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Successful Drilling of an Outfield Injection Well into a Shallow Steam Horizon, Maibarara Geothermal Field, Philippines

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INTRODUCTION

The Maibarara Geothermal Field is situated on the northwest flank of an inactive stratovolcano, Mt. Makiling, on the island of Luzon, Philippines. The field was initially explored by Philippine Geothermal, Inc. (PGI), which drilled twelve (12) deep exploratory wells from 1977 to 1983 (Buban et al, 1994), and though an active geothermal system was discovered, PGI did not develop the Maibarara geothermal resource for commercial operations. Maibarara was later developed by a joint venture company named Maibarara Geothermal, Inc. (MGI) following the Philippine Department of Energy's (DOE) award of the 16-km^2 Maibarara Geothermal Renewable Energy Service Contract (GRESC) to its parent company, PetroEnergy Resources Corporation (PERC).

The Maibarara Geothermal Power Facility (MGPF) was developed in a compact area with the steamfield and two power plants, all located within a 9-hectare development area. The reinjection schemes have been optimized numerous times to adapt to the reservoir response to injection conditions and surface facilities requirements. Esberto et al., 2021). Tracer studies conducted in 2016 and 2022 established a connection between the infield injection wells and production wells. (Marzan et al., 2021; MGI Internal Report, 2025).

The necessity of drilling the first outfield reinjection well (MB-19R) mainly came from the anticipated cooling of the main production reservoir caused by reinjection returns over the years of the infield reinjection scheme. A shift to an outfield reinjection scheme was planned to disperse the cold reinjection fluids farther from the production area. This paper discusses challenges encountered during the drilling of MB-19R, along with the successful strategies employed by MGI to achieve the well's objectives.

1 DRILLING OBJECTIVES AND TARGET

MB-19R was drilled about 1 km north of the MGPF. Its main objective is to disperse the injection of produced brine and plant condensates away from the main production area. MB-19R was collared 11 meters northwest of a legacy well, Mai-1. Mai-1 was drilled vertically to a depth of 1,022 m by PGI in 1977 but was subsequently plugged and abandoned in 2003. Drilling of Mai-1 encountered significant partial and total loss of circulation (TLC) and was drilled blind to its total depth (MGI Internal Report, 2011). MB-19R was designed to duplicate Mai-1 to intersect the same loss zones intersected by the well.

MB-19R drilling adapted a vertical, standard hole, three-string casing design with a programmed total depth of 1,400 mMD-CHF. The setting depths for casing shoes were similar to those of Mai-1. Circulation loss was expected to be as shallow as 90 mMD and was planned to be plugged with cement once intersected.

Actual drilling became more challenging when problems such as frequent gas kicks, irrecoverable loss of circulation, and complications in directional drilling occurred. Ultimately, MB-19R was successfully drilled to its target depth, and its completion tests confirmed that its objectives were met.

2 GEOLOGICAL PROGNOSIS AND DRILLING PROGRAM

Drilling information from Mai-1, being the sole offset well within the drill site, served as the basis for determining the expected lithologies to be intersected by ORI. The permeability targets were primarily lithological contacts, rather than the usual fault structures, which aligned with the encountered loss circulation zones (LCZs) of Mai-1. The major LCZs at 513 mMD (272 mRSL) and 1010 mMD (769 mRSL) were identified as the permeability targets for MB-19R.

The setting depths of Mai-1 were adapted except for the total depth (TD), which was deepened to 1400 m compared to Mai-1's 1022 mMD to add exploratory value to the well. The Anchor Casing Shoe (ACS) and Production Casing Shoe (PCS) were initially programmed to 264 and 424 mMD, respectively.

Swelling clays and TLC zones were anticipated within the shallow 17-1/2" hole interval (0 – 265 mMD), which required the use of clay-inhibitive drilling mud and Loss Circulation Materials (LCMs). A mud motor with an Electromagnetic Measurement While Drilling (e-MWD) bottomhole assembly was programmed to be used from this section onwards to prevent possible collision with Mai-1. Minimal fluid losses were expected in the 12-1/4" hole interval (265 – 425 mMD).

3 DRILLING CHALLENGES

3.1 Steam and Gas Kicks

The drilling of MB-19R experienced multiple events of steam and gas kicks, resulting in a total operational delay of 2.21 days (Figure 1). These persistent gas kicks were not encountered during Mai-1 drilling. Although most of the reservoir and lithological logs resemble those of Mai-1, the differences in drilling parameters might have played a role in the unexpected gas kicks. The mud weight used in MB-19R as a cooling and kill fluid before cementing at the 12-1/4" hole was 8.6 to 8.7 pounds per gallon (ppg), while 8.9 to 9.0 ppg was used in the same section during Mai-1 drilling. The more underbalanced condition might have allowed more of these gas kicks to occur, which were unnoticed in previous drilling.

