GEOCHEMISTRY MONITORING DURING DRILLING IN WAYANG WINDU FIELD, INDONESIA

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ABSTRACT

Drilling campaign started at Northern area of Wayang Windu area and already drilled for 5 wells. Aerated drilling technique has been becoming a common practice in geothermal well drilling to ensure that the rock cutting sample will not be collected in the borehole and reach to the surface as much as possible or push it into the formation as far as possible. It is also a common practice to keep a production well is kept on running while drilling at the same wellpad. The air entrance into wellbore during drilling may impact the gas chemistry content of adjacent production well due to the existence of similar permeability pathway or fault. The result from gas chemistry monitoring will become strong evidence of fault existence that previously interpreted from geological modeling and geomorphological study.

Evaluation of gas breakthrough during drilling indicated by the increasing of gas/ steam ratio or total gas content in steam as the effect of steam condensation process in reservoir when water injected. Detail analyses is include the least soluble gases, such as nitrogen, argon, etc. Major indication is showing by significant increase of N_2 and Ar as both are the principal atmospheric gases which are dominantly contributed to geothermal fluid by meteoric water recharge or due to aerated drilling. Other changes observed in gas ratio, such as CO_2/N_2 ratio and CO_2/NH_3.

This geochemistry observation during drilling gives confirmation about well connectivity in Wayang Windu. Some wells were proofed connected by Cibulak, Pangkalan, and Tunggah Lebak fault, and other fault are unknown at the northernmost well.

1. INTRODUCTION

1.1 Wayang Windu Field

Wayang Windu geothermal area is part of southern mountain range in Java and located nearby the other operated geothermal field such as Kamojang and Darajat. The transition between vapor and two-phase reservoir make Wayang Windu field become interesting and challenging for future development.

Wayang Windu has been operated for 12 years with 220 MWe installed capacity. Field exploration for development is heading to the north, located on Malabar Mountain. It was initiated based on the geophysical anomaly, such as microgravity, leveling, and Magneto Telluric. Meanwhile, there are insufficient supporting data from surface feature such as no thermal manifestation, limited hydothermal alteration, and minor geological fault in outcrop due to intense soil overburden.

The northernmost pad area is MBB, where MBB1 as the only one production well at that time. Other new drilled wells in MBB pad are MBB-2, MBB-3, MBB-4, MBB-5, and MBB-6, which targeted directionally to other permeability zone mostly located in northern reservoir. The northernmost is MBB-6 which is also as an exploration well since we have no geoscientific data at surrounding area.

Figure 1: Map of Wayang Windu Geothermal area, West Java province, Indonesia.

The drilling process at those MBB wells is using aerated drilling technique considering more benefits gained, such as preventing stuck pipe. Geochemistry monitoring then take places during drilling in order to understand permeability pathway.

1.2 Drilling Technique in Wayang Windu

Drilling campaign was starting at Wayang Windu on March 2011, conducted at MBB pad.

The conventional drilling operation in geothermal is only use drilling mud, but later invention is using aerated drilling technique. Aerated drilling has become common practices in drilling operation since some problem comes during conventional drilling.

Aerated drilling is a drilling technique with underbalanced concept which conditioning the wellbore to have lower hydrostatic pressure than the formation. This underbalanced

condition could reach by injecting compressed air into drilling fluid. Thus, it will decrease the drilling fluid into lower density that conventional drilling fluid.

Some benefits taken by operating this aerated drilling technique is to reduce potential loss problem during drilling and to solve well cleansing problem after drilling.

By applying the aerated drilling fluid in Wayang Windu, other positive aspect can be taken such as permeability understanding through geochemistry monitoring. The monitoring result become evidence of fault existence that previously interpreted by geological modeling and geomorphologic study.

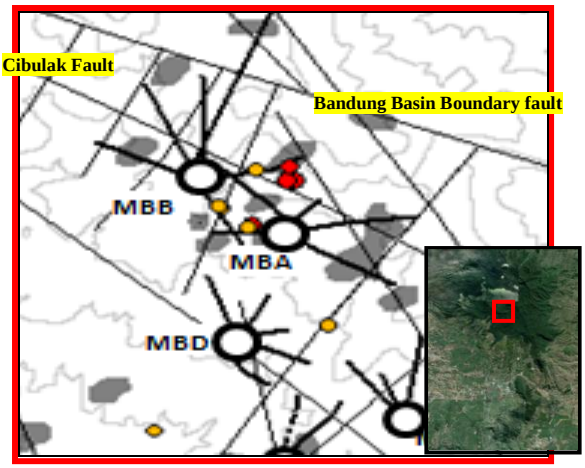

Figure 2: Map of MBB pad with trajectories of all MBB wells and surrounding wells.

