INVEST White Paper

Development of high temperature drilling technologies for 21st century Mohole

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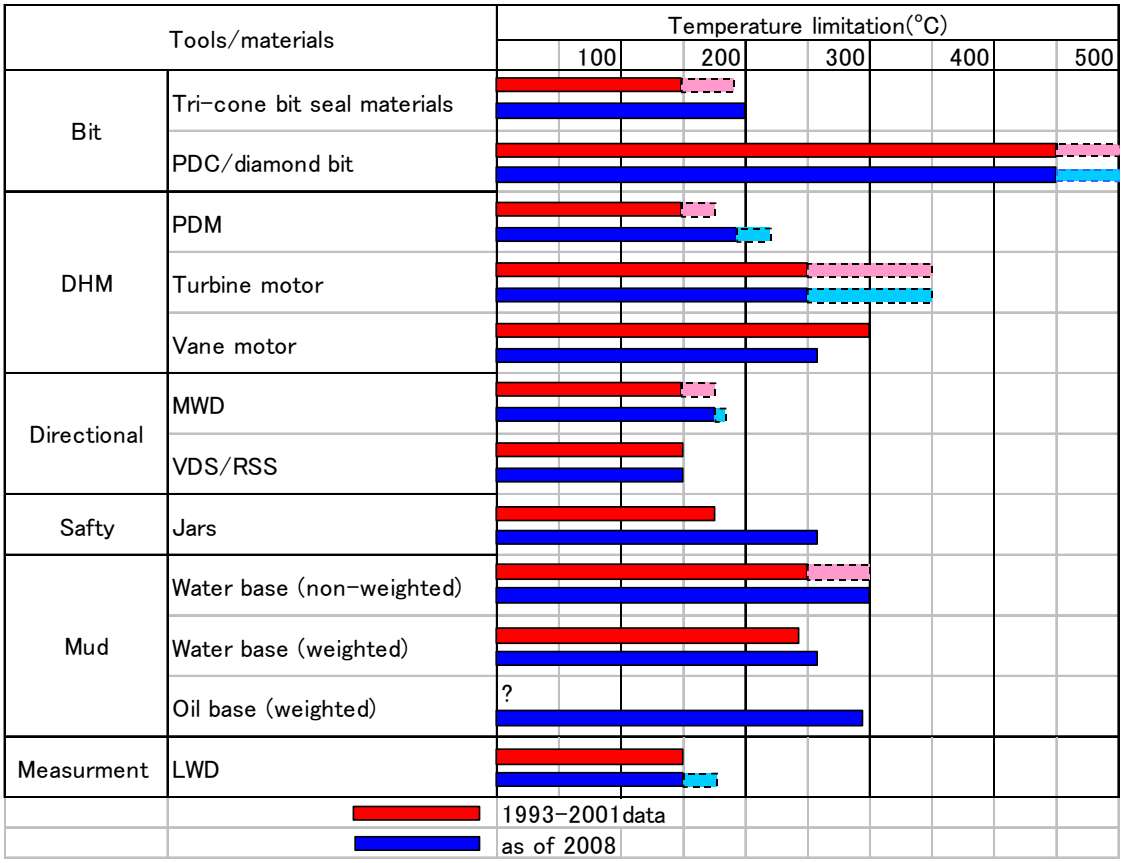
Abstract

In IODP phase-2, scientists are planning to penetrate into high temperature formation. For example, formation temperature exceeding 250 deg-C is expected in the 21st Mohole. Existing technologies guarantee operation of drill tools up to 150-200 deg-C and drill mud up to 260-300deg-C. Experiences of penetration into high temperature formation (>300 deg-C) in land drilling have demonstrated that adequate cooling by the circulation of the drill mud enables operation of the tools in high temperature formation, hence, it is expected that this concept can be introduced to IODP. However, complex harsh environments in IODP boreholes, such as high temperature, deep sea, and high pressure, it is expected that reduction/loss of performance of the tools disables us to penetrate into the formation. Development of cooling technologies/system of the borehole with sufficient effectiveness and acceptable cost is expected. Improvement of temperature durability of the drill mud is indispensable technological development, because the drill mud directly contacts to the high temperature formation.

1. Temperature limitation of the existing drilling technology

A summary of temperature limitation for high temperature drilling tools and materials[1)] is shown below.



It is seen in the table that significant improvement in heat durability has been achieved only in Jars and the temperature limitation for the other major tool is remaining around 150-200 deg-C. However, it should be noted that in most of the cases the temperature in borehole is lower than that in formation. Hence, there tools are available in higher temperature formation if the borehole is adequately cooled by the drill mud or water. For example, in geothermal field in Kakkonda Japan, granite exceeding 500 deg-C had been drill with TDS (Top-drive Drilling System) Cooling Method (Fig. 1) [2].

