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Tompaso Geothermal Field: Early Monitoring

Teguh Prabowo, Imam Prasetyo, Sardiyanto, Wahyu Firmansyah, Fernando Pasaribu and Marihot Silaban

PT. Pertamina Geothermal Energy

Skyline Building 19th Floor Jl. MH. Thamrin no. 9 Jakarta 10340 Indonesia

teguh.prabowo@pertamina.com

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ABSTRACT

Tompaso geothermal field is an adjacent geothermal system, part of the Lahendong geothermal field; which is the first commercially developed geothermal field in North Sulawesi by PT.Pertamina Geothermal Energy (PGE). Tompaso field is currently delivering steam to support 2 x 20 MW geothermal power plant. Even though both fields are a part of the Greater Tondano geothermal system, it has different characteristic than the Lahendong field. Tompaso is a liquid dominated reservoir, with temperature ranging from 250 – 330 °C and a fluid enthalpy about 1000 – 1150 kJ/kg. Furthermore, the reservoir permeability of Tompaso field is higher than Lahendong and well-distributed on flatter terrain.

The production of Tompaso field is contributed from five production wells in a single production cluster. The brine and condensate are injected into four injection wells which are separated by two neighbouring injection clusters. The transient period of the field for the first year production are derived from pressure and production profiles. This paper intended to present the history, characterization, and early monitoring of the field.

1. INTRODUCTION

Tompaso geothermal field is located about 60 km south from Manado, the capital city of Northern Sulawesi Province, on the northern arm of Sulawesi Island (Figure 1). The field can be accessed by any land transportation from the capital. The altitude of the field ranges from 700 – 900 meters above sea level. The area is situated on flat terrain surrounded by massive old Tondano Caldera close to Tondano Lake as product of volcanic eruption of Tondano Volcano. The field is part of Lahendong working area, owned and operated as one development with Lahendong field by PT. Pertamina Geothermal Energy (PGE). It supply 40 MW (2 x 20 MW) electricity to Lahendong Unit 5 and 6 Power Plant, which is also owned and operated by PT PGE. However, Tompaso field is believed to have a different reservoir from Lahendong field separated by the Lengkoan mountain range.

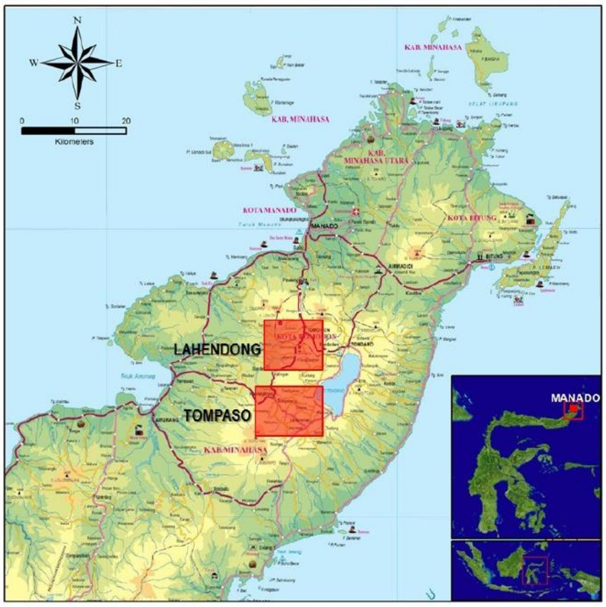

Figure 1. Tompaso field location

PT PGE had started the exploration and feasibility study of the field in 1982, this included geology, geophysics and a geochemical survey and investigation. It was followed with a drilling campaign for three exploration wells and five development wells, from September 2008 to August 2009. In order to directly develop a 2 unit power plant, additional development and drilling campaigns requesting two production wells and 4 injection wells, was conducted from March 2014 to May 2015. The Lahendong Unit 5 power plant operation commencement occurred in September 2016, followed by Unit 6 in December 2016. The utilisation of production wells also gradually executed followed by the operation of power plant, it started with three wells and continued until two wells remained.

