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West Edgefield Evaluation of the Darajat Geothermal Field, Indonesia

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ABSTRACT

One of the main objectives of the West Darajat Edgefield Evaluation was to gain a better understanding of the southwest, west and northwest portions of the Darajat reservoir by using information from newly drilled wells and combining them with recent reservoir interpretations. Three step-out and edgefield wells in southwest and west Darajat were drilled during 2009-2011, and these wells offered new information about these portions of the reservoir. The long-term objective of this study is to assist in the strategic field development, specifically, whether to build a new pad in the northwest from which to drill additional production wells.

Recent analyses indicate that the upflow of the Darajat geothermal system is located in the northwest based on consistent high CH_4 (since initial production), heavier stable isotopes, high initial steam deliverabilities, low production decline rates and high initial reservoir pressures and temperatures. The results of the edgefield wells in the west indicate the possible extent of the commercial reservoir in this area although further evaluation of the productivity and permeability of both wells F1 and F2 is still incomplete. Meanwhile W3, the southwest step-out well, shows non-commercial permeability and encountered low temperatures. Re-interpretation of the MT/TDEM data shows thickening and deepening of the clay cap in the southwest, west and northwest outside the current production area, and may eventually represent a limit to commercial permeability as well. This hypothesis is corroborated by the MEQ clusters during blind drilling of the step-out and edgefield wells.

The Kendang Fault appears to be the geologic boundary of the Darajat geothermal system in the west and southwest based on results of wells F1, F2 and W3 wells. Similar thickening and deepening of the clay cap and MEQ swarms in northwest Darajat suggest that this fault may also be the boundary of the reservoir in this part of the field. However, the presence of young domes and the upflow in this area makes northwest Darajat interesting. A step out well towards the northwest could validate this hypothesis.

1. INTRODUCTION

The Darajat geothermal field is located about 50 kilometers southeast of Bandung in West Java, Indonesia at an elevation of 1,750 – 2,000 m above sea level. Although geothermal investigations at Darajat began in the early 1970's, commercial production started in 1994 with the commissioning of the 55 MWe Unit I which is owned and operated by PLN. Current installed capacity at Darajat is 271 MWe with the additions of Unit II (95 MWe) in 2000 and Unit III (121 MWe) in 2007; both Units II and III are owned and operated by Chevron Geothermal Indonesia.

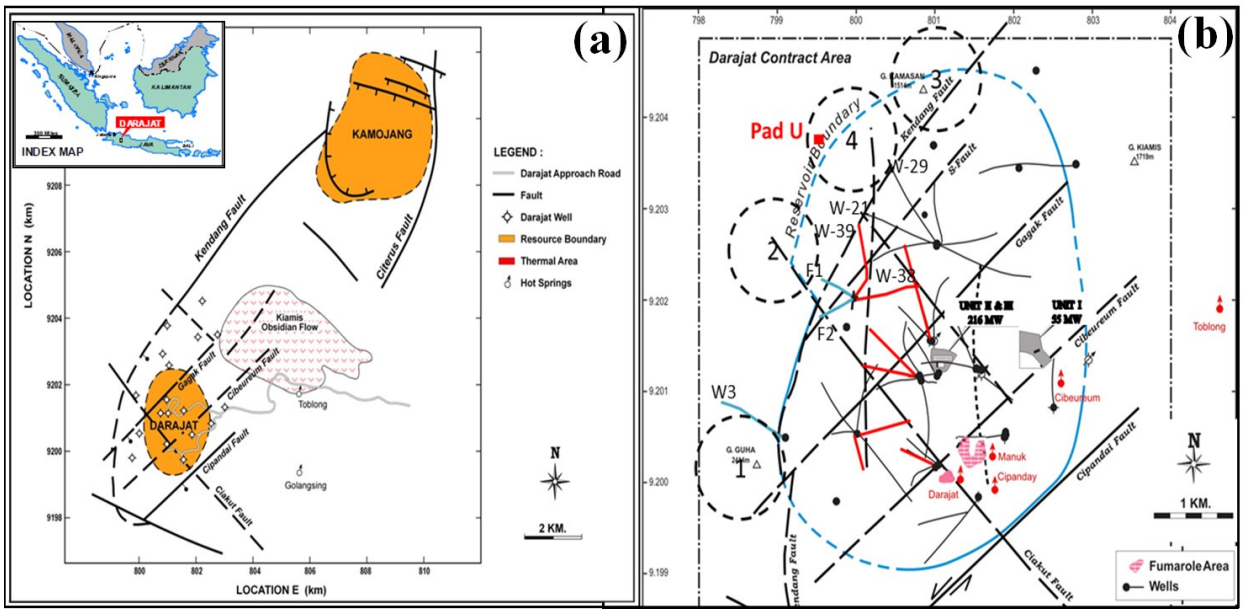


Figure 1: (a) Maps showing the regional structures and locations of the Darajat and Kamojang geothermal fields (modified from Stimac et al., 2011). (b) Darajat field map showing the wells (red and blue lines) drilled during the 2009-2011 Drilling Campaign, the four recommended prioritized step-out areas (dashed circles with numbers) and proposed location of Pad U.

One of the objectives of the 2009 - 2011 Darajat Drilling Campaign was to probe the extension of the commercial reservoir towards the west as defined by the updated interpretation of resistivity, gravity and micro-earthquake (MEQ) data (Rohrs et al., 2009). Aside from drilling production make-up wells, four wells were originally designed to test the extension of the main reservoir towards the west and southwest as denoted by the step-out priority areas (Figure 1). Pad U has been identified as a potential location for drilling make-up wells in the future. In the 2012 Darajat Asset Development Plan (Pasaribu et al., 2012), this pad is supposed to be built prior to the next drilling campaign in 2017, and this was the main driver used to justify this study.

2. RESULTS OF DRILLING

Drilling of make-up wells Well-21, 29 and 39 within the commercial production area (but directed towards the edge of the field) did not encounter any significant problems or surprises in terms of both drilling operations and steam deliverability (Tables 1 and 2). Unfortunately, drilling of step-out and edgefield wells F1, F2 and W3 was characterized with significant drilling problems, which resulted to the premature abandonment of one of the wells and disappointing steam deliverabilities. Well-40 was eventually abandoned after drilling to the 20" casing setting depth and encountering an obstruction at 367' MD while preparing the hole for the installation of the 26" casing (Figure 1). F1 was sidetracked from 5,039' MD due to a stuck pipe in the 12-¼" hole. Similarly, F2 was sidetracked due to significant drilling problems starting at 6,031' MD in the original hole. Although delineation well W3 was drilled without any significant problems, a fish was left at 8,406' MD when the drill pipe got stuck after TD'ing the well.

