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Slimhole Drilling Design and Operation in Indonesia: What Can We Learn?

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ABSTRACT

Starting at Kamojang Field, the application of slimhole well for geothermal exploration drilling in Indonesia was executed in the 1920s. This implementation was only considerably carried out around the 1920s-1990s. For the past 20 years, slimhole drilling has been infrequent to be executed in Indonesia. Lack of uncertainty and risk of exploration drilling concept becomes one of the reasons why it is infrequent. This void makes the drilling practices that have been performed before swallowed and not inherited to other successors. The best practices in slimhole drilling collected during the past period are lost, and it is like repeating everything from the beginning; thus, there will be a new learning curve. Learning and comprehending the slimhole practices from scratch again is also one of the reasons why slimhole has not yet been massively implemented in Indonesia. This paper collects and summarizes past slimhole drilling experiences to identify the trends and lessons learned from each drilling campaign in Indonesia. Also, this paper will provide recommendations of slimhole drilling methods concerning well design and rig type in the interest of future slimhole drilling campaigns.

1. INTRODUCTION

1.1 Background

Technology of slimhole well is not new in petroleum and geothermal industry which it has actively applied in the 1920s. Since then, slimhole drilling to explore and delineate the geothermal resource has been increasingly used in many geothermal fields worldwide. Although the usage of slimhole has been increased, many fields have not implemented slimhole for a few reasons. Lack of understanding about uncertainty and risk in the exploration phase is one reason. Substantial expenditures are required to drill geothermal wells, which are usually located in mountainous areas with limited road access when the resource uncertainty level is still high. In the early exploration phase, we only have indirect data from the Geology, Geochemistry, and Geophysics (3G) interpretation. If only the analyzed data mentioned before are available, the existence of the resource beneath the surface could not be confirmed yet. The only way to prove the presence of the geothermal system is by doing exploration drilling. Three types of wells could be used in geothermal drilling based on size: big, standard, and slimhole. Any type of well mentioned could penetrate down to the reservoir zone to collect direct data, but they have the same drilling success rate since the phase is still in exploration. It means that we may not necessarily get results, so we want to mitigate the risk by reducing failure's expense and cost. Slimhole could be preferred for exploration drilling wherefore it could lessen the risk.

In Indonesia, slimhole was implemented in several geothermal fields around the 1920s-1990s. After this period, slimhole drilling was not carried out again until Tangkuban Parahu and Blawan-Ijen executed slimhole drilling in 2014 and 2016, respectively. The existence of this void makes the drilling practices that have been carried out before swallowed and not inherited to other successors. The best practices in slimhole drilling collected during the past period are lost, and it is like repeating everything from the beginning. Thus, there will be a new learning curve. What is meant by best practices are the experiences in a well design, drilling equipment, and the availability of the equipment. Having to learn and comprehend the slimhole practices from scratch again is also one of the reasons why slimhole is not yet massively implemented.

1.2 Slimhole Definition

Slimhole well described by a borehole that is significantly smaller than a standard approach, commonly a wellbore less than 6 inches in diameter according to Schlumberger (2021), while others said slim-hole drilling refers to the drilling of a well with wellbore typically less than 7 inch in diameter. Slimhole is considered beneficial to the low-budget operator because of time efficiency and smaller rig size.

1.3 Drilling Method

1.3.1 Rotary

This type of rig could be used in the exploration and development phase in the oil and gas industry and geothermal industry. The borehole size that is drillable using this rig is about 6”-26” in diameter. For the depth, it could frequently reach more than 20,000 feet. The drill string consists of a drill bit, drill pipe, and Bottom Hole Assembly (BHA) that includes drill collars, stabilizers, reamers, crossovers, and other special tools. The top drive or rotary table turns the string and will go down through the hole under its weight. This rig uses the rock crushing mechanism of the high value of Weight On Bit (WOB) and low value of Rotation Per Minute (RPM). The sample obtained from the drilling is cuttings.