Several monitoring programs were conducted directly after production to observe the response of reservoir, well head pressure, enthalpy, geochemistry, and steam/brine flow of production wells show length of transient period of reservoir. A tracer study was then accomplished in order to examine the connectivity of reservoir, especially from injection wells to production wells.

2. GEOLOGY OF THE FIELD

The Tompaso field is located in the northern arm of the K-shaped Sulawesi Island, Indonesia. The geothermal field lies in a quaternary volcanic area that sits on top of tertiary sediment (Siahaan 2005, after Hamilton, 1990). The area is geologically located inside of caldera complex which is called the Tondano caldera, in the Minahasa compartment.

The Minahasa compartment consists of active volcanoes that still frequently erupt, such as Mt. Soputan in the south. These volcanoes are part of the greater old Tondano volcano, which catastrophically erupted during the Plio-Pleistocene. Caldera forming deposits include a thick layer of ignimbrite (tuff, pumice, lapili) and pyroclastic breccia (Prasetyo et al., 2015). On top of that, deposits of younger volcanics including andesite and basalt lavas from Mt. Rindengan and Mt. Soputan, are settled.

A permeability study of the reservoir rocks in Tompaso suggests that the main role of permeability is faults and fractures, or second permeability (Prasetyo et al., 2015). The major faut related to the field is the Soputan fault which has NE-SW trend. The fault generates open fractures approximately trending N 45^o E to N 50^o E (Sardiyanto et al. 2015). However, based on experience in other geothermal fields of caldera setting, the role of permeability from inherent rock porsity from thick layer of ignimbrites and pyroclastics role, may also play part in the thermal fluid flow.