2. GEOCHEMISTRY MONITORING

Geochemistry monitoring in wayang Windu conducted in production wells, injection wells, surface facilities, and some thermal manifestation. Other monitoring is only conducted as per request or situational if necessary.

Drilling campaign in Wayang Windu becomes best opportunity to understand permeability pathway between wells through geochemical evidence. The processes which may involved during drilling are condensation process and atmospheric gas entrance into wellbore.

Major permeability in Wayang Windu is secondary permeability such as fractures and fault. Well connectivity by the similar fault was observed along geochemistry monitoring by the response of some gases parameter as gas breakthrough. The different solubility and abundance of gases in reservoir result concentration changes.

Selection for monitoring well is based on the existing geological fault modeling which connect some wells through the similar fault. Those faults believed carry the steam and possibly connected with the other wells.

The term well connection here expected have positive meaning to proofed subsurface permeability and not as well interference issue.

Monitoring activity started by taking separated water and gas samples at wellhead for detail gas and water analyses. Gas samples analyzed for CO_2, H_2S, NH_3, CH_4, H_2, N_2, O_2, Ar, and Total Gas Content (TGC). While water samples analyzed for some basic elements such as SiO_2, HCO_3, Ca, SO_4, Cl, B, Fe, TDS, and pH.

2.1 Condensation Process

Condensation is fluid phase changes from vapor into liquid. It commonly occurred in vapor dominated wells indicated by decreasing steam fraction in reservoir.

Condensation process occurred due to temperature drop as the result of injected fluid for circulation during drilling. Difference solubility of each gas parameter will give different respond indicating drilling activity recorded in monitoring well.

Common evaluation regarding gas breakthrough during drilling are the increasing of gas/steam ratio or total gas content in steam as the effect of steam condensation within reservoir when water was injected. So major monitoring discussed in this paper emphasized to total gas in steam, residual gases/ insoluble gases, or gas ratio trend. The steam condensate will dissolve some of the more soluble gases, and the proportion of less soluble gases in the remaining steam will increase.

2.2 Gas Breaktrough

Gas breakthrough during drilling was summarized below at each drilled wells. It indicates by increasing of N_2 and Ar as both are the principal atmospheric gases which dominantly contribute to geothermal fluid whether by meteoric water recharge or aerated drilling.

Gas ratio is used to verify the trend of breakthrough which identified by decreasing of CO_2/N_2 ratio, but the CO_2/NH_3 increased due to most soluble gas (NH_3) dissolved by the steam condensate.

Relative decrease or increase of each parameter value is based on comparison with actual value before drilling operation. The gas concentration at normal operation prior to drilling can see in table 1.

<u>Monitoring During MBB-2 Well Drilling</u>

- MBB2 drilling target are the major feeders that have connectivity with MBA-3ST and MBA-4 by Tunggah Lebak fault; and with MBA-5 and MBB-1 by Cibulak Fault.
- Geochemistry monitoring conducted at well: MBA-1, MBA-2, MBA-3, MBA-4, MBA-5, and MBB-1.
- Monitoring result: respond at MBA-4 by increase total gas content up to 2.5 wt% in steam, and increase of residual gases up to 1.4 wt%. Respond in MBB-1 by increasing total gas content up to 1.8wt% and residual gases up to 0.3 wt%. Gas ratio of CO_2/NH_3 also increased in MBB-1 as the effect of NH_3 decreasing due to dissolved in steam condensate. N_2 as the indication of atmospheric

origin was increased at MBA-4 which is correlate with aerated drilling operation. (see fig.3)

- It concludes that MBB-2 has connectivity with MBB-1 and MBA-4 through Tunggah Lebak and Cibulak fault respectively.

Well	CO_2/H_2S	Residual Gases	Total Gas in steam
MBA-1	11	0.03	0.58
MBA-2	7	0.02	0.26
MBA-3	17	0.04	0.48
MBA-4	28	0.03	1.02
MBA-5	14	0.02	0.47
MBB-1	63	0.02	1.43
MBB-3	43	0.02	1.08
MBB-4	89	0.05	2.40
MBB-5	39	0.07	1.22

Table 1: Gas concentration baseline at monitoring wells. Concentration is in mole %, except total gas content (TGC) is in wt% in steam.

