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The Initial-State Geochemistry as a Baseline for Geochemical Monitoring at Ulubelu Geothermal Field, Indonesia

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ABSTRACT

Ulubelu, the newest operating geothermal field in Indonesia, is being operated since the end of 2011 with installed capacity of 110 MW. As a reference in the geochemical production monitoring activities, a baseline is made by using chemical data from seven active production wells that is collected during the discharge test is performed. It is expected will assist in monitoring the changes in the chemical fluid composition from the production wells in response to fluid extraction from the reservoir as well as the response of brine and condensate reinjection into the reservoir. The relationship between the enthalpy-chloride, the chloride distribution, the distribution of SiO2, the NCG distribution, and the temperature distribution was made to see the condition of the geochemistry reservoir in the early phase of production and as a baseline monitoring program planned in the exploitation phase. The geochemical distribution map presenting hydrologic patterns that occur in the reservoir, where the fluid moves from north to south in the Ulubelu system by following the structure patterns in the field. This chemical distribution pattern also confirmed the presence a thin steam zone in the reservoir. All trends are illustrated in initials condition will likely change rapidly along with the effectiveness of the management of production and reinjection applied.

1. INTRODUCTION

Ulubelu Geothermal Field is located in Tanggamus District, approximately 100 km from Tanjung Karang city, the capital city of Lampung Province (Figure 1). A 110 MW power plant has been operating since the end of 2011 with 2 x 55MW single flash turbines. To date, ten production wells have been operated to supply steam to the power plant. The brine and power plant condensate are injected to five reinjection wells south from the production sector (Figure 2).

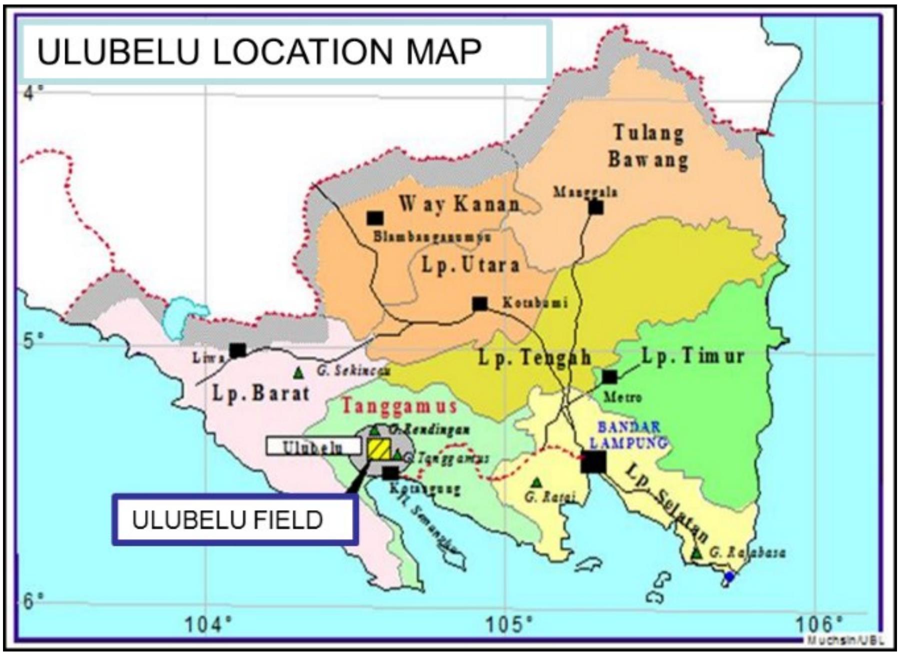

Figure 1: Ulubelu Location Map

Geochemical data before the production is gathered to generate a baseline and update the conceptual model. This paper describes how this geochemical baseline can characterize the hydrology pattern in the field. This is will be used as the basis for geochemical production monitoring activities (see Giriarso et al, 2015).