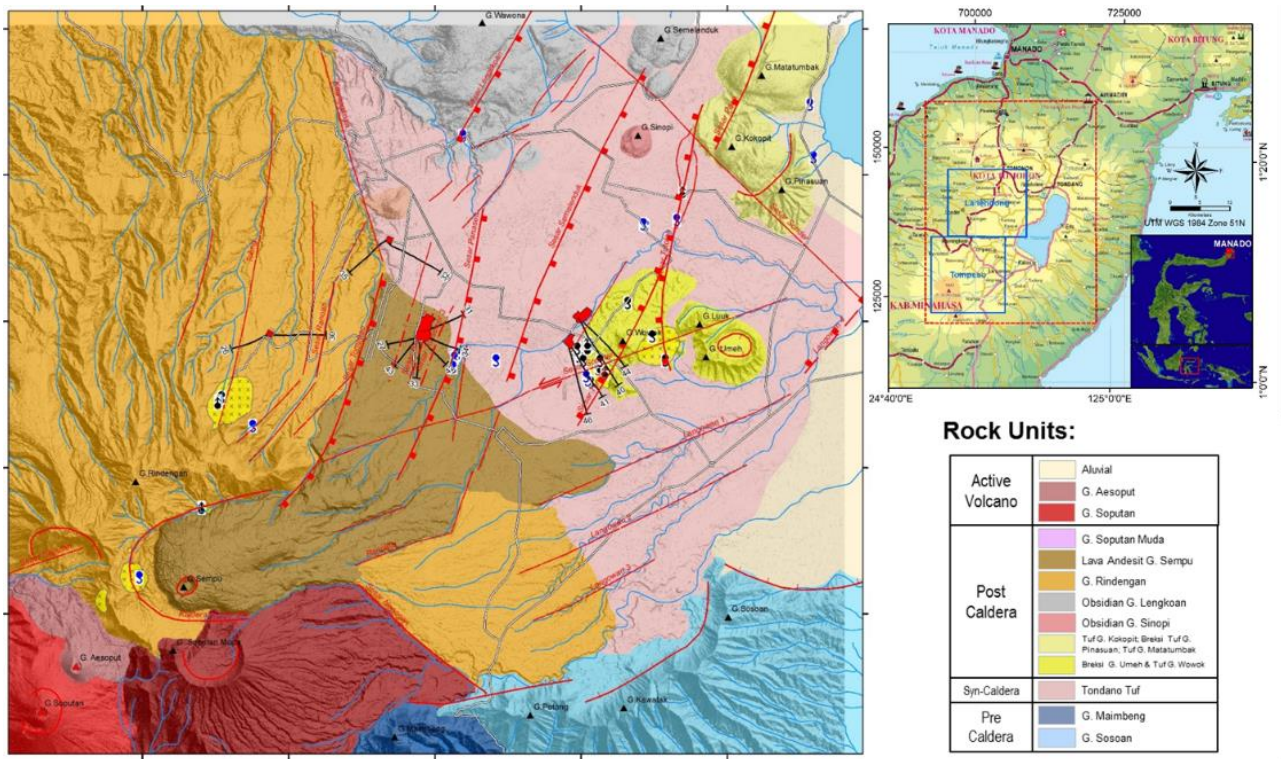

Figure 2. The geologic setting of Tompaso geothermal field (modified from Prasetyo et al., 2015)

3. FIELD OVERVIEW

Tompaso field has 14 wells in total; five production wells, four injection wells, four monitoring wells and one plug-abandoned well. The production wells are located in one production cluster, whereas the injection wells are distributed in two adjacent injection clusters. The pressure and temperature of reservoir in the production zone are typical ranging from 250 – 270 ^{o}C and 75 – 80 bar (Figure 3.a). However, the injection zone of the reservoir has higher temperature up to 330 ^{o}C (figure 3.b). Shallow boiling reservoir may appear around injection zone, but the main reservoir fluid is in compressed liquid condition.