1.3.2 Coring

This rig is commonly used in the mineral industry. The hole diameters this rig could drill ranged from 2- 6”. With this rig, the core sample is obtained by drilling for about 5-20 ft and storing it in the center of the drillstring (innertube). Then, the wireline will run down to retrieve the core sample from the barrel. The core is generated from the rock crushing mechanism of low WOB and high RPM. Drilling with a coring drilling rig is less risky to the loss zone.

1.4 Objectives

This paper aims to:

- Summarize and compare the past slimhole drilling experiences regarding well design and rig of several wells in Indonesia.
- Identify the trends in the slimhole wells drilling campaign for future slimhole drilling campaign

2. SLIMHOLE DRILLING EXPERIENCE IN INDONESIA

2.1 Kamojang (1926)

Kamojang field is located about 40 km southeast of the West Java capital. This field system is a vapor-dominated field. There are several period drillings in this field:

- 1926 – 1928

The Dutch drilled several wells with a depth of 66 – 128 m. There is no detailed information about casing design or rig used for this well.

- 1974 – 1975

PERTAMINA & the NZ consultant group Geothermal Energy Ltd. (GENZL) drilled several wells with depths varying from 536 – 753 m. These wells were completed by slimhole drilling. 13-3/8” Stovepipe to 4-1/2” production casing were cemented. There is no detailed information about casing design or rig used for this well.

- 1976 – 1979

PERTAMINA & GENZL drilled several wells with depths of 935 – 1,800 m using semi-standard casing diameters from 18” stove pipe to 7” production liner. Later, in 1979 - 1986, the stovepipe casing changed from 18” to 20” and the well varied from 1,150 – 2,200 m. There is no detailed information about casing design or rig used for this well.

- 1986 – present

Several wells drilled with depth up to 1,003 – 2,200 m using standard casing of 30” diameter of stove pipe, 9 5/8” production casing, and 7” production liner according to Suryadarma et al. (2005). There is no detailed information about casing design or rig used for this well.

2.2 Wayang Windu (1993-1994)

Wayang Windu field is located in the east of town Pangalengan in West Java, and it is near twin volcanoes of mount Wayang and mount Windu. Pertamina drilled the slimhole in this field in 1993 – 1994. Universal Drill Rig (UDR) Model 1500 drilled the holes with rotary drilling at the upper section and continued coring until the total depth (1,500 m). Slimhole drilling was chosen to delineate the reservoir to help accelerate the financial closure. In 1996, other slimholes (4 x 1,500 m) were drilled by Mandala Nusantara Limited that signified the start of the development phase. These slimholes are used as monitoring well permanently. There is no detailed information about well design in this field.

2.3 Sarulla (1993-1998)

This field is located in North Sumatra, Indonesia. Unocal, Pertamina, and PLN signed joint operation and energy sales contracts for exploring and developing geothermal energy in the Sarulla area. Several wells were drilled in this field to find productive wells. The drilling method used was the hybrid-slimhole which uses rotary drill followed by coring until the bottom depth. The depth could reach 1,709 m – 2,330 m. There is no detailed information about well design in this field.

2.4 Darajat (1996-1998)

Darajat field is located at Kendang Volcano, West Java. The reservoir is vapor dominated system, so the discharge is mainly dry steam. In this field, there was a power plant commissioned in late 1994. The steam was supplied by the deep production well that Pertamina has drilled in the last 1970s. Amoseas Indonesia Inc, the contractor of Pertamina who owns the field, conducted a new slimhole drilling program in 1996 – 1998. The goals of slimhole drilling in this field were to confirm the additional reserves at Darajat, discover the top of the reservoir, uncover the geology structure, and allow the Formation Microscanner (FMS) tool to run. In total, in the slimhole program, 6 wells were successfully drilled, and 3 existing wells were deepened.

Slimhole was drilled in this field using two rigs. For a total depth of 1,585 m, the UDR 1500 Truck mounted multipurpose hydraulic rig (mast length 15.8m, pullback capacity of 32.000 lbs, pulldown 15.400 lbs) was used. UDR 5000 was used to drill another well for 2,195 m deep.