Well-21 is currently the biggest producer in Darajat Field while both Well-29 and 39 produced higher actual compared with their expected steam rates (Table 2). Unfortunately, step-out and edgefield wells F1, F2 and W3 were all not commercial. F1 and F2 appear to have encountered some permeability but access problems have prevented full testing and complete evaluation of these wells.

Well	TD	Target	Azimuth / Inclination, °	TLC (ft MD)	Remarks
21	7,839' MD (818' BSL)	Feed zone cluster; Kendang Fault	283 / 39	3,665	The biggest producer in the field.
29	8,472' MD (1,262' BSL)	Feed zone cluster; Kendang Fault	330 / 25	3,914	
39	7,396' MD (331' BSL)	S and Kendang Faults; Feed zone cluster;	348 / 45	4,894	The first 3D "Build-Turn-Hold" trajectory well in Darajat field.
F1	7,437' MD (306' BSL)	S and Kendang Faults	299 / 34	4,384	Sidetracked due to drilling problems.
F2	6,686' MD (381' BSL)	S and Kendang Faults	288 / 44	5,522	Sidetracked due to hole cleaning issues and possible sloughing paleosol.
W3	8,923' MD (690' BSL)	Extension of the S Fault	282 / 40	8,234	Heat-up surveys indicate that well did not encounter reservoir conditions.

Table 1: Drilling summary for step-out and edgefield wells in west Darajat

Well	Expected Steam, kg/s	Actual Steam, kg/s	WHP, bara	Remarks
21		67	15	Value of Information well
29	29	49	17.5	Initial steam rate
39	29	30	19.5	Initial steam rate
40	7	N/A	N/A	Suspended well
F1	7			Not flowed yet
F2	11			Not flowed yet
W3				Value of Information well; outside the reservoir

Table 2: Comparison of expected versus initial steam rates for step-out and edgefield make-up wells

3. LITHOLOGY AND ALTERATION

Most of the lithology was identified using a binocular microscope from rock cuttings sampled every 20' of drilled depth. In some wells, borehole image from Formation Micro Imaging (FMI) data, sidewall core and thin sections were used to identify the lithology especially in the reservoir hole section where mud circulation was lost and rock cuttings are absent.

Edgefield Well-21 and 29 encountered similar rocks as intersected by wells drilled inside the Darajat production area. The upper sequence consists of fine grain tuff and volcanic block breccias with intense argillic alteration which forms the cap to the geothermal system. The middle sequence consists of andesite lava and microdiorite (quartz diorite) intrusions that comprise the "andesite lava/intrusive complex" the main reservoir. The lower sequence consists of intercalated tuffs and andesite lava flows.

In general, the lithologies encountered by the step-out wells were dominantly pyroclastics. This was unexpected as both F1 and W3 were designed to penetrate the andesite/intrusive complex comprising the main Darajat reservoir in their bottom portions. Another significant surprise was the dacite unit encountered by Well-39, F1 and F2 (and 38) as earlier drilled wells did not encounter any dacitic rocks in this part of the field. Moore (2012) reported that the dacite encountered in Well-38, 39 and F1 appears to be part of a shallow intrusion (cryptodome). In addition, these three wells encountered a thicker sequence of lahar with andesite lava and dacite intrusion with strong propylitic alteration. The presence of lahar in the bottom part of Well-39 and F1 indicates that these wells are probably at a fair distance from the volcanic vent/s. Alteration and veining varies from weak to strong with the most

intense alteration occurring at intermediate depths. Silicification of the lahars is common suggesting that the lahars were altered by upwelling thermal fluids with temperatures >200°C. The location of edgefield well F2 suggests that it was drilled in a fault zone that allowed thermal fluids to migrate upward.

The mineral assemblages in F1 and F2 are consistent with those found in wells within the central production area in the Darajat field. The top of the propylitic zone, defined by the first appearance of epidote occurs at a depth of ~3,600' MD. The alteration assemblage in the propylitic zone appears to reflect a complex thermal history (Moore, 2007). An older thermal regime is characterized by epidote, garnet and traces of actinolite and this mineral assemblage suggests temperatures in excess of 290°C. This is probably the initial liquid-dominated geothermal system that was a precursor of the current steam-dominated system in Darajat (Moore, 2007). As the system cooled, marginal waters invaded the reservoir and resulted in the deposition of anhydrite and wairakite. The absence of contemporaneous epidote suggests temperatures did not exceed about 250°C. With continued cooling, laumontite, late-stage calcite and mixed layered illite-smectite and chlorite-smectite formed which are typical of temperatures <225°C (which corresponds to the highest measured temperature in F2). The formation of inter-layered illite-smectite with high contents of smectite is consistent with low-to moderate-temperature alteration above 180°C. These minerals may have formed as the system cooled and marginal waters invaded and the rocks further validating the observation that Well-F2 is at the edge of the reservoir.

In southwest step-out well W3, Moore (2012) postulated that the occurrence of smectite and inter-layered chlorite-smectite in the lower portions of the well where typical high-temperature epidote, garnet, prehnite and wairakite are found suggests that the rocks intersected by W3 have had a complex thermal history similar to F2. However, temperature and other evidences indicate that W3 was drilled outside the Darajat geothermal system.

4. STRUCTURES

Rohrs et al. (2009) stated that the dominant regional geologic structures in Darajat have a NE-SW trend although NW-trending structures are also apparent at both the Darajat and Kamojang geothermal fields (Figure 1). At Darajat, the NE-SW trending structures include the Kendang, Gagak, Cibeureum and Cipandai Faults while the NW-SE trending faults include the Ciakut Fault within the production area and an unnamed fault to the south. Both the Darajat and Kamojang fields are located east of the Kendang Fault, a significant NE-trending regional structure that straddles both geothermal fields. Structures such as the Kendang and the Citerus Faults (east of Kamojang) could form structural boundaries to the geothermal systems (Figure 1), but this still needs to be confirmed through exploratory drilling at both fields. The non-commercial deliverability and low measured temperatures in step-out (W3) and edgefield wells (F1 and F2) suggest that the Kendang Fault is the west-southwest boundary of the commercial production area of the Darajat Field.