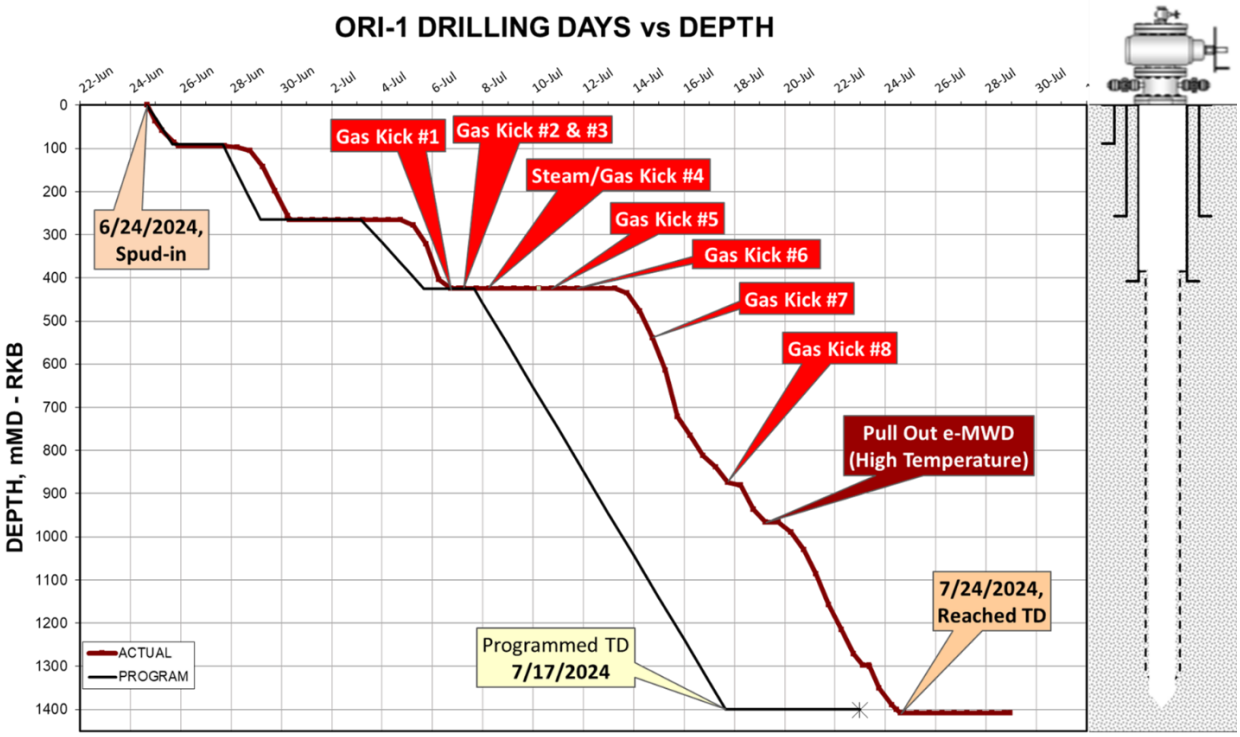


Figure 1. Drilling Days vs Depth of MB-19R showing persistent well kicks encountered during well drilling.

The gas kicks often released high concentrations of Hydrogen Sulfide (H_2S), which pose a serious hazard throughout the drilling. The H_2S concentrations released by the well were as high as 200 ppm. Table 1 enumerates the well kick events and the drilling activities when the well kicks occurred. The good permeability under Mai-1 and MB-19R was also hypothesized to have allowed the migration of steam and gas from an upflow zone, hence the frequency of experienced gas kicks (MGI Internal Report, 2024).

Table 1. Summary of well kicks during MB-19R drilling, along with the gas concentrations recorded.