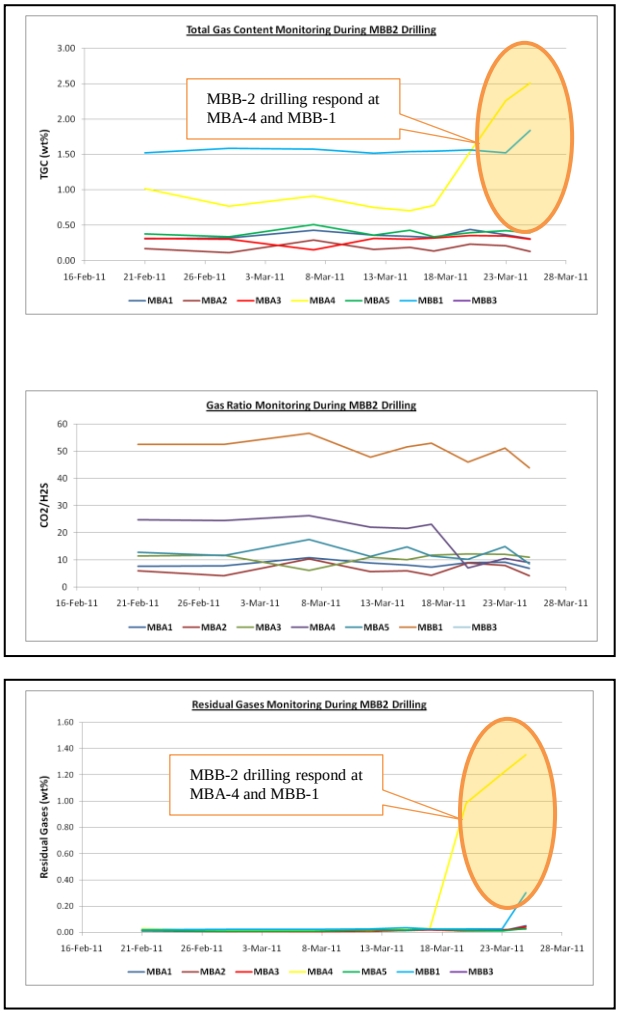

Figure 3: Graph of gas monitoring trend versus time during MBB-2 drilling.

Monitoring During MBB-3 Well Drilling

- MBB-3 drilling target are the major feeders that have connectivity with MBB-1, MBB-2, and MBA-5 by Cibulak fault; and with MBB-1 by Pangkalan Fault.
- Geochemistry monitoring conducted at well: MBA-1, MBA-2, MBA-3, MBA-4, MBA-5, and MBB-1.
- Monitoring result: respond only resulted at MBB-1 by the increasing of total gas content up to 3.5 wt%, and increasing residual gases up to 2.7% consist of increasing the least soluble gases (N_2 and Ar). Those insoluble gases increased due to aerated drilling fluid. Other changes also observed from CO_2/H_2S decreasing ratio due to decreasing H_2S which is more soluble in condensate. (see fig. 4)
- It concludes that well connectivity only existed between MBB-3 and MBB-1 by Pangkalan Fault.

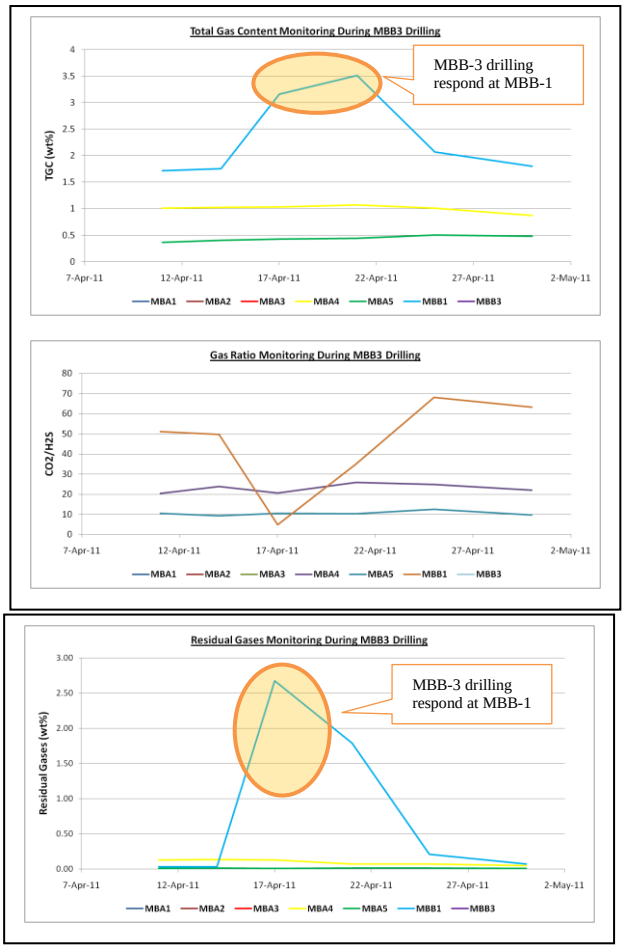

Figure 4: Graph of gas monitoring trend versus time during MBB-3 drilling.