Recent surface mapping by Stimac et al. (2011) delineated surface traces of the N-S and NW-SE structures and reported that NW Darajat seems to host numerous young volcanic domes indicative of more recent volcanism in this part of the field. Recently, Simatupang and Golla (2012) provided geochemical evidence that supports the occurrence of the N-S and NW-SE structures.

In northwest Darajat, Stimac et al. (2011) deduced that the one of the youngest lavas appeared to have erupted from a volcanic vent that wrapped up the west and south sides of the Kiamis dome, and include vents at Puncak Cae and Gagak (Figure 1). These latter lavas appear to have buried the Kendang Fault scarp and flowed downhill to the west hence it appears that there may be potential high temperatures beyond the Kendang Fault. Northwest Darajat is characterized by numerous young circular volcanic centers that may be related to the high temperatures encountered by edgefield Well-21 and 29. The dacitic cryptodome identified in the step-out wells may provide further evidence of the presence of high temperatures (heat source?) in this part of the field. Similarly, the theory of Simatupang and Golla (2012) that the main upflow of the Darajat field is in the northwest may be validated with further evaluation of the role of the dacitic cryptodome.

5. RESERVOIR PRESSURE AND TEMPERATURE

Measured temperatures and pressures indicate that W3 in southwest Darajat intersected a region outside a geothermal reservoir (Fitriyanto, 2011; Pasaribu et al., 2012). Maximum measured temperature in this well is only 180°C while typical temperatures in the Darajat reservoir is >220°C (Figure 2). Also, pressure data shows that W3 encountered liquid at 7,086' (255 m BSL) while typical producers exhibit all steam conditions. Even if the bottom is liquid-filled, average wellhead pressure (WHP) a year after W3 was completed is only 10-15 barg indicating that the liquid at the bottom of the well is probably drilling mud and that this well has tight permeability at/near the bottom. The low measured temperatures in W3 combined with its slow heat-up suggest that this well penetrated an area of low permeability and probably outside the commercial reservoir.

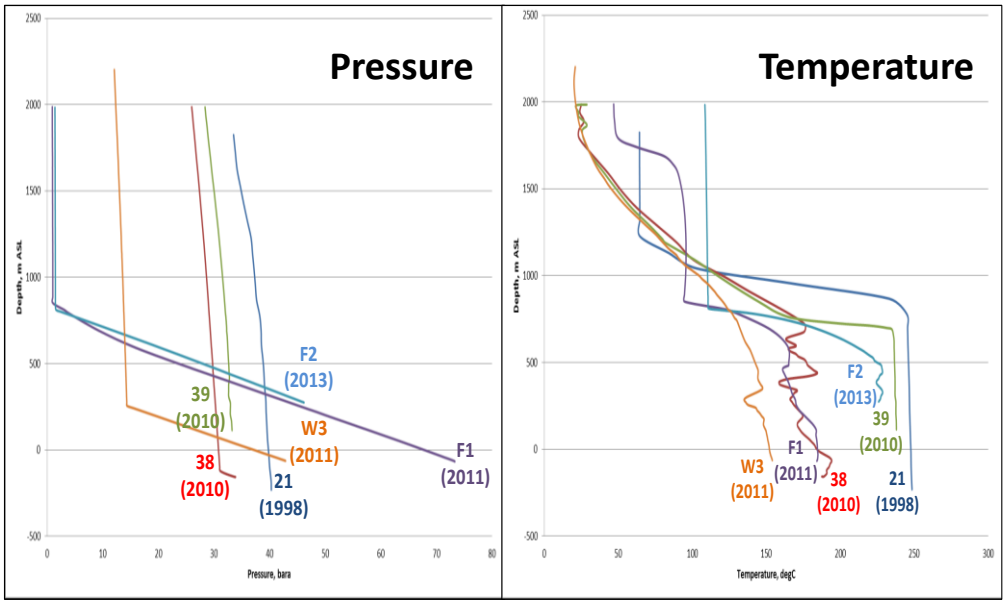


Figure 2: Measured pressures and temperatures of step-out and edgefield wells in west Darajat. Except for Well-21, all wells were drilled during the 2009-2011 drilling campaign.

Edgefield wells F1 and F2 in west Darajat exhibit slow heat-up behavior untypical of production wells at Darajat (Figure 2). Although both the temperature data shown in Figure 2 for F1 and F2 are not stable yet, this slow heat-up probably indicates that both these wells did not encounter commercial permeability. Maximum measured temperature in F2 was 222°C while F1 was <200°C. Similar with the temperature data, the unstable pressure data cannot really be used to decipher the reservoir pressures that F1 and F2 intersected. The liquid level at about 850 m ASL is probably trapped drilling fluids inside the wellbore and not representative of reservoir water levels (Figure 2).

Unlike the step-out wells, both Well-29 and 39 show the characteristics of a typical production well in vapor-dominated geothermal systems. Both wells have rapid heat-up period with temperatures quickly reaching above 220°C. Both wells (and Well-21) were drilled in the high pressure reservoir sector of the field and targeted to intersect the Kendang Fault. The shut-in pressures of these wells are >28 barg, higher than the shut-in pressure at F1 and F2 at 24 barg; both F1 and F2 also targeted the Kendang Fault.

Analysis of wells W3, F1 and F2 suggests that the Kendang Fault is the boundary of the reservoir in southwest Darajat especially south of the NW-SE trending Ciakut Fault (Figure 1). However, this cannot be said with a fair degree of certainty north of the Ciakut fault. There is appears to be apparent good permeability along both S and Kendang Faults as exhibited by Well-21, 29 and 39 (Figure 1) which have intersected both structures. F1 appears to have encountered the S and Kendang Faults at 4,991' MD (-482 m BSL) and 6,700' MD (67 m BSL), respectively, but permeability was likely damaged with cement while side-tracking this well. The relatively higher temperatures encountered by F2 (compared with W3 and F1) suggests that this well was drilled very close to the commercial geothermal system.

