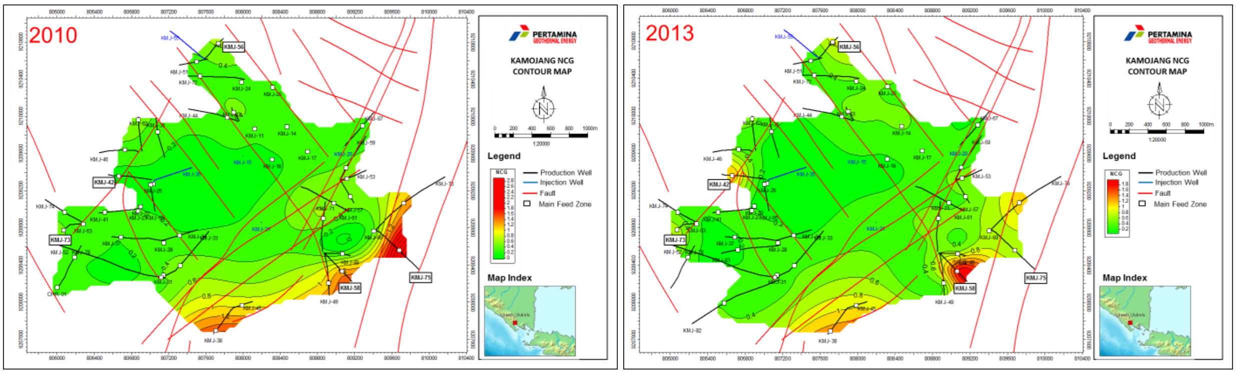


Figure 5: NCG contours at the Kamojang geothermal field.

Noncondensable gases (NCG) were collected from discharging wells using the ASTM E947-83 sampling procedures for single phase fluids. In 2010, the highest NCG values (Figure 5) were in the south-southeast area. This trend was still the same in 2013, but some wells (KMJ-42 and KMJ-73 in the west, KMJ-56 in the north, KMJ-58 in the southeast, and KMJ-75 in the east) showed declining values. This change can be caused by processes such as condensation, boiling and/or mixing with surface fluids (Nicholson, 1993).

2.2 Temperature

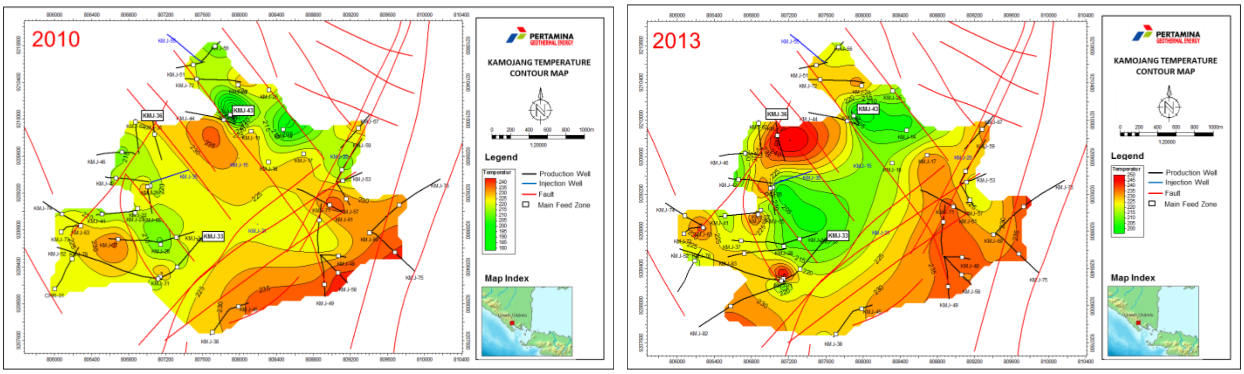


Figure 6: Temperature (^oC) contours at the Kamojang geothermal field.