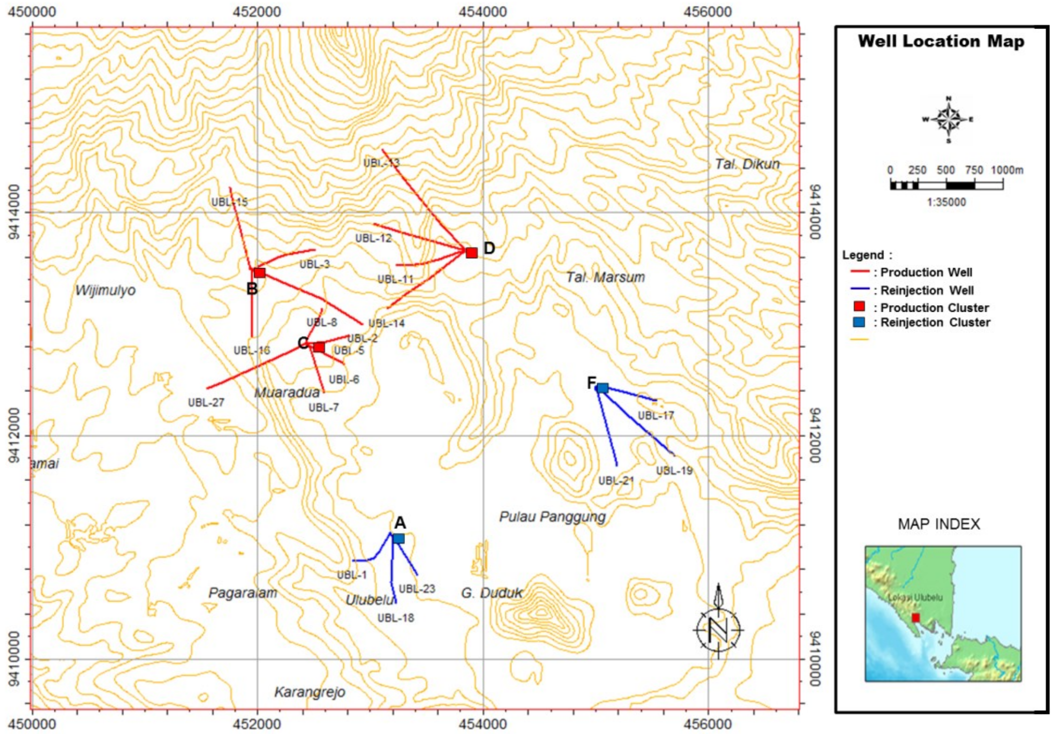

Figure 2: Location map showing the wells trajectories

2. GENERAL GEOLOGY

Ulubelu Geothermal Field is one of the geothermal systems associated with the existence of the Great Sumatran Fault. It is located (Fig. 3) in the southern part of Sumatra fault and is surrounded by several volcanoes such as Sula Mountain on the west, Korupan Mountain in the east, Rendingan Mountain in the north, Duduk Mountain in the middle, and Kukusan Mountain in the south. Geological structure are evolving dominant NW-SE normal faults with direction of dominant NW-SE and some structures with NE-SW direction. These structures form a NW-SE Graben that extends in the NW-SE direction. The NW-SE trending structure is also sub-parallel with the Great Sumatran Fault that located in the southwestern part of the field. Circular structure at the center of the depression zone was evolved as a part of permeable zone in this field. The presence of NW-SE and NE-SW structures also control the appearance of the manifestations on the west and south of the field.