Monitoring During MBB-4 Well Drilling

- MBB-4 drilling target are the major feeders that have connectivity with MBB-1 and MBB-3 by Pangkalan fault.
- Geochemistry monitoring conducted at well: MBB-1, MBA3, and MBA4.
- Monitoring result: response at monitoring wells obviously occurred at MBB-1 by the increasing of total gas content up to 5.6 wt%, and residual gases up to 2.2 wt%. Respond also shown from increased gas ratio (CO_2/H_2S). (see fig. 5)
- It concludes that MBB-4 has connectivity with MBB-1 by the existence of Pangkalan Fault.

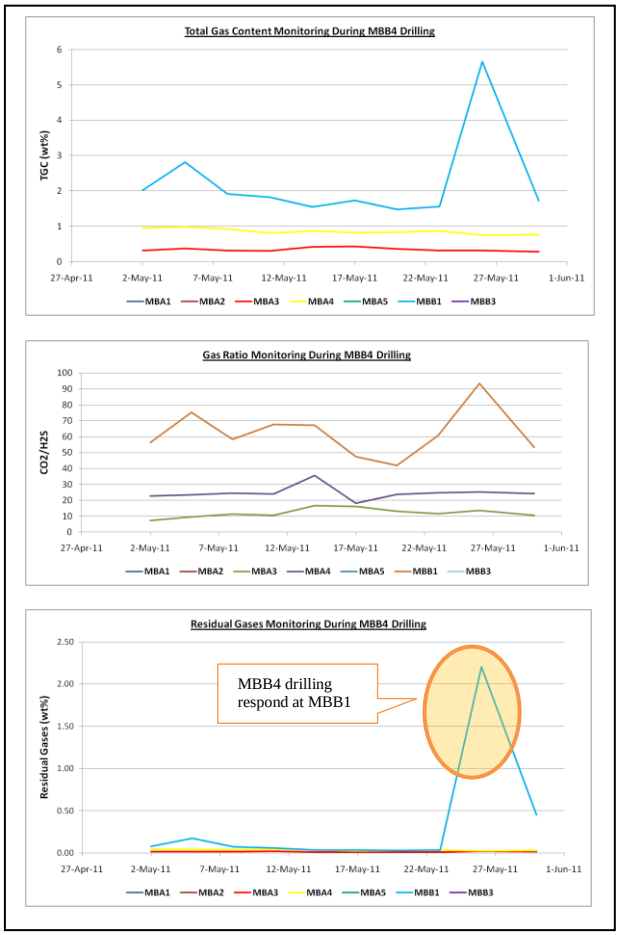

Figure 5: Graph of gas monitoring trend versus time during MBB-4 drilling.

Monitoring During MBB-5 Well Drilling

- MBB-5 drilling target is Tunggah Lebak Fault as the major feeder for MBA-3
- Geochemistry monitoring conducted at well: MBB-1, MBA-3, and MBA-4.
- Monitoring result: gas breakthrough during MBB-5 drilling indicated by the increasing total gas content up to 1 wt%, gas ratio (CO_2/H_2S), and residual gases of MBA-3 up to 0.5 wt%. Changes of gas concentration in MBA-3 is not clearly observed at all parameter which probably due to poor permeability between them. Other changes is in MBA-4, even it is not become drill target but it just informed that there is unknown permeability pathway between MBB-5 with MBA-4. (see fig. 6)
- It concludes that MBB-5 has connectivity with MBA-3 by the existence of Tunggah Lebak fault, and with MBA-4 may be through minor fault or fractures.