Temperatures at the main feed zone were plotted for the 2010 and 2013 downhole measurements (Figure 6). In 2010, the highest temperatures were also found in the southeast-east area. The trend did not change in 2013, but a slight decrease was found in most wells. Temperatures were found to increase in wells KMJ-33 in the south, and, KMJ-36 and KMJ-43 in the north. The decrease of temperatures in a well can be caused by mixing processes with the fluid from the surface, marginal inflow, and/or condensate layers (Nicholson, 1993). However, the increase in temperature in the well is an anomaly that cannot be explained by mixing and/or boiling. Most likely, these can be explained by superheated conditions in these wells.

2.3 Pressure

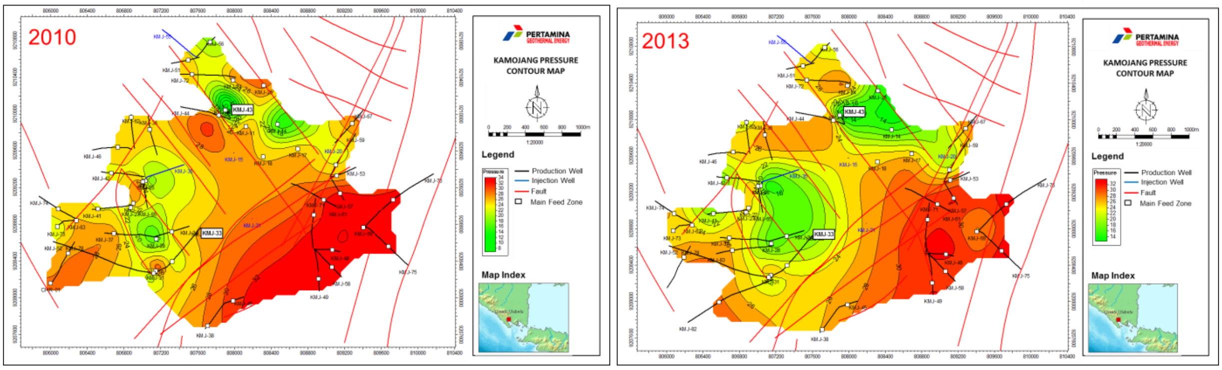


Figure 7: Pressure (bars) contours at the Kamojang geothermal field.

Pressures at the main feed zone are plotted for 2010 and 2013 downhole measurements (Figure 7). The highest pressures again can be found in the southeast-east area. This trend did not change in 2013, and, similar to temperature, generally a decrease in pressure was observed. However, some wells such as KMJ-33 and KMJ-43, showed a pressure increase.

2.4 Steam Production

The steam production rate (tons/hr) during sampling were plotted at the main feed zones (Figure 8). In 2010, the highest production was also found in the southeast-east area. This did not change in 2013, although generally the wells showed a decrease in steam production. However, some wells showed a significant production increase (KMJ-14, KMJ-26, KMJ-33, KMJ-43 in the center, and KMJ-38 in the south). These wells were near the reinjection wells with high injection rates.

A significant decline was observed in wells KMJ-25, KMJ-27, KMJ-28, KMJ-46, and KMJ-69, which were generally further away from the reinjection wells. To address this, a program was created to inject near these wells in the future. There was also a plan to inject lake water, similar to the Geysers (Stark et al., 2005), to maintain steam availability.

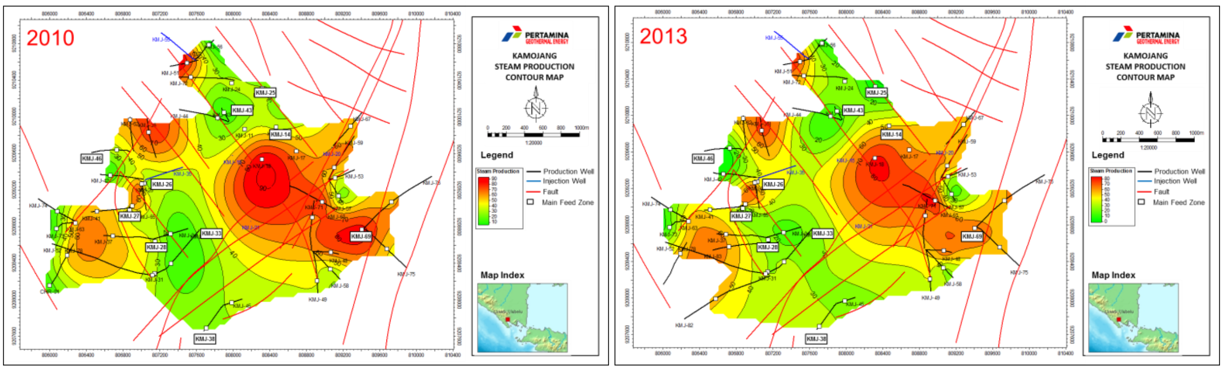


Figure 8: Steam production contours at the Kamojang geothermal field.