7. MICRO-EARTHQUAKE (MEQ) MONITORING

Micro-earthquake (MEQ) monitoring in Darajat has been used to improve the understanding of the induction mechanism of low magnitude seismic events and determination of injection pathways in the reservoir. At Darajat, the dominant mechanism of MEQ events is interpreted to be due to condensate injection into the reservoir. In this mechanism, as the condensate injectate travels through hot rocks in the fracture system, it cools and contracts the rocks thus the frictional force across the fractures lessens and allows the rocks to be more prone to slip. This is analogous to the induction mechanism interpreted for The Geysers field by Stark (1992). It is believed that the presence of abundant MEQs indicates the areas where fractures have relatively lower permeability and where the stress can be easily accumulated. Together with thermal contraction, there is pressure build-up inside these fractures as injected fluids downflow on these pre-existing but tight fractures until pressure exceeds the frictional force and failure occurs. This failure produces the low magnitude (M3) MEQs.

The MEQ clusters in Darajat are mostly located around the injection wells and the new wells during and after the blind drilling with water phase. Blind drilling with water starts after the first loss circulation in the reservoir hole section of the well. The largest number of MEQs was induced during the drilling of step-out and edgefield wells (Figure 3). Contouring the density of MEQs showed that a big portion of the drilling-related MEQs are located near and align with the southwestern traces of both S and Kendang Faults. The elongated contours of MEQ density during the drilling of F2 suggest that the S Fault possibly extends further to the southwest. In fact, W3 appeared to have encountered the trace of the S Fault near its bottom but the fish at 8,406' – 8,923' MD probably blocked this potential feed zone.

Epicenter maps for MEQs above and below sea level while drilling F1, F2 and W3 show that majority of the MEQs occurred deep (Figure 4). This suggests that the drilling fluids downflow along these tight fractures that extend deeper than commercial reservoir depths. The MEQ epicenters also suggest that permeability is tight (or non-commercial) immediately outside and at the edge of the known commercial production area.

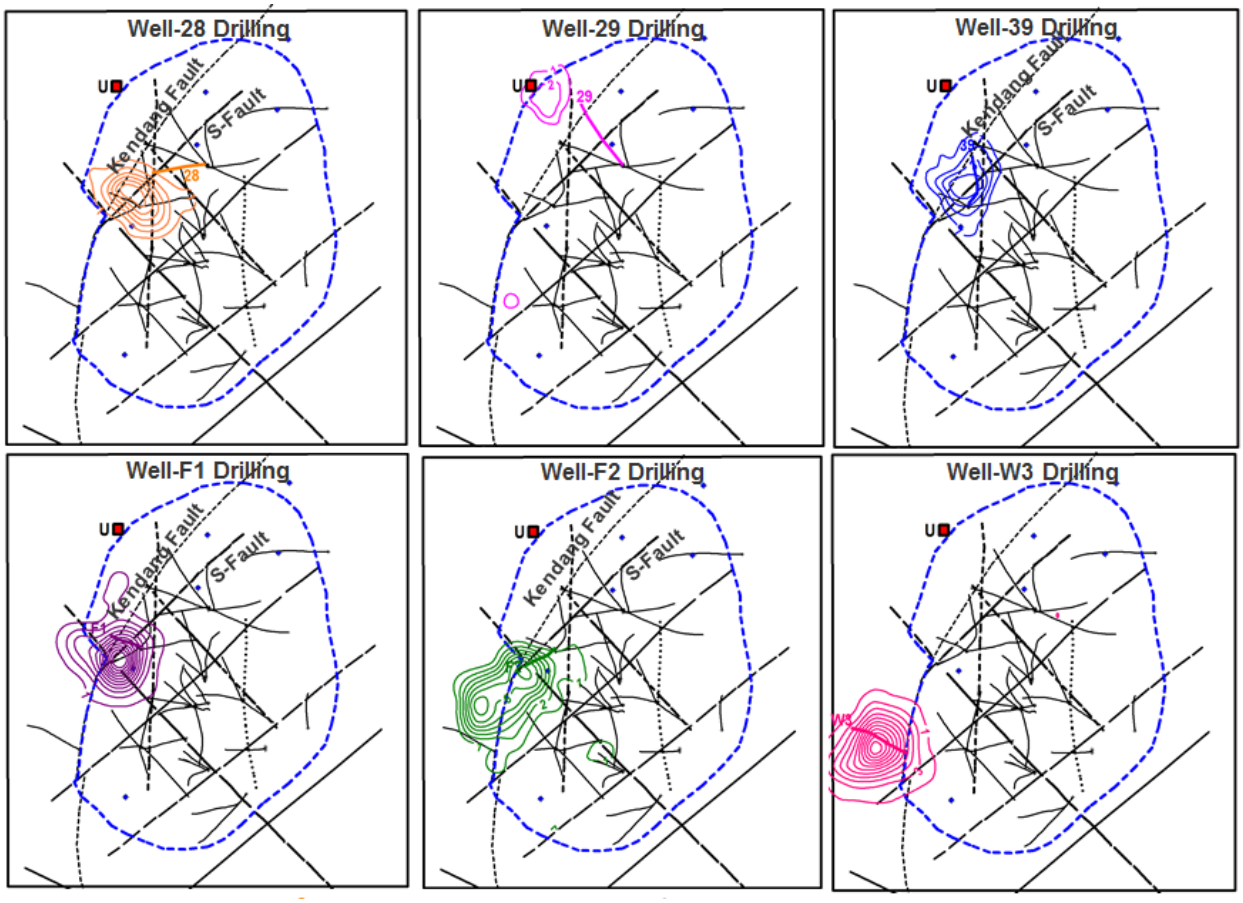


Figure 3: Maps showing contours of MEQ density during the blind drilling of the edgefield and step-out wells in west and southwest Darajat. These contour maps were produced by binning the epicenters into 250 m x 250 m grids and then contouring the binned data.