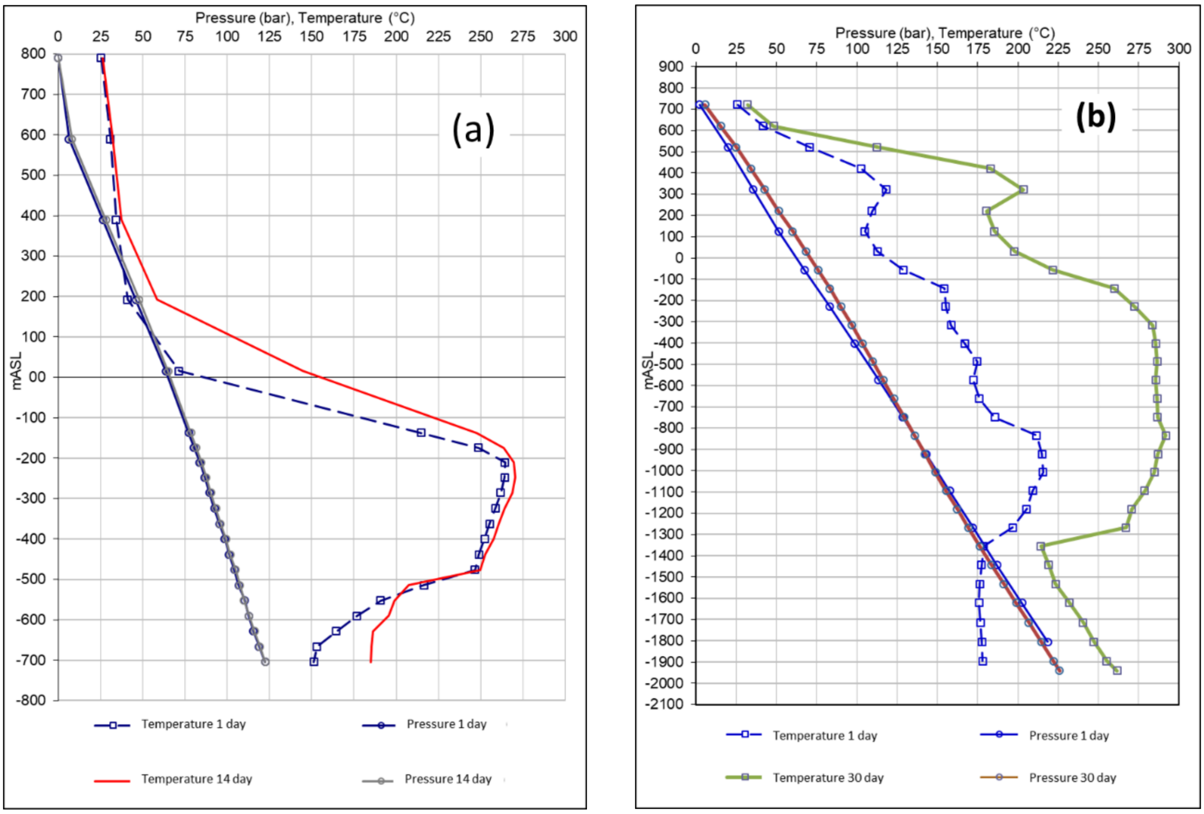

Figure 3. (a) Typical pressure and temperature profile of production wells, (b) Typical pressure and temperature profile of injection wells

The Tompaso reservoir is situated in a flat terrain which is predominantly controlled by lateral permeability, although some structures also contribute to dictate the distribution of permeability. The permeabilies were somewhat uniformly distributed from moderate to good. The top of tompaso reservoir starts from 100 meter below sea level with thickness about 400 to 500 meters. Different from Lahendong, there is no indiciation of a shallow reservoir around the production zone. However, a shallow reservoir and thermal manifestations appear around the injection zone.

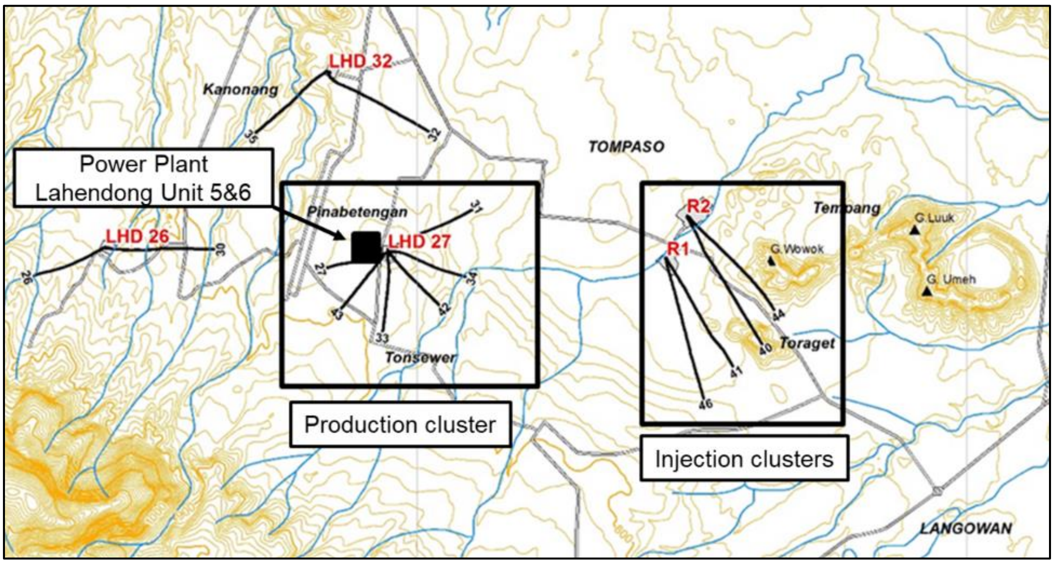

Figure 4. Well Position and directions of Tompaso Field

From the production cluster, an average of 1750 ton/hour total mass flow production, dryness varies from 15 – 18%, and entalphy ranges from 1000 to 1150 kJ/kg. In this cluster, two major production wells contribute to ~57% of total steam production, their pressure is higher than other wells (Figure 5). All brine and condensates were mixed and injected separately into 4 injection wells within a close distance and targetted in the same layer. The injection wells have deeper target than production wells in order to generate balance impact to reservoir pressure and temperature. The amount of injection fluid to the reservoir is third-quarter of the injection well capacity.