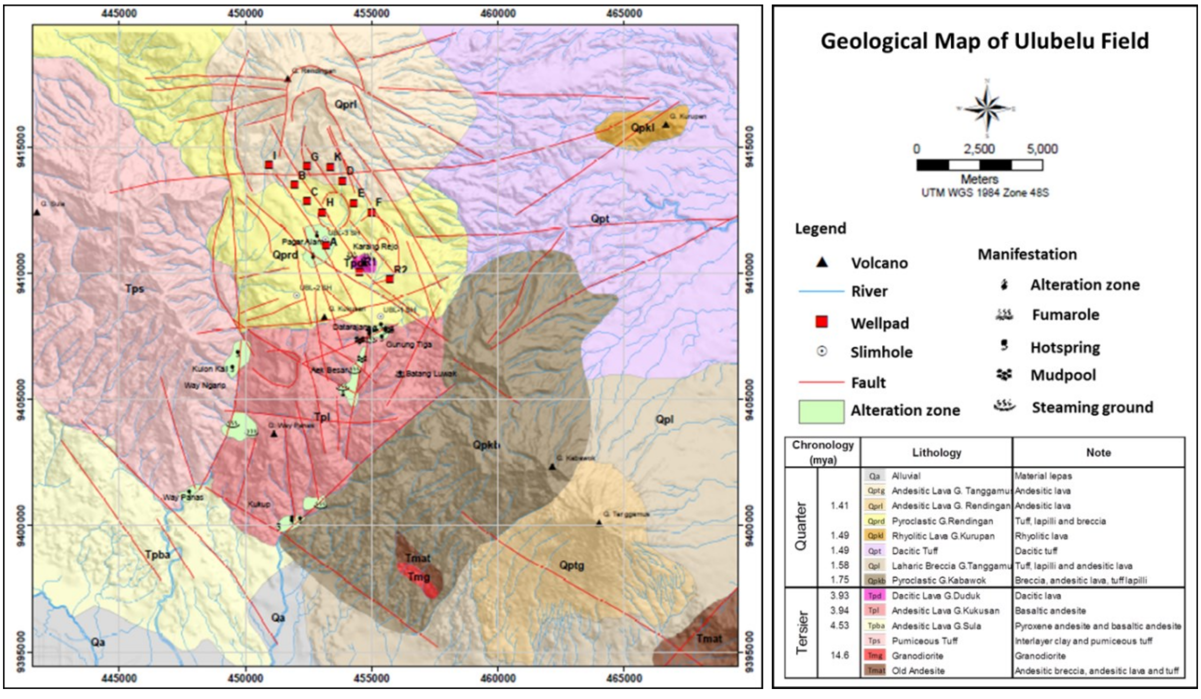

Figure 3: Geological Map of Ulubelu – Waypanas Geothermal Prospect (modified after Masdjuk, 1989).

3. SURFACE THERMAL MANIFESTATIONS

Surface thermal features in the Ulubelu Geothermal Field (Fig. 4) consist of fumaroles, steaming ground, mudpool and hot springs. Neutral chloride hot springs are found in Waypanas at lower elevations. Zone and is postulated to be the possible outflow of the Ulubelu geothermal system. From the latest survey, the chloride content of these springs ranged from 600 ppm to 700 ppm. The low magnesium content (<1 ppm) indicate that these are only slightly affected by the mixing with shallow groundwater.

At higher elevations steam-heated water, steaming ground and fumaroles are found in Pagar Alam, Gunung Tiga and Wayngarip Villages. These areas are predicted to be close to the upflow zone of the Ulubelu system. D'Amore F. and Truesdell (1985) CO_2/Ar-H_2/Ar grid from fumaroles show its reservoir temperatures range between 250-280 ^oC. These are near the measured downhole measurements from the production wells.

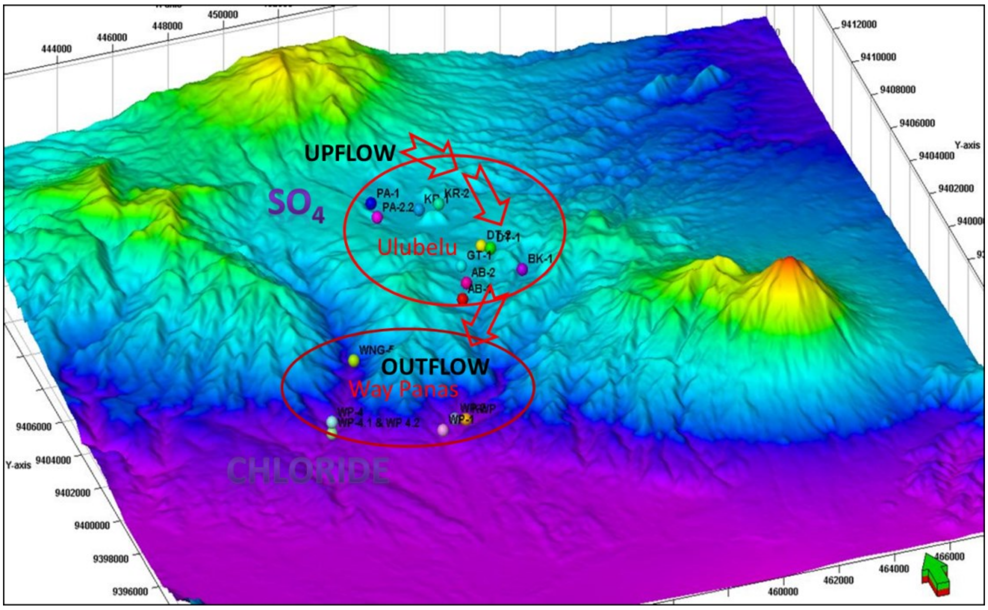

Figure 4: Surface thermal manifestation distribution map

4. BASELINE DATA SELECTION

There are seven production wells spread over three clusters. Geochemical well data were collected from the production wells two-phase lines following ASTM (2014) procedures with modifications to adapt to local conditions..