Hole Section	Event	Tool Depth (mMD)	Tool in hole	Activity	Maximum H_2S Registered (ppm)
12-1/4"	Mud Flush	301	Steerable BHA w/ MWD	Cooling off hole / Wiper trip	78
	Gas Emission	301	Steerable BHA w/ MWD	Re-opening of BOP	-
	Mud Flush	424	Steerable BHA w/ MWD	Cooling off hole (by choke manifold) / Wiper trip	62
	Gas Kick / Mud Flush	27	Steerable BHA w/ MWD	POOH / Circ. (by choke manifold)	-
	Gas Kick / Mud Flush	359	Slick BHA	Drilling out obstruction at 359m	100
	Steam Kick	250	9-5/8" Casing	RIH 9-5/8" casings	-
	Steam/Gas Kick	352	9-5/8" Casing	RIH 9-5/8" casings / Circ. thru casing	6.2
	Gas Kick / Mud Flush	422	9-5/8" Casing	Circ. thru casing prior cementing	28.19
	Steam/Gas Kick	409	5" stab in cement string	Circ. thru stabbed in cement string	0.7
	Gas Kick / Mud Flush	409	5" stab in cement string	Circ. thru stabbed in cement string prior cementing	100
8-1/2"	Gas Kick	548	Steerable BHA w/ MWD	Blind drilling	200
	Gas Kick	786	Steerable BHA w/ MWD	Blind drilling	50

3.2 Losses (Fluid and Cement)

3.2.1 Loose formation and 13-3/8" cement losses

A paleosol layer, which was also encountered in several MGI drilled wells and was previously inferred as 'fault zone' during Mai-1 drilling, was intersected from 210 – 265 m at MB-19R. The loose and permeable nature of paleosol formation posed a challenge for maintaining fluid circulation, cementing, and wellbore pressure containment integrity. During the cementing of 13-3/8" casing, a TLC occurred while pumping the main cement slurry. The identified paleosol layer yielded to the hydrostatic pressure of the cement slurry column within the casing-to-casing annulus. Despite pumping at 90% excess cement volume, it failed to return to the surface.

3.2.2 Total Loss of Circulation during 9-5/8" casing cementing

Cement pumping was proceeded on the 9-5/8" casing after the recurring disengagement of the cement string from the casing's float collar, caused by gas kicks, was resolved. Upon pumping the total volume of the cement, a TLC occurred, and it failed to reach the surface. However, attempts to displace the cement were also unsuccessful, as it had already set after all the delays caused by gas kicks during the initial attempts to pump in cement.

3.2.3 Blind drilling of the 8-1/2" hole to Total Depth

According to MB-19R's geological prognosis, TLC was expected during the drilling of the liner hole section at 513 mMD depth. This was inferred as the lithological contact between andesite and tuff formation and was one of the major permeability targets of MB-19R. However, irrecoverable TLC was encountered at a shallower depth of 457 m and proceeded with blind drilling down to the total depth. The shallower TLC was later inferred to be associated with the Kubol Fault, a recently mapped structure using a 3D electromagnetic (EM) survey. This fault dips almost vertically, and MB-19R's closer proximity to this fault provided slightly different permeable depths than Mai-1.

3.3 Magnetic interference with Mai-1

The lack of accurate survey data from Mai-1 posed a high risk of well track collision for MB-19R. As a mitigation measure, e-MWD was used to provide accurate feedback and control over MB-19R's trajectory. However, at shallow depths of 280 to 424 mMD, high magnetic interference was registered from the survey tool, making the survey data inaccurate at these depths.

3.4 High Bottomhole Temperatures

The e-MWD tool experienced several instances of sudden, elevated temperatures, particularly during gas/steam kicks. The tool had a maximum rating of 150°C and registered a maximum temperature of 137°C at a depth of 966 mMD.

4 STRATEGIES APPLIED

4.1 Safety

The frequent well kicks necessitated the implementation of reinforced safety protocols throughout the drilling. Gas mapping was frequently conducted across the site, and Self-Contained Breathing Apparatuses (SCBAs) were always available. H_2S detectors were strategically installed on the rig floor, shale shakers, and in the well cellar to provide instant warning during gas emission events. A separate third-party team was engaged to enforce safety procedures across the drill site.

Despite the frequent kicks and gas emissions, no associated untoward safety incident occurred throughout the drilling.

4.2 Well Control during Well Kicks

To manage the well kicks encountered during drilling, two primary controls were implemented: bullheading, and increasing circulating mud weight. The bullheading procedure involved pumping of fluid, usually at higher flow and pressures, into the wellbore while it was shut (Koederitz, 1995). This method forces all injected fluid, along with the influx gases, back into the formation of good permeability. This was conducted three times as a short-term strategy to halt the influx of reservoir gas and enable critical drill string operations to proceed.

Mud weight was increased to 8.9 ppg by adding calcium carbonate ($CaCO_3$), which eventually stopped the well's backflow. The hole was slug pumped with High Viscosity Mud (HVM) every time the BHA was pulled out. Additionally, LCMs were continuously mixed into the mud during the drilling of cased sections to address sudden drops in circulation pressure. The availability of brine and water to the drill site was maintained as much as possible for cooling the hole.