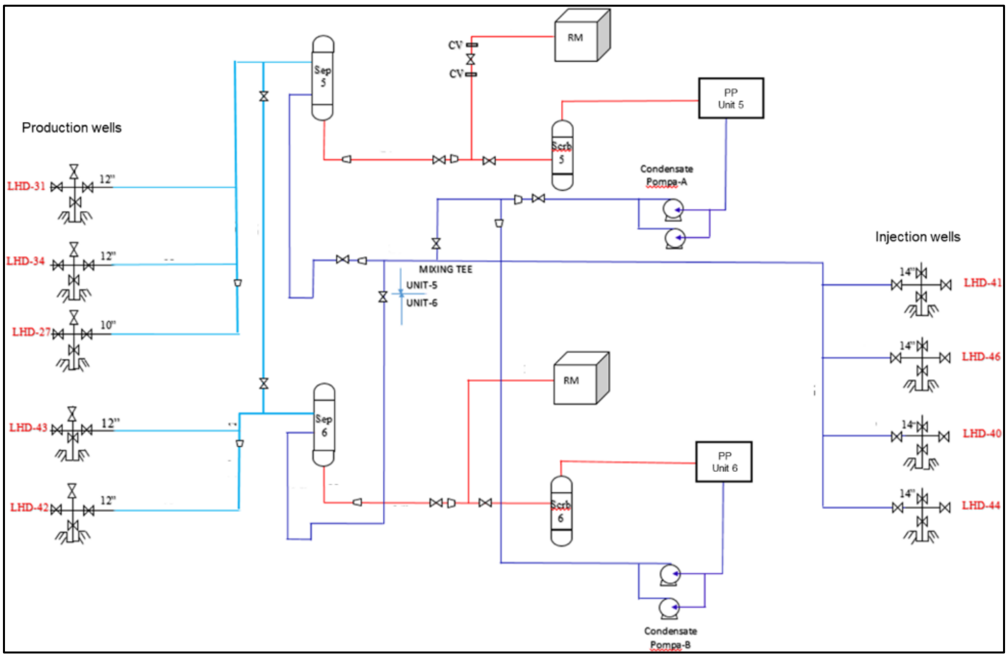

Figure 5. Gathering system of Tompaso Field

The location of the power plants at Tompaso (Lahendong Unit 5 and 6) is in the same area where the production cluster exists (Figure 4). However, the distance from the power plants to the injection area is about 3.5 km. The power plants use a single flash condense unit design with inlet pressure 7.1bar-g. Different with Lahendong, the Tompaso power plant owned by PGE and operated under energy sales contract. The challenge with the Tompaso power plant operations is the fluctuative demand from the buyer which is monopolized by PLN (the state electricity company).

4. EARLY MONITORING RESULT AND DISCUSSION

The reservoir monitoring program for Tompaso field is a combination of surface observations and subsurface observations, which is separated into several periods of time. For daily monitoring, surface data includes wellhead pressure, well throttle opening, and separator flow rate are recorded and stored into monitoring database. Geochemical, individual steam flow, brine flow, and entalphy data by tracer flow test are monitored biannually to observe major changes in reservoir. Annually, re-production test and flow performance tests are conducted to monitor the production profile change of the reservoir, insisted for each production wells. In addition, well integrity checking, subsurface pressure, temperature, and spinner measurement for production wells are conducted coherently with the power plant shut down schedule to get the based data and the changes possibly happen; blockage, temperature change, pressure drop.