Holes from the surface down to the depth of 7" casing were rotary drilled using conventional rig using water-based mud. Next section, 6-1/8", was drilled by coring continuously using CHD 134 equipment. 6-1/8" hole size was chosen because it considered the adequate cementing job that could be obtained in the annulus outside 4-1/2" casing. Moreover, it is for logging tools to run on this hole size to obtain geological formation and to be compared against the core attained. Later, it was discovered that continuous coring of the 6-1/8" section was complex and slower than rotary drilling of the same section hole. Furthermore, after the four wells were drilled, it was decided to substitute them with rotary drilling to save drilling time. In the rest hole section, all wells were drilled with continuous coring from the reservoir until the actual depth to obtain a continuous core. The size suggestion of the equipment is HQ (3.83") and NQ (2.98"). NQ was used when there was a stuck pipe on using HQ. The well schematic can be seen in Figure 1.

Some advantages of the slimhole program based on the program in Darajat Field:

- Less cost due to the use of coring rig, which is 40% of the total daily rate of the conventional rig (at that time).
- Less environmental impact in the challenging area due to less requisite footprint for coring rig.
- Obtained continuous core that is valuable for the geologist to scrutinize reservoir rock.

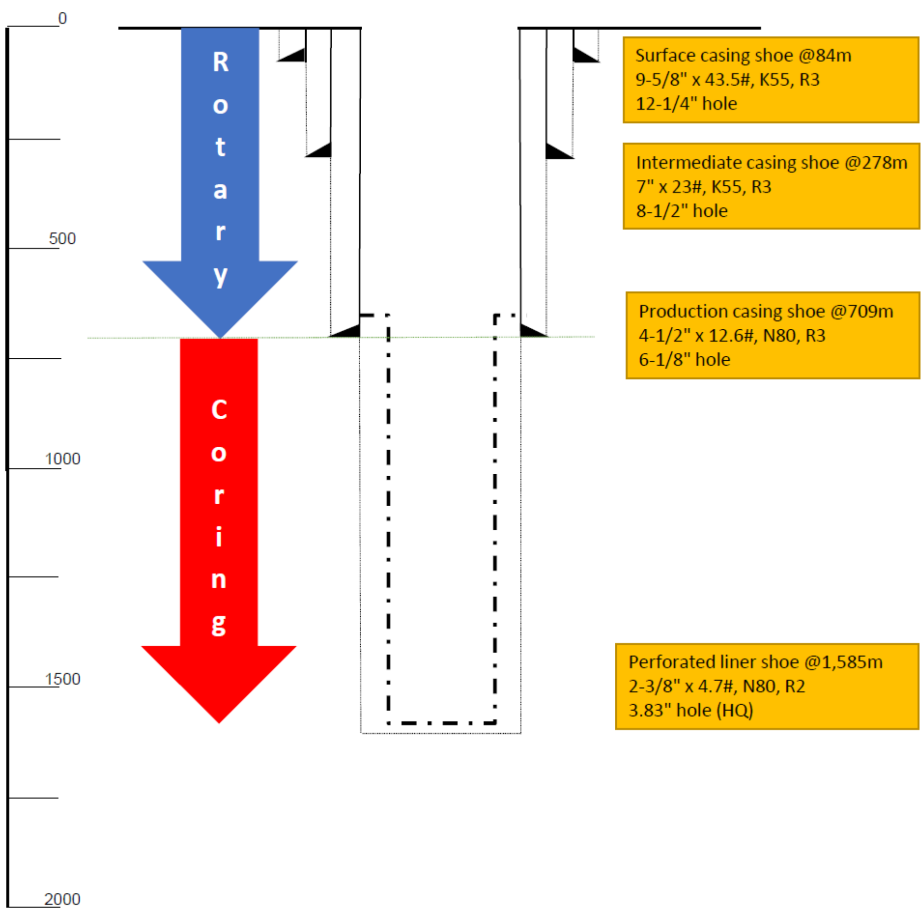

Figure 1. Well Schematic of Darajat Field modified by Riza, B. R. Berry (1998)

2.5 Tangkuban Parahu (2014)

This field is located in the Tangkuban Parahu (TPB) volcano in Central West Java. 3 Slimholes were planned to be drilled in the Kancah area, the south of TBP. Rotary drilling was designed to drill about 630 m and then continue with core drilling until the target depths of about 1,500 m. Later, the core obtained from slimhole drilling will be used for full-sized well drilling for production tests.