These are from wells UBL-3 and UBL-15 in cluster B, UBL-5, UBL-7 and UBL-8 from cluster C, and, UBL-11 and UBL-14 from cluster D. Baseline data used is from samples collected when these wells were discharged together.

5. GEOCHEMICAL TRENDS

From the available chemistry data, contour maps showing the distribution of Cl, Fournier and Truesdell's (1973) Na-K-Ca temperatures, and, NCG show patterns of initial state before exploitation.

IsoCl distribution patterns (Fig. 5) show that the highest Cl (950-1,050 ppm) is derived from wells UBL-15 and UBL-14 located on the north of the production zone. This decreases to the south towards the cluster C especially well UBL-5 with a chloride content of only 760 ppm.

Fournier and Truesdell's (1973) Na-K-Ca geothermometer was selected for to make isotemperature contours as the results are nearest to subsurface temperature measurements. The isotemperature contours (Fig. 6) shows the highest temperature are at the northern part of the field, which is represented by the well UBL-15, UBL-11 and UBL-14 with a temperature ranging from 270 C to 275 °C. Temperatures decrease to between 250-260 °C towards the south. The lowest temperature encountered in well UBL-8 (253 °C).

The NCG distribution pattern (Fig. 7) show that the highest concentrations are found in the cluster B wells, with the largest NCG 1.26% (wt) in well UBL-3. Meanwhile, the lowest value of NCG was found in the cluster C well UBL-5 with a value of 0.3% (wt). The NCG distribution trend is different compared to other geochemical distribution patterns may be due to the presence of a thin vapor zone in wells at cluster B which contribute to the high content of NCG in this cluster. This zone was also identified by the temperature and pressure measurement data which show subsurface boiling zone at a depth of -200 to -400 masl. However, this vapor zone does not contribute significantly to the steam production rate and wells discharge enthalpy in cluster B, as no excess enthalpy was found. The existence of the steam cap is quite interesting in reservoir management because this zone has the potential to thicken and extend due to the pressure drop and water level drop. It may change the reservoir management strategy that currently applied.

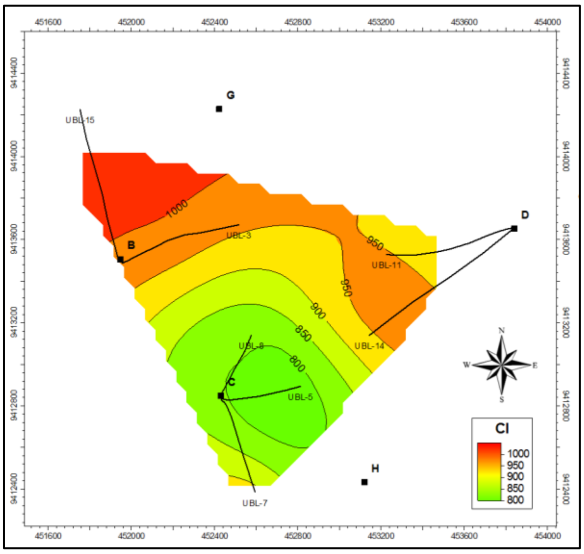

Figure 5: Ulubelu isoCl contour map

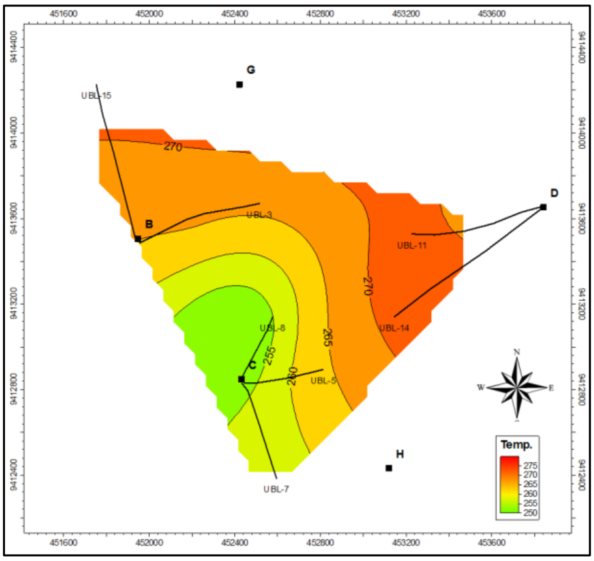

Figure 6: Ulubelu Fournier and Truesdell (1973) Na-K-Ca isotemperatures

The above distribution patterns, verify the present conceptual model that stated the upflow zone is around Rendingan Mountain or in the northern part of the field. The hot fluids, then flow towards the south through the NW –SE trending faults and outflow in Waypanas.