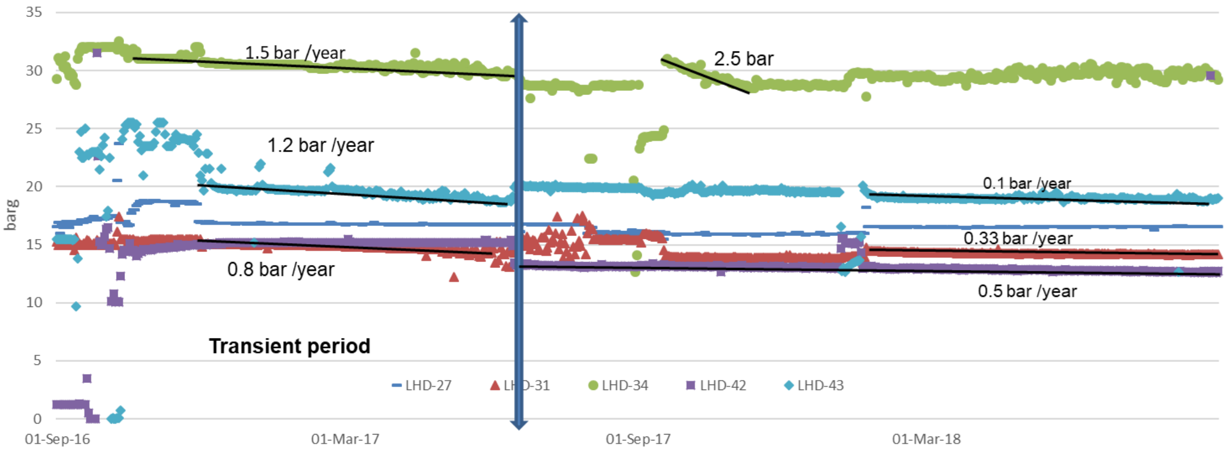

Figure 6. Well head pressure monitoring

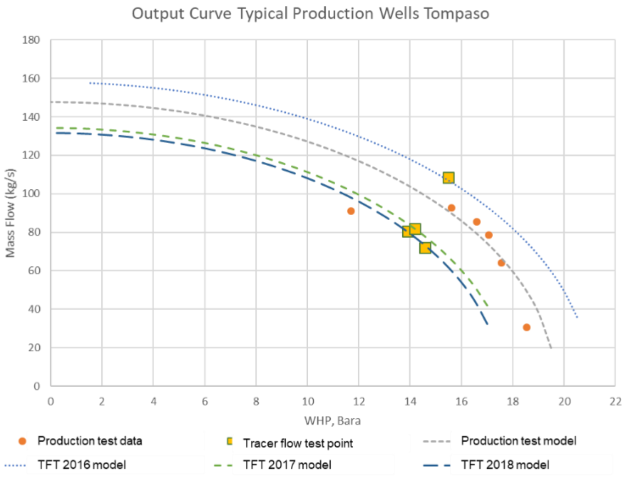

Figure 7. Typical production profile of Tompaso production wells

From wellhead pressure monitoring in constant well throttle, shown in Figure 6, some production wells experienced pressure decline. Wells with higher mass production rate suffered more pressure decline than the lowers, even LHD-27 showed almost no pressure decline. Transient Pressure Effect (TPE) period of the production happen in first 7-8 months operation, showed by steeper pressure decline (0.8-1.5 bar/year) than the period after TPE (0.1-0.5 bar/year). For the mass production decline monitoring, flow performance test or re-production test is conducted annually adjusted with the power plant shut down schedule. Combined with wellbore modelling, the average of mass production decline of the reservoir after TPE period of Tompaso field is 4%/year. This could be the result of good pressure support from injection wells or the drainage area of the production wells is quite small compared to the entire area of reservoir.