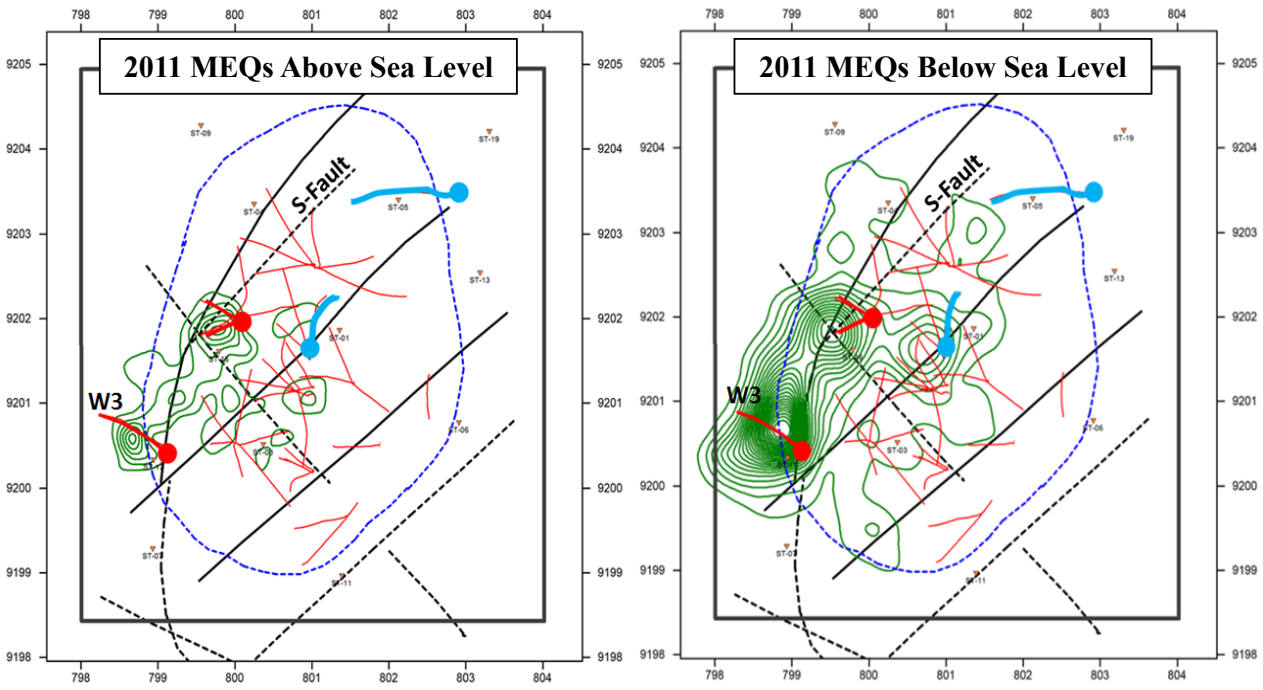


Figure 4: Maps showing density contours of MEQs recorded in 2011. Deep MEQs are mostly located in the central and western portions of the production area while shallow MEQs are mostly located southwestern tails of both S and Kendang Faults. Red lines are production wells while blue lines are injectors (from Irfan, 2012).

Another interesting feature of these MEQs is the occurrence of seismicity about half kilometer away from Well-29 towards the proposed location of pad U (Figure 3). The significant seismicity immediately northwest of the Kendang Fault suggests that drilling fluids moved through some permeable pathway away from Well-29 towards the area under Pad U where there are relatively lower permeability rocks (Figure 5). There is an upside potential to test the reservoir between the bottomhole of Well-29 and the

MEQ hypocenters (500 – 1,000 m BSL) under Pad U. The downside of this clustering of MEQs is that it suggests Kendang Fault is the geologic boundary of the reservoir even in northwest Darajat.

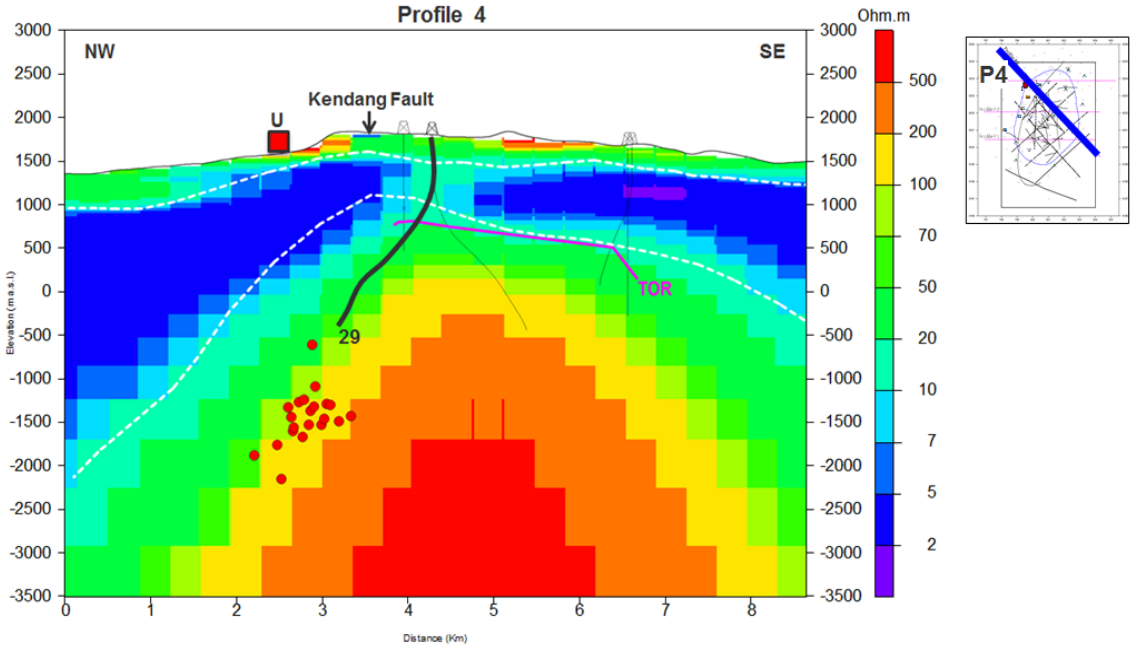


Figure 5: Cross-section across step-out well F1 showing the interpreted base of the clay cap between the 1D model using the invariant mode (dashed white line) and 3D MT model (dark blue in colored background). Red dots are MEQ hypocenters during the blind drilling of Well-29 in 2008.