The first spud began on April 22nd, 2014. K-3, the first slimhole exploratory well in this field, was drilled to obtain the core that could lead to multiple necessities. The core would show the advantage of observing subsurface lithology and also helpful for future reservoir management.

The plan of the slimhole well schematic in TBP can be seen in Figure 2. The drilling rig used in this well was hydraulic MCQ 700 with an overall mast up to 22 m, pull down capacity of 160 KN, and hoisting capacity of 800 KN. Another capable alternative drilling rig is a truck-mounted hydraulic rig with the lifting rig horsepower of 800 KN capable of running 7” casing at 350 m long.

During the drilling process in this field, many problems were encountered, such as loss circulations and pipe stuck throughout the hole section. The problems in the well caused damage to the equipment, the top drive, which could later affect the rig's personal safety. Based on the specification, MCQ 700 could drill the well, as it has sufficient hoisting capacity and mud pump for rotary. It was decided to continue drilling with another rig that could take 1 – 1.5 months, whereas the original drilling day plan was only 35 days. The location of the permeable zone needs to be considered to drill well in another location so that the problem does not happen again. Also, preparation of drilling rig is critical to anticipate unforeseen problems occurred while drilling.

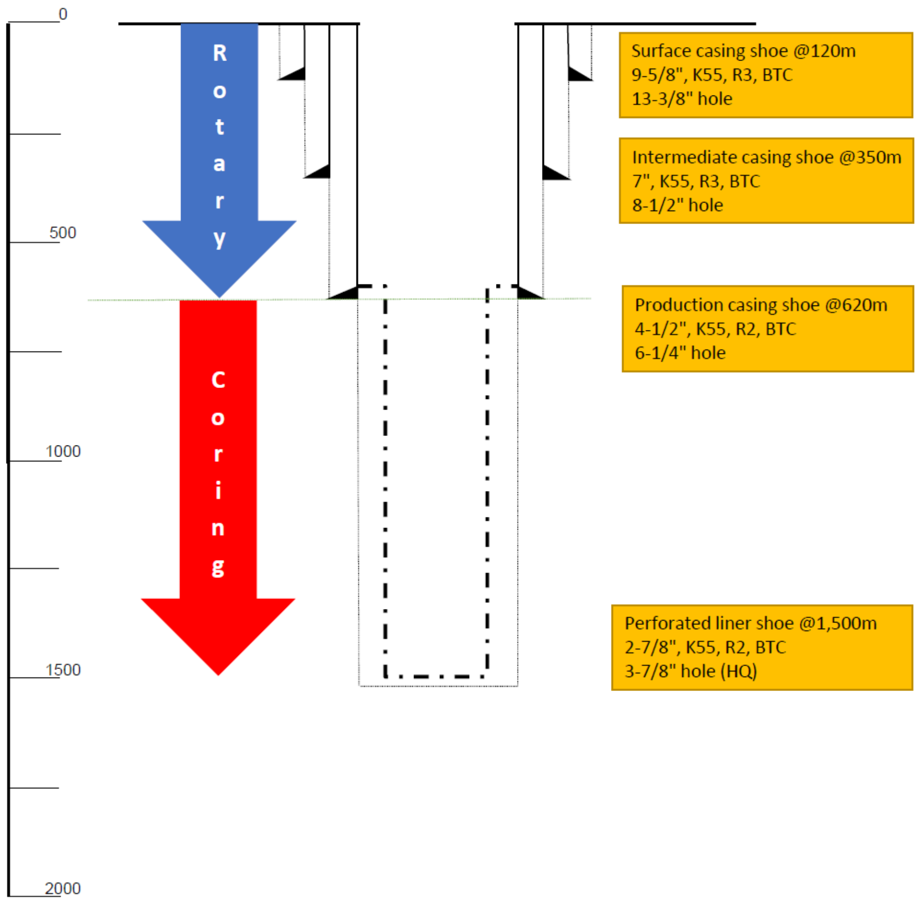

Figure 2. Planned Well Schematic of Tangkuban Parahu modified by Darnel, Artono and Triyono et al. (2015)