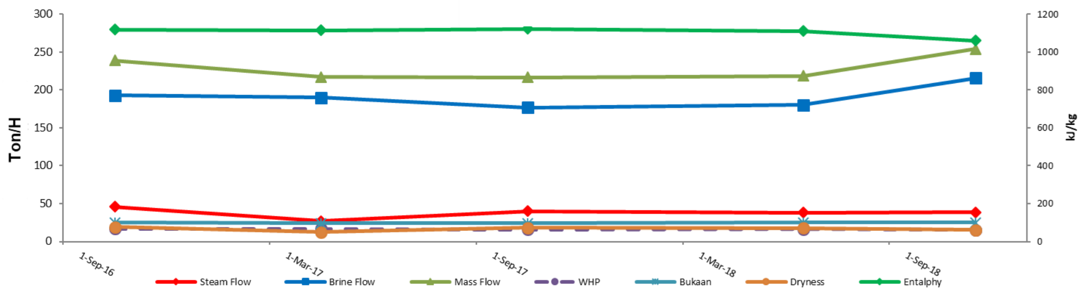

Figure 8. Typical production history profile of Tompaso production wells

Production monitoring from tracer flow test (TFT) for all production wells is quite stable for about 2 years, then there is an increase in brine production in all wells as shown in Figure 8. This increase is combined with the increase of chloride concentration sampled from production wells. From the chemistry data, it could be inferred that the rise of brine related to injection effect. However, subsurface team right now is still monitoring the change in flowrate and chemistry to confirm the continuity of the trend and the possibility of the water source.

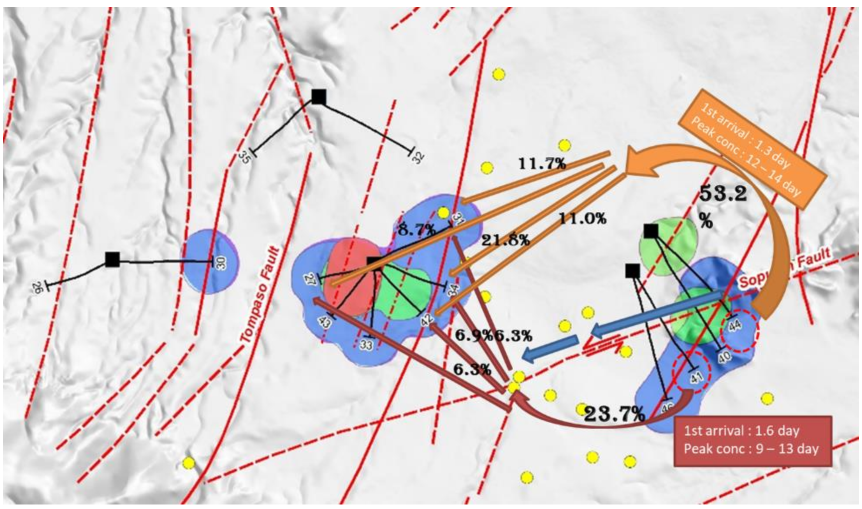

Figure 9. Tracer test result of Tompaso

Study of the production-injection connectivity itself has started by injecting a tracer into 2 injection wells, then monitoring the tracer return on 4 production wells. After the tracer return data is collected and analysed using Axelsson methods, it can be quantified into recovery of injection fluid to the production wells. The result of the study as shown in Figure 9, illistrates that about 23.7% injection fluid from LHD-41and 53.2% of injection fluid from LHD-44 (the biggest injection well capacity in Tompaso) returns back to 4 production wells. If the data results extrapolated into all injection wells and production wells with the assumption that LHD-43 and LHD-34 have similiar tracer result, LHD-40 and LHD-46 give identical impacts as LHD-41. It can then be determined that 56.2% of injection wells drive back into the production zone. The first arrival of tracer from injection wells to production wells is not more than 2 days, a peak concentration is reached after 9 to 14 days. This result inferred that the connection between the injection zone and the production zone has good permeability that could provide enough pressure support for the production zone. The flip side is that the lower temperature injection fluid might effect reservoir temperature in the production zone. This influence is continously monitored by reservoir and geoscientist in charge.

5. CONCLUSIONS

1. Tompaso geothermal field is a separated system from Lahendong geothermal field eventhough, both areas are part of the gigantic Tondano geothermal system. The characteristics of Tompaso field is flat terrain, majorly controlled by lateral permeability, with a liquid dominated reservoir fluid.

2. Based on monitoring, the average of mass production decline of the reservoir after Pressure Transient Effect period of Tompaso field is 4%/year and last TFT data indicates water infiltration to production zone.

3. The result of tracer study inferred that the connection between injection zone and production zone has good permeability that could provide enough pressure support for the production zone.

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