8. MAGNETO-TELLURIC (MT) AND TIME DOMAIN ELECTRO-MAGNETIC (TDEM) INTERPRETATION

The 1997 and 2004 Magneto-Telluric (MT) data was re-evaluated to better define the western boundary of the Darajat field especially after the results of drilling step-out well W3. Re-analysis included static shift correction using Time Domain Electro-Magnetic (TDEM) data, 1D forward modeling using invariant mode and comparison with a 3D inversion model. A Lesson Learned during the review of step-out well W3 (Figure 6) and F1 (Figure 7) was that the thick clay cap encountered by these wells was better matched with the 1D model using the invariant mode approach. In this re-evaluation, the reservoir boundary was delineated by areas where the low resistivity layer steeply dips and significantly thickens. The low resistivity layer was defined as the layer where the value of resistivity is <10 ohm-m and usually indicates the presence of smectite clay which caps the geothermal reservoir.

There is good correlation between the 1D and 3D MT models, especially the base of the clay cap, directly atop the geothermal system and poor correlation away from or at the edge of the reservoir in southwest Darajat (Figure 6). Also, there is a little bit of offset (~200 m) with the base of the clay cap defined from the Methylene Blue (MeB) analysis of rock cuttings from W3 compared with the 1D model. Note that the MEQs occur directly below W3 suggesting that the reservoir directly beneath this well has tight fractures or non-commercial permeability. Thus, it is expected that the Top of Reservoir (TOR) will steeply dip as it normally follows the 240ºC isotherm hence putting W3 outside the commercial Darajat reservoir.

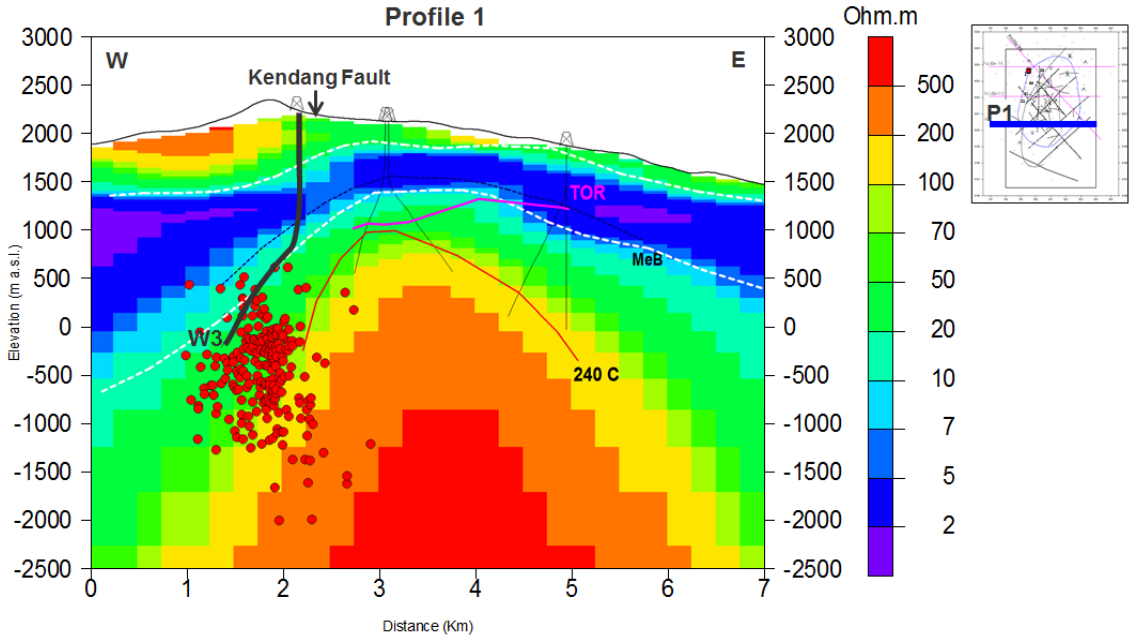


Figure 6: Cross-section across step-out well W3 showing the good correlation of the interpreted base of the clay cap based on the 1D model using the invariant mode (dashed white line), 3D MT model (dark blue in colored background) and as observed from Methylene Blue (MeB) analysis of rock cuttings (dashed black line). Red dots are MEQ hypocenters during the blind drilling of W3 in 2011.

In west Darajat, there appears to be good correlation between the 1D and 3D models and the MeB analysis regarding the base of the clay cap (Figure 7). Also, the MEQs along F1 and directly below this well suggest tight permeability in the immediate vicinity of this well.

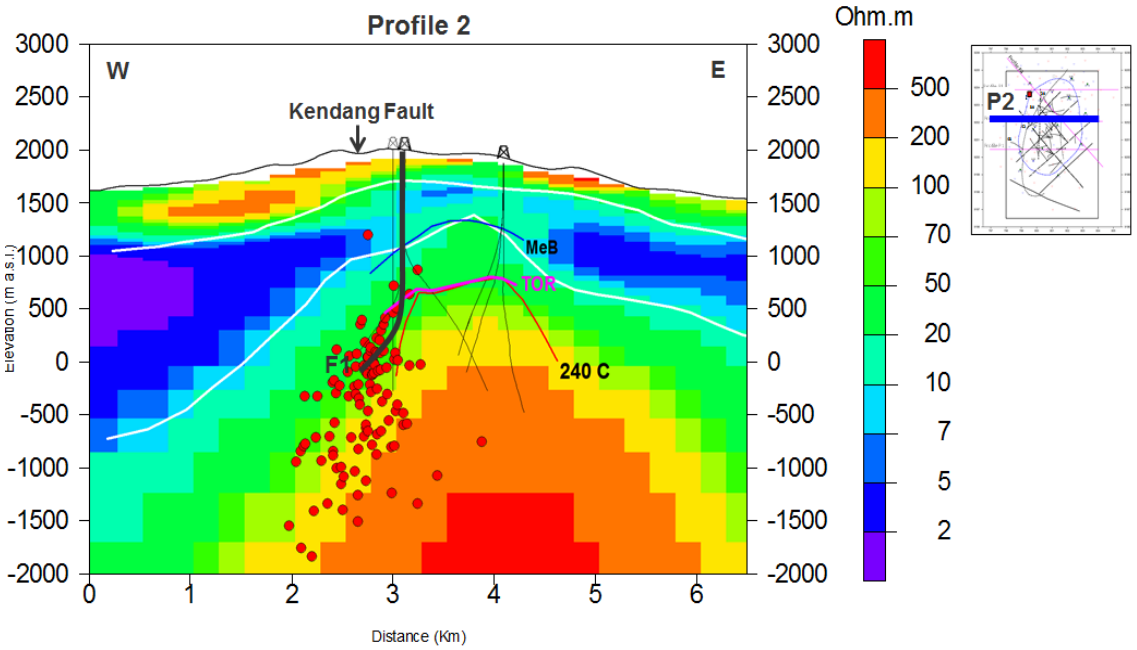


Figure 7: Cross-section across edgefield well F1 showing the good correlation of the interpreted base of the clay cap between the 1D model using the invariant mode (solid white line), 3D MT model (dark blue in colored background) and as denoted from Methylene Blue (MeB) analysis of rock cuttings (solid blue line). Red dots are MEQ hypocenters during the blind drilling of F1 in 2011.