2.6 Blawan-Ijen (2016)

The location of Blawan-Ijen is at the eastern end of Java Island. PT. Medco Cahaya Geothermal (MCG) explored the field by conducting slimhole drilling. Previously in this field, a slimhole well had been drilled in 2013 by GeothermEx with a depth of 620 m, named ISH-01. The discovered geology prognosis was used to be the basis for drilling IJN-01. The first exploration well drilled by MCG at the Ijen-Blawan Field is IJN-01. This well was drilled to penetrate the thick clay cap, reach 2,000 m where hot, neutral chloride water exists, and prove whether the slimhole well could flow or not. IJN-01 was drilled using a KWL-1600H multipurpose rig. The rig only requires 40 x 60 m2 wellpad, which is much lesser than a conventional rig (up to 100,000 m2).

On Jan 15th, 2016, IJN-01 was spudded. Figure 3 illustrates the actual casing setting depth. The coring method is used from the surface until the bottom depth. To largen the upper section of the well, hole enlarging with drilling bits was executed. Not too many changes have occurred compared to the original plan. While for the drilling days, there was a veer from the original planning. It was planned to take 61.6 days to reach 2,000 m, but the actual drilling took 169 days to complete. The things that made the duration longer were the coring and enlarging activity with 87 days. For these problems, it is recommended to prepare contingency equipment to anticipate hole problems like pipe stuck and lost circulation and modify the rig according to the needs of the well.