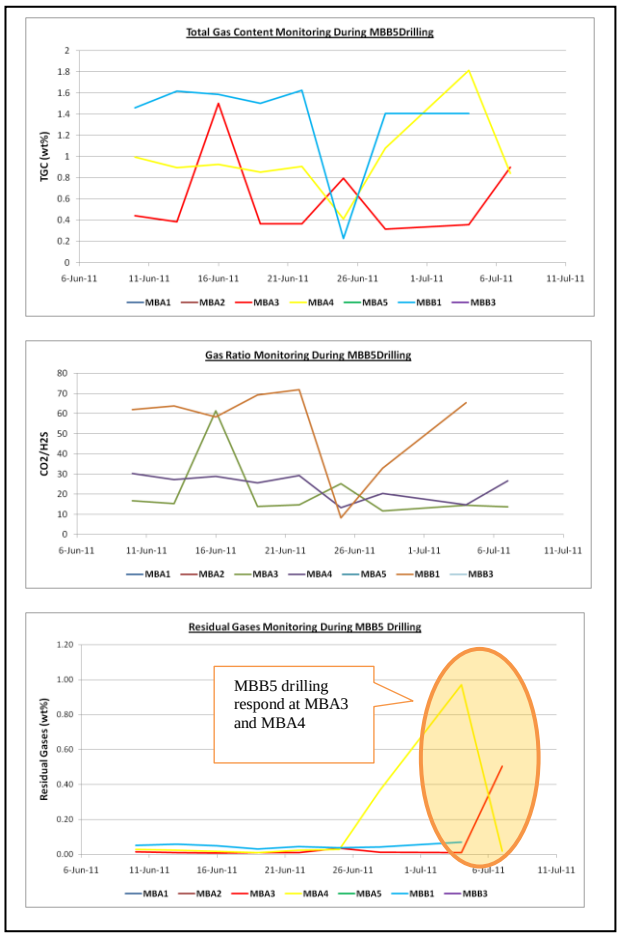

Figure 6: Graph of gas monitoring trend versus time during MBB-5 drilling.

Monitoring During MBB-6 Well Drilling

- MBB-6 drilling was targeted to three interpreted fault which are Bandung Basin Boundary, Puncak Besar, Puncak Besar Splay fault; and fractured zone between those last two fault. MBB-6 is the northernmost well, so the data will meaningful for expansion to the north.
- Geochemistry monitoring so preferably conducted at the nearest well location since no proven existing production well has been feeded by those faults. Monitoring well are MBB-1, MBB-3, MBA-4, and MBA-5.
- Monitoring result: chemistry respond obviously shown by the increasing of residual gases at all monitoring wells as the impact of aerated drilling fluid. Detail gas analysis of Ar and N_2 are showing increased at all monitoring wells except MBB-3. (see fig.7)

- It concludes that there is permeability pathway between MBB-6 with MBA-4, MBA-5, MBB-1, and MBB-3.

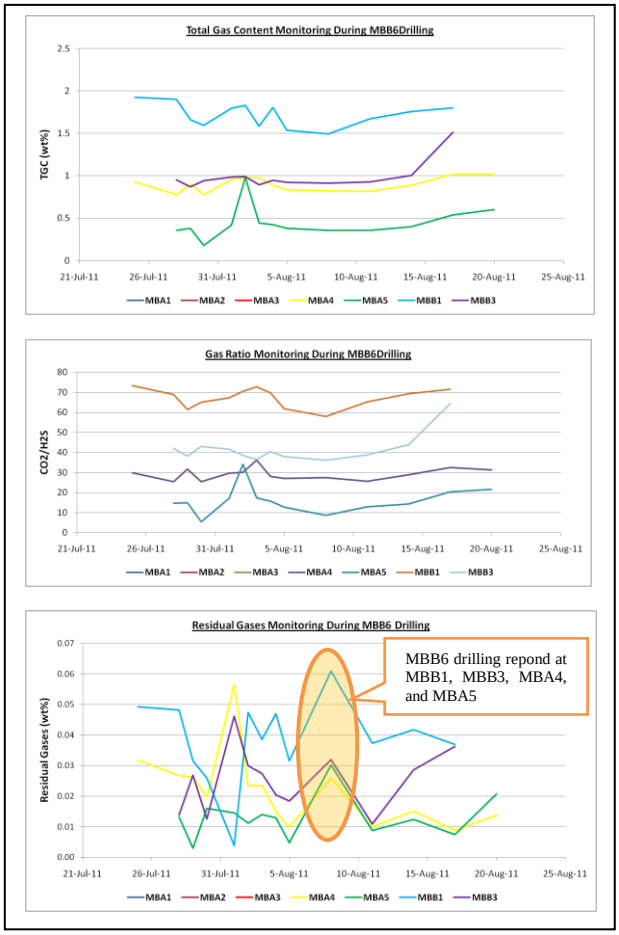

Figure 7: Graph of gas monitoring trend versus time during MBB-6 drilling. Minor respond from TGC due to very low residual gases proportion

In general, gas monitoring trend during all MBB drilling described in figure below. Respond due to drilling operation mostly shown in MBB-1 and MBA-4. It caused by the similar permeability connected those wells and become drilling target. Minor respond which also occurred in other wells even the fault target is similar, probably due to poor permeability existed.