Figure 5 shows poor correlation between the 1D and 3D models I defining the base of the clay cap in northwest Darajat. Work is underway with additional 3D and 2D stochastic modeling to check the uncertainty of the conductive layer thickness in this area. However, there is a general thickening of the clay cap and deepening of its base in the northwest similar with the trends observed in both southwest and west Darajat suggesting that Pad U is already outside the Darajat reservoir. As stated earlier, the 500 m horizon between the bottom of Well-29 and the MEQ cluster below the well may suggest the presence of a commercial reservoir that can be developed from Pad U.

8. GEOCHEMISTRY

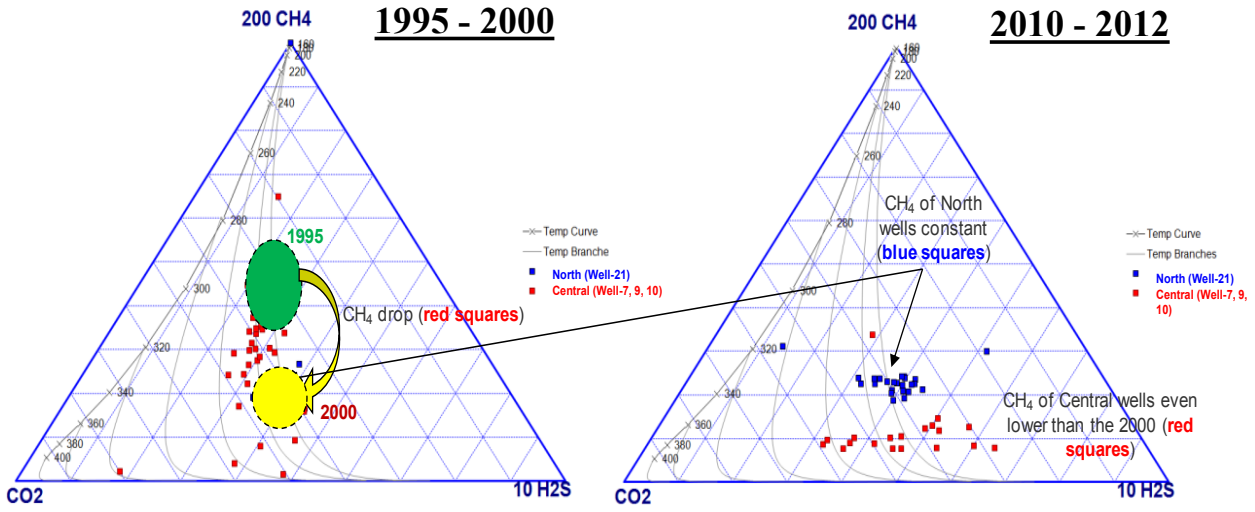
This section details the geochemical interpretation of wells that are located along the western portion of the Darajat Geothermal Field. In this analysis, west Darajat was grouped into three geographic areas, namely, North West (represented by Well-19, 21, 28, 29, 30 and 39), Central West (F1 and F2) and South West (W3). No samples were collected from W3 because this well was interpreted to be outside the commercial reservoir and the current liquid inside the wellbore is probably the drilling fluid used to drill the well.

8.1 North West Darajat

Both Molling (2007) and Rohrs et al. (2009) identified re-boiled brine and Marginal Recharge (MR) as the two end-member fluids in Darajat. On the other hand, Hadi (2001) and Rohrs et al. (2009) postulated that upflow fluids could exist in the northwest portion of the field based on the low Non-Condensable Gas (NCG) in steam, low CO_2/H_2S ratio, heavier $\delta^{18}O$ and mineral and clay alteration, although the afore-mentioned chemical parameters are also consistent with a re-boiled Darajat liquid composition.

Recently, Simatupang and Golla (2012) presented evidences that point to the presence of the upflow of the Darajat geothermal system in the northwest portion of the field. Although upflows of geothermal systems are normally associated with where high-temperature brine is produced, the upflow in this analysis refers to the area where it is believed deep permeability exist that connects the geothermal system to the high-temperature brine underlying the Darajat geothermal system. The mass produced by Well-21 (one of the first wells drilled in northwest Darajat) exhibits typical upflow composition including constant CH_4 (Figure 8), lower NCG, heavier $\delta_{18}O$ and constant CO_2/H_2S and N_2-CO_2-Ar ratios over time. Furthermore, the presence of a northwest upflow is validated by other datasets, such as high reservoir pressures and initial steam deliverabilities and low decline rate of wells drilled in northwest Darajat – all indicative of constant connection to a direct source of geothermal fluids thus suggesting upflow conditions.

A concern regarding the presence of the main upflow in northwest Darajat is the extent of the upflow specifically west of the Kendang Fault (i.e., the area between the Kendang Fault and Pad U). A step-out well towards Pad U may assist in resolving this issue. In addition, it will be important to monitor the producers at the central Darajat after terminating infield condensate injection at Well-15. The rebound of the central wells may allow for upflow characteristics to "re-appear" in central Darajat, the location of the system's upflow based on previous interpretations (Molling, 2007; Rohrs et al., 2009).



Initial CH_4-CO_2-H_2S both North (Well-21) and Central (Well-7, 9, 10) indicating mature system relative to other wells data

Current CH_4-CO_2-H_2S North (Well-21) demonstrating consistent high CH_4 compared to initial while Central (Well-7, 9, 10) indicating CH_4 decrease relatively compared to initial

Figure 8: CH_4-CO_2-H_2S ternary diagram showing the comparison of North (Well-21) and Central (Well-7, 9, 10) wells. The constant CH_4 demonstrated by North wells (Well-21) indicates continuous source of CH_4 beneath as this organic component is neither burned out nor added.