Therefore, we have to find either (a) or (b) in drilling of high temperature formation:

(a) Cooling method of the tools below the temperature limitation.

(b) Alternate methods/tools which enable drilling without the tools with lower temperature limitation.

Development of high temperature drill mud (>250 deg-C) is indispensable, if the formation temperature is expected to exceed the temperature limitation of the mud, because the drill mud directly contact to the formation.

2. Technological developments for HT drilling

High temperature drilling technologies can contribute to deep scientific drilling, e.g. 21st Mohole. We also may face high temperature problems in shallow penetration boreholes around volcanic zones.

2-1 Formation temperature and associated drilling difficulties

CASE-1: Formation temperature around/below 200 deg-C

Water base weighted mud and TDS can be effectively used to cool downhole tools by continuous mud circulation. TDS Cooling Method enables us to cool the BHA and other downhole tools while POOH/RIH operations.

CASE-2: Formation temperature <250 deg-C

In most of in this case, the circulated drill mud can cool the tools under their temperature limitation, and the temperature of the drill mud is also under the limitation (although nearly critical). However, any trouble in mud circulation will easily bring failure of the tool (Fig. 2). TDS Cooling Method is also effective in this case.

CASE-3: Formation Temp. <300deg-C

In this temperature condition, water base weighted mud will lose designed function as a drilling fluid, i.e. adequate viscosity, gel strength, fluid loss and mud cake. Even the water based drill mud loses function, there is some drilling possibility if no high

pressure gas/fluid or no extreme formation pressure are found.

Case-4: Formation temperature >300 deg-C

This is an extremely harsh drilling condition, because the water based weighted drill mud loses all the expected functions. Injection of a large amount of sea water may realize drill into such formation, although no trouble in the borehole is allowed.

2-2 Indispensable technological improvement and development in future

Considering the technological developments in oil/geothermal industries, drastic improvements in temperature limitation can not be expected within a few years for almost all the drilling/measurement tools. Hence, the development of high density drill mud with high temperature durability (>300 deg-C) is of importance from cooling point of view. Such drill mud also should be stable under sea water temperature. New concept of cooling method of the tools, such as Water-jacket Casing Cooling System (Fig. 3) and insulated drill-pipe, would be also effective to realize the high temperature drilling in IODP.

3. Problems and recommendations

Because there is no large market needs for high temperature drilling tool, significant development of high temperature drill tools can not be expected in oil/gas or in the other industries. This means that IODP community should develop (a) drill mud for high temperature drilling, and (b) techniques to effectively cool the tools with acceptable costs. However, such developments needs human/financial resources, organization (collaboration among governments, academia, and industries), and enthusiasm.

Reference

1) Sakuma, S.: High temperature drilling technology for Mohole project, Domestic INVEST Technology Development WS, 2008（in Japanese）

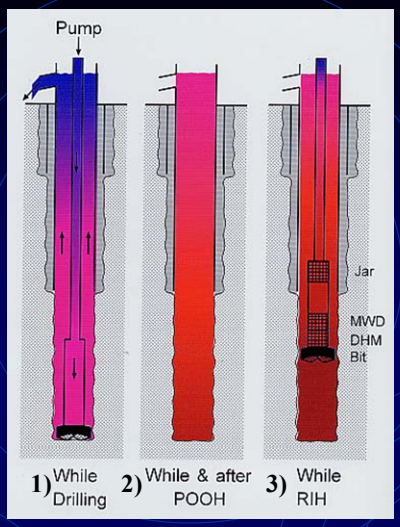
2) Saito, S., Sakuma, S.: Frontier geothermal drilling operations succeed at 500℃ BHST, SPE Drill & Completion. 15(3), 152-161, 2000

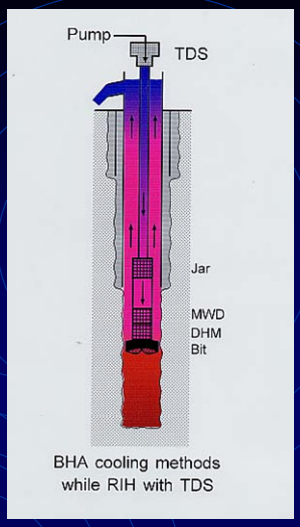
Figure captions

Fig.1: TDS Cooling Method

Fig 2: Drilling difficulty under complex harsh condition

Fig 3: Concept of the Water Jacket Casing Cooling System





1) **Drilling tools can be cooled while mud circulation**
2) **Stop circulation and/or POOH BHA, formation temperature goes up**
3) **New drilling tools brake before TD, when RIH**

TDS-cooling method can cool drilling tools while RIH with mud circulation using TDS

Fig.-1 TDS Cooling method

Saito, Sakuma (2000)