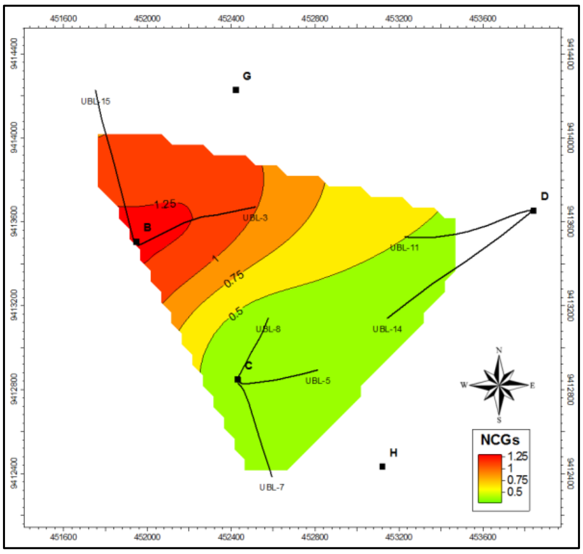

Figure 7: Ulubelu NCG contour map

6. MIXING MODELS

An Enthalpy-Cl diagram (adopted from Nicholson, 1993 and shown in Fig. 8) was made by plotting the Eenthalpy, based on calculated Na-K-Ca geothermometer (Fournier & Truesdell, 1973), and well discharge reservoir Cl. It also includes the Waypanas neutral Cl thermal manifestations plotted with respect to its enthalpy based on Truesdell's (1976) quartz adiabatic geothermometer. The plot shows two general patterns of mixing processes.

The first is obtained from the variation of Cl content and enthalpy of the wells. Wells in clusters C and D with the highest enthalpy (1100 - 1150 kJ/kg) and Cl are almost similar to the parent fluid that has a temperature of 280 °C. Mixing processes found a more dilute fluid with the lower enthalpy ranged from 950 - 1090 kJ/kg in the cluster C wells. However, the enthalpy is still high if it is projected to zero Cl. This suggests that steam heated water is a part in the mixing process.

The second pattern is the conductive cooling line toward the neutral Cl Waypanas manifestations. This occurs when the hot fluid flowing to the surface at a fast rate through the permeable zones without mixing or dilution with shallow ground water. This process is a possible origin of the Waypanas Cl manifestations with low enthalpy (around 700 kJ/kg or 166 °C).

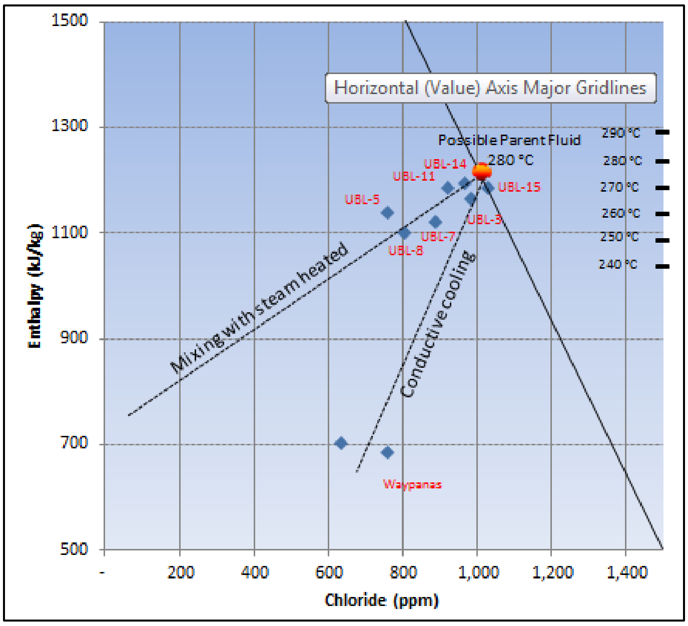

Figure 8: Ulubelu Enthalpy-Cl diagram

7. CONCLUSIONS

- The geochemical distribution patterns such as Cl content, SiO2 content and temperature distribution consistently give an overview the hydrology of the Ulubelu geothermal system where the hot fluid coming from the north flowing to the south.
- Enthalpy-Cl diagram shows the mixing process of the wells with steam heated waters, and, possible conductive cooling from the Ulubelu reservoir fluids to Waypanas.

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