8.2 Central West Darajat

There is little that geochemistry information can add to the conceptual model of the Central West area due to access restrictions at F1 and F2. So far, there are chemical data from both Down Hole Sampling (DHS) and flowtest but the flowtest results will not be discussed in this report because the flowtest was conducted when the well was still unstable and filled with drilling fluids as described below.

Based on the Na-K-Mg ternary plot, the columns of liquid existing in the wellbores of F1 and F2 are consistent with drilling fluid chemistry (Figure 9). The shift from the Mg corner to the K-enrichment region is likely to be the product of mixing between condensate and drilling fluid additives (e.g., KOH). The different liquid chemistry of both F1 and F2 is obvious when compared to the DHS chemistry of other wells, such as, Well-31 and 5A which are considered to be wells impacted by marginal recharge (Figure 9).

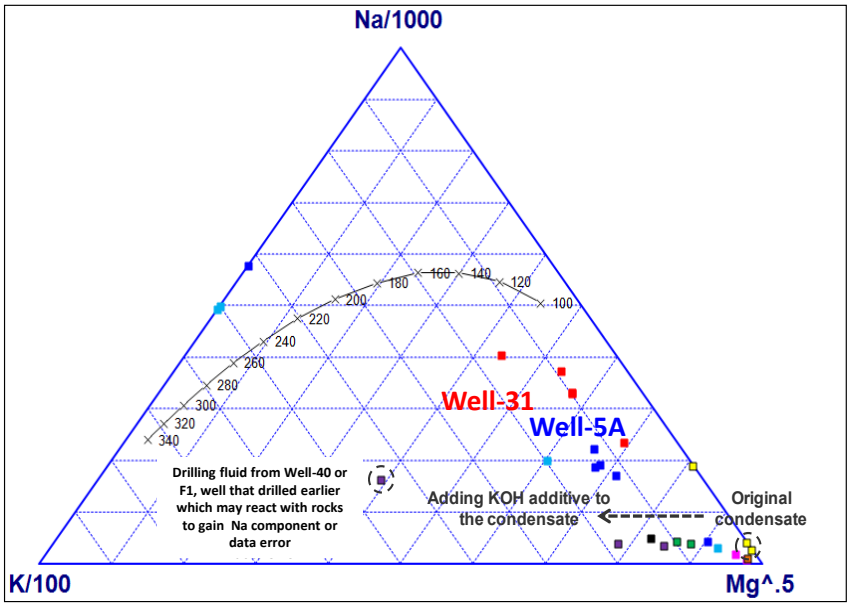


Figure 9: Na-K-Mg ternary diagram showing the comparison of liquid chemistry from Well-F1 and F2 with the downhole sample (DHS) data from other Darajat wells. Yellow squares represent condensate liquid from injection well. This liquid has been practically used for drilling in Darajat. The purple square represents Well-40 and F1. The shift of the chemical between original condensate and downhole liquid at production well indicates K enrichment due to mixing with the drilling fluid additives (e.g., KOH). The presence of this liquid is the evidence of the drilling impact.

8.3 South West Darajat

Step-out well W3 was the last well drilled during the 2009-2011 Darajat drilling campaign. This well encountered permeability at the bottom of the hole but its slow temperature build-up suggests this well was drilled outside the commercial reservoir hence W3 may be a good well to represent the chemistry of fluids immediately outside the Darajat field. Unfortunately, the well's current liquid column is still believed to be remnant drilling fluids hence impractical for analysis and interpretation.

This analysis shows that the main upflow of the Darajat geothermal system is in the northwest portion of the field (Figure 10). From the northwest, geothermal fluids flow towards the south and outflow through the fumaroles in the southeast and hot springs in the east. The extent of the northwest upflow is currently unknown and there is a plan to test the area between the Kendang Fault and Pad U for commercial production in the next drilling campaign at Darajat.

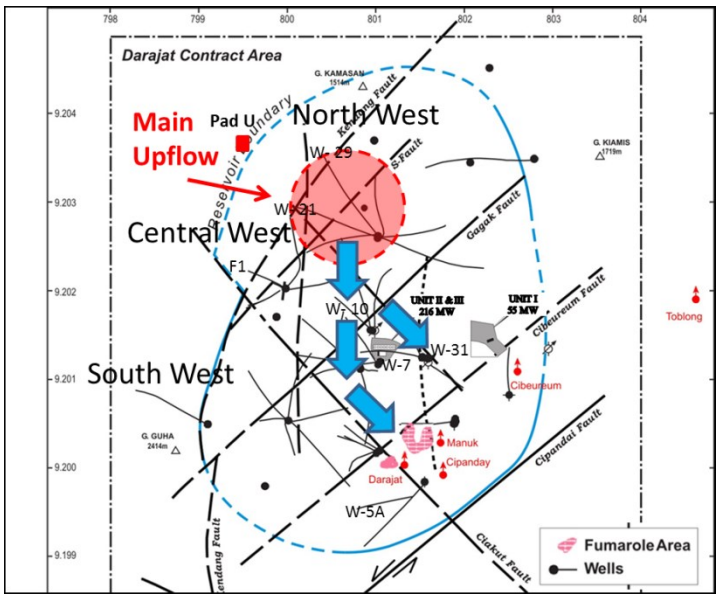


Figure 10: Map showing the geochemical conceptual model of Darajat showing the upflow in the northwest portion of the field. Fluids upflow in the NW, move to the central part of the field and then outflow to the southeast and east through the fumaroles and springs, respectively.

9. CONCLUSIONS

Review of available data indicates that the Kendang Fault is the geologic boundary of the Darajat geothermal system in the southwest and west. However, there is uncertainty about the role of the Kendang Fault in the northwest. Although the analysis of MEQ and MT-TDEM data shows that Pad U is possibly outside the commercial production area because of the thickening and deepening of the clay cap in the northwest, the unknown extent of the main upflow, presence of young volcanic vents and

commercial permeability of the Kendang Fault in the northwest makes the area between Pad U and the Kendang Fault a prime area to test for commercial production. A step-out producer towards Pad U will be key in confirming the above hypotheses.

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