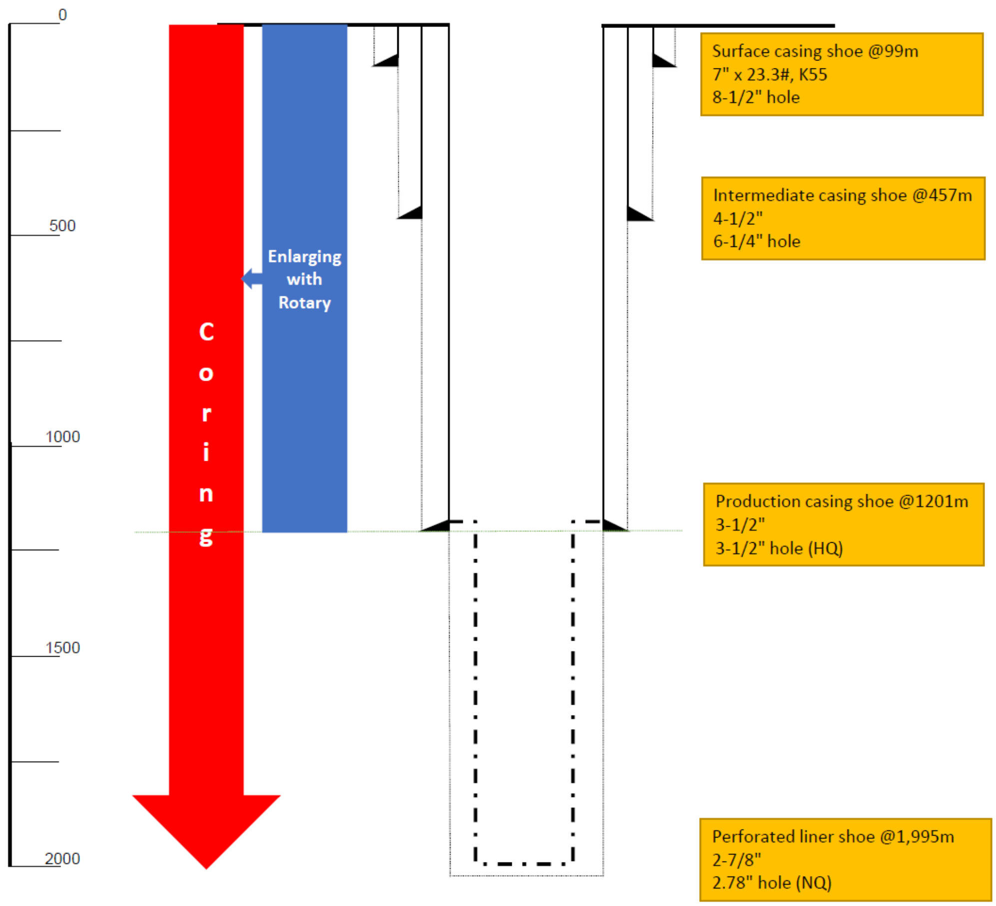

Figure 3. Well Schematic of Blawan-Ijen modified by Sunarso. et. al (2020)

3. SLIMHOLE DRILLING TREND FOR FUTURE CAMPAIGN

From the slimhole drilling campaign information stated in the previous section, the comparison of each well design and rig used can be seen in Table 1. The well schematic and drilling methods frequently used in a particular depth could be extracted as a trend. Conductor, surface, intermediate, and production casing are chosen depending on the field condition, and it may vary on 13-3/8", 9-5/8, or 7". It is shown that for the liner section, HQ is mainly used to drill that section with the liner size of 2-7/8". Also, the liner is installed when it has entered the reservoir zone.

In slimhole drilling, the drilling rigs that can be used are conventional rig, coring rig (mining), or a hybrid between rotary and coring (multipurpose rig). The multipurpose rig was mainly used from the several drilling experiences above. The multipurpose rig gives considerable remarks in slimhole drilling.

- Give substantial cost reduction as a result of the smaller size of casing, the smaller volume of cement needed for the casing, smaller downhole tools. Smaller rig size, pad, and sump will also reduce rig mobilization and site construction costs.
- Give more information about the reservoir geologic from the core samples obtained.
- Rotary drilling could be used to drill the upper zone of the well, usually until the depth of production casing, to reduce the drilling time. Then, the core drilling method could be used from the production zone until the actual depth.

4. CONCLUSION AND RECOMMENDATION

This paper has summarized six geothermal fields in Indonesia that have applied slimhole. The comparison of each well design and rig used can be seen in Table 1 below.

Table 4: Comparison of Well Design and Rig Used in Indonesian Slimhole Campaign Design Recommendation

Section	Kamojang (753 m)			Wayang Windu (1,500 m)			Sarulla (2,330 m)			Darajat (1,585 m)			Tangkuban Parahu (1,500 m)			Blawan-Ijen (2,000 m)		
	Size	Rig	Method	Size	Rig	Method	Size	Rig	Method	Size	Rig	Method	Size	Rig	Method	Size	Rig	Method
Conductor	13-3/8"									No data			13-3/8"			9-5/8"		
Surface	No data									9-5/8"			9-5/8"			7"		Coring and enlarge with rotary
Intermediate	No data	No data	No data	No data	UDR 1500	Rotary	No data	No data	Rotary	7"	UDR 1500	Rotary	7"	MCQ 700	Rotary	4-1/2"	KWL-1600H	
Production	4-1/2"									4-1/2"			4-1/2"			3-1/2"		
Liner	No data					Coring			Coring	2-3/8"		Coring	2-7/8"		Coring	2-7/8"		Coring

Based on the comparison above, well and rig design trends of slimhole drilling could be seen. From the trend analysis, we can conclude to obtain the recommendation for future slimhole drilling campaigns as follows:

Table 2: Recommendation for Future Slimhole Drilling Campaigns

Drilling Rig	Multipurpose rig
Drilling method	Rotary for the upper part of well (surface to production casing) then coring for the remaining depth
Conductor casing	Depends on the field (13-3/8" or 9-5/8")
Surface Casing	Depends on the field (9-5/8" or 7")
Intermediate	Depends on the field (7" or 5-1/2" or 4-1/2")
Production Casing	Depends on the field (4-1/2" or 3-1/2")
Production Liner	HQ or NQ

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