4.3 Wellbore Integrity

The paleosol intersected during the drilling of a 17-1/2" hole extended down to the depth of the originally programmed ACS setting depth. To ensure wellbore containment integrity during and after the drilling, the hole section had to be deepened. The hole was extended by 4 meters, at which a transition from clay to a moderately hard andesitic formation was observed. The ACS was then set at a depth of 268 mMD.

The losses during the cement job on the 13-3/8" casing were properly addressed by actions compliant with NZS 2403:2025 standards. Once the absence of return to the surface was realized, water was immediately pumped continuously from the top of the 20" to 13-3/8" casing annulus to break and flush the cement column along the casing to the casing annulus. The annulus was successfully filled to the surface with cement after three consecutive top jobs consisting of 135, 40, and 35 barrels of 14.9 ppg cement.



Figure 2. Filled up casing to casing annulus with cement as seen after the 9-5/8" cement top-job.

As for the 9-5/8" production casing, the Top of Cement (TOC) was tagged at 30 meters below the surface. A ½" tubing, serving as a tremie pipe, was used to fill the annulus with cement from TOC to the surface (Figure 2).

The target permeability in the 8-½" open section was maintained by performing blind drilling from the TLC depth of 457 mMD. To ensure wellbore stability during this section, frequent mud slugging with HVM and wiper tripping were performed. This ensured that the open section was clear of debris and cuttings, allowing for a relatively safe drilling operation.

4.4 Directional Drilling

The inadvertent magnetic interference of e-MWD with Mai-1's well track during the drilling at 280 to 424 mMD-RKB rendered inaccurate survey data at these depths. However, close monitoring of the inclination, a parameter unaffected by interference, was conducted to maintain the wellbore within the 3-degree deviation limit. Interference decreased at the lower depths, indicating a successful deviation from Mai-1.

Even then, the high downhole temperatures experienced by the e-MWD tool at 966 mMD necessitated pulling it out of the hole to protect the tool's integrity. The bottom hole assembly (BHA) was then replaced with a slick-type BHA, lacking directional features. The drilling until the target total depth was then meticulously guided by projections.

5 RESULTS

Well MB-19R was safely and successfully drilled to its target depth of 1,400 mMD-CHF and completed after 34 days. The subsequent completion tests revealed multiple permeable feed zones, ranging from 446 mMD to 915 mMD-CHF. The well also accepts fluids at an injectivity index of 81.3 li/s-MPa, which is the highest measured from all wells drilled by MGI, so far. The quick switch to blind drilling with water down the permeable open section prevented skin damage of the wellbore, as indicated by the calculated negative skin pressure. The objective to add reinjection capacity to the Maibarara Field was well accomplished.

6 CONCLUSIONS

The drilling of MB-19R presented multiple challenges, some of which were unexpected, such as the frequent gas kicks, shallower TLC, high downhole temperatures, and loose formation horizon. Despite the challenges encountered, the MGI drilling team effectively employed multiple strategies for safety and well control, minimizing total drilling delays to only 2.21 days and completing the well within budget. Lessons learned were well-documented and will be applied to potential future drilling campaigns in Maibarara.

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REFERENCES

Buban, A.C., Villadolid-Abrigo, M.F., Sta Maria, R.B., and Sussman, D.: Geologic and Reservoir Model of the Maibarara Geothermal Field, *Proceedings*, 16th New Zealand Geothermal Workshop, Auckland, New Zealand, (1994).

Esberto, M. B., Sinogba, A. B., Llenarizas, L. J., Fernandez, L. C. D., Mendivil, I. L., Maturgo, K. M., and Callos, P. G., Jr.: Evolution of the Reinjection System in a Compact Operating Geothermal Field: The Maibarara Experience, *Proceedings,* World Geothermal Congress 2020+1, Reykjavik, Iceland, (2021).

Internal Reports and Memorandum, Maibarara Geothermal, Inc., unpublished (2011-2025).

Koederitz, W. L.: Gas kick Behavior During Bullheading Operations in Vertical Wells, *PhD thesis*, Louisiana State University, Baton Rouge, USA (1995).

Marzan, M. Q., Fernandez, L. C. D., Maturgo, K. M., Romey, R. F. C., Olivar, M. V. M., and Esberto, M. B.: Reservoir Tracer Testing in the Maibarara Geothermal Field, Philippines, *Proceedings,* World Geothermal Congress 2020+1, Reykjavik, Iceland, (2021).

Standards New Zealand: Code of Practice for Deep Geothermal Wells (NZS 2403:2015), Standards New Zealand, Wellington, New Zealand, (2015).