Major indication is by increasing total gas concentration in steam up to 5 wt% found in MBB-1 when MBB-4 drilling. Those increasing due to increasing residual gases, such as N_2, Ar, etc., which commonly below 1 wt% but significantly increased up to 2.5 wt% respond to drilling.

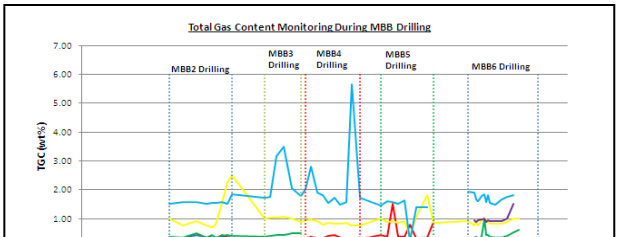

Figure 8: Graph of gas monitoring trend versus time during all new MBB wells drilling. Minor respond from TGC due to very low residual gases proportion

The applications of N2 and Ar analysis are useful in clearly identify causes of increasing residual gases concentration. Both gases were significantly increased as the respond to drilling operation which showing significant value up to 0.025 wt%.

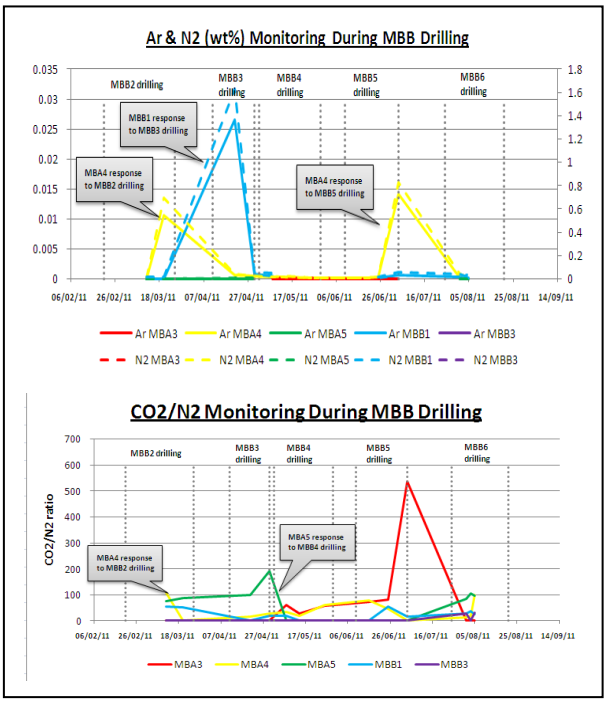

Figure 9: Graph of the least soluble gases (N_2, Ar) versus time as the indication of aerated drilling.

3. CONCLUSION

Well connectivity has been assessed during drilling by geochemistry monitoring with some evidence of gas breakthrough. This monitoring result also becomes evidence of fault existence as previously interpreted by geological modeling.

Major respond are from increasing N_2 and Ar which are more indicative in define the aerated drilling effect. Other changes are from total gas concentration in steam, and also from some gas ratio (CO_2/H_2S, CO_2/NH_3, CO_2/N_2, etc).

Some faults were proofed existed and give good respond, but some respond occurred even not defined as drilling target. Significant concentration changes may determine quality of permeability existed. Good respond may act as good permeability pathway, while poor permeability will give slow or bad respond in monitoring result. Some faults confirmed from this monitoring are Cibulak, Pangkalan, and Tunggah Lebak Fault. The Cibulak Fault confirmed by the response of MBA4 during MBB2 drilling. Pangkalan Fault confirmed by the response of MBB1 during MBB3 and MBB4 drilling. Tunggah Lebak Fault confirmed by the response of MBB1 during MBB2 drilling and response of MBA3 during MBB5 drilling. Meanwhile, the chemistry monitoring respond were occurred at all monitoring wells during MBB6 drilling.

Field expansion to the north is still become limited interpretation since this monitoring only confirm permeability within existing wells.

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