2.5 Boron distribution

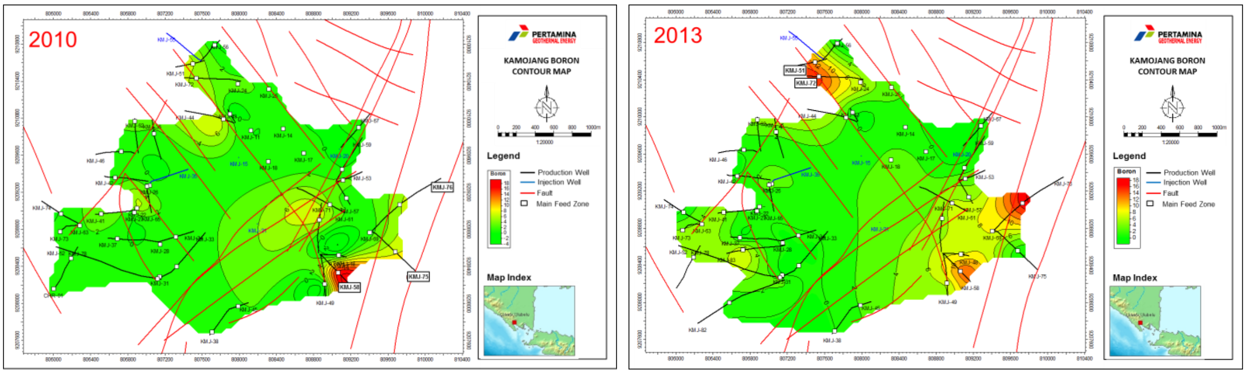


Figure 9: Boron contours at the Kamojang geothermal field.

Boron has been found to be a natural tracer of reinjection returns (Hidayaturrobi et al, 2010). In 2010, the highest boron concentrations (Figure 9) were found in the southeast area, and in wells KMJ-58, KMJ-75 and KMJ-76. In 2013, in addition to these three wells, higher boron concentrations were also found in the northern sector, and in wells KMJ-72 and KMJ-51. This was due to more condensate injected in this sector compared to 2010.

2.6 Tracer tests

Around 200 kg of tracer HFC R134a was injected to well KMJ-21 on February 2013. Samples were then collected from eight production wells (Figure 10). The response time was around 5 to 22 days, based on the peak concentrations of the tracer. Most of the injected condensate flowed into the eastern part of the field, as inferred from the high concentrations of the tracer. The highest amount of tracer return was from KMJ-69 and KMJ-76. These wells also had the highest concentration of boron. More tracer tests in the future will be programmed using the other injection wells.

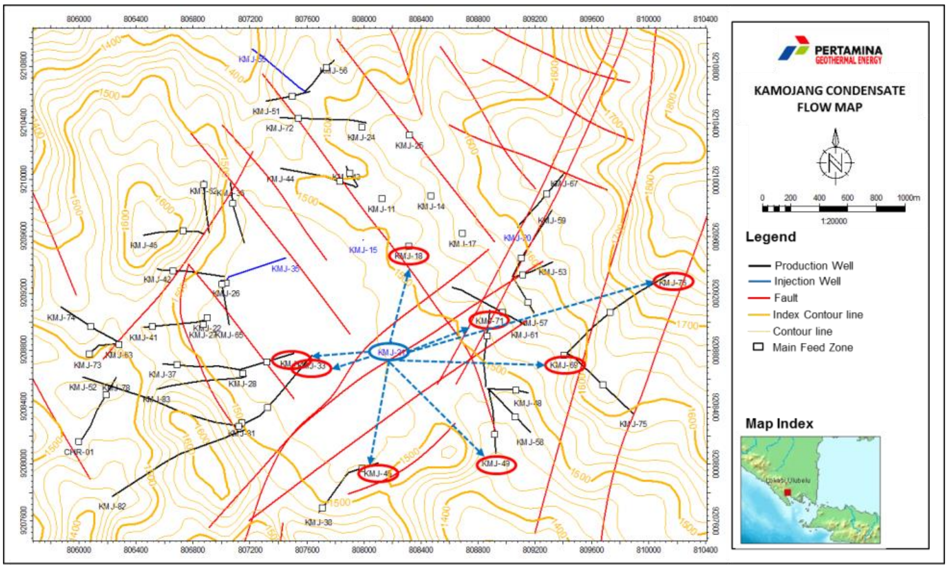


Figure 10: Map of condensate flow direction from KMJ-21.

3. CONCLUSIONS

From 2010 to 2013, the highest NCG value was found in the south-southeastern part of the field. The highest temperature, pressure, and steam production values were found in the east-southeast sector. Boron was highest in the southeast in 2010, and in the north and southeast sectors in 2013. The increase in the north was correlated to the additional injection of condensate in that sector.

Tracer tests conducted in 2013 showed that the tracer injected in well KMJ-21 was observed in production wells KMJ-18, KMJ-34, KMJ-45, KMJ-49, KMJ-71, KMJ-69, and KMJ-76, after 5 to 22 days. The time required to reach the peak concentration of the tracer in the production wells was about 5 to 22 days.

The increase of pressure in some wells corresponded to an increase in temperature, steam production, and boron. This indicated that the injected condensate enhanced the productivity of the wells.

4. ACKNOWLEDGEMENTS

The authors thank the geoscientists and reservoir engineers of Pertamina Geothermal Energy Kamojang for their support and assistance in the preparation of this paper. They would also like to thank Resty Baltasar who helped finish the paper as a geochemistry advisor.

5. REFERENCES

ASTM International. Standard specification for sampling single-phase geothermal liquid or steam for purposes of chemical analysis. Designation E947-83, 2014.

Giggenbach, W.F. "Chemical techniques in geothermal exploration." In UNITAR/UNDP Guidebook: Application of geochemistry in resources development. 1991, pp 119-144.

Giggenbach, W.F. "Magma degassing and mineral deposition in hydrothermal systems along convergent plate boundaries." SEG distinguished lecture: Economic Geology vol 87, 1992, pp 495-510.

Hidayaturrobi, A., Roberts, J.W., Sugandhi, A., Mahagyo, P., and Molling, P. "The Role of Boron Cycling and Superheat Monitoring for Field Production and Injection Strategies at the Darajat Geothermal Field, Indonesia." Proceedings World Geothermal Congress, 2010.

Nicholson, K. Geothermal Fluids: "Chemistry and Exploration Techniques." Springer-Verlag Berlin Heidelberg 1993.

Pertamina Geothermal Energy. "Feasibility Evaluation of Kamojang Geothermal Development." Internal report, 1995.

Pertamina Geothermal Energy. "Penembangan Total Project Geothermal Kamojang Unit-5 Kapasitas 1 x 30 MW." Internal report, 2010.

Powell, T. and Cumming, W. "Spreadsheets for geothermal water and gas geochemistry." Proceedings Thirty-Fifth Workshop on Geothermal Reservoir Engineering Stanford University, 2010 SGP-TR-188.

Stark, M.A., Tom Box, W. Jr., Beall, J.J., Goyal, K.P. and Pingol, A.S. The Santa Rosa – Geysers Recharge Project, Geysers geothermal field, California, USA. Proceedings World Geothermal Congress, 2005.

Suryadarma, Dwikoarianto, T., Zuhro, A. A. and Yani, A., "Sustainable development of the Kamojang geothermal field." Geothermics vol 39, 2010, pp 391-399.

Utami, P. and Browne, P.R.L., "Subsurface Hydrothermal Alteration In The Kamojang Geothermal Field, West Java, Indonesia". Proceedings Twenty-Fourth Workshop on Geothermal Reservoir Engineering, Stanford University, 1999 SGP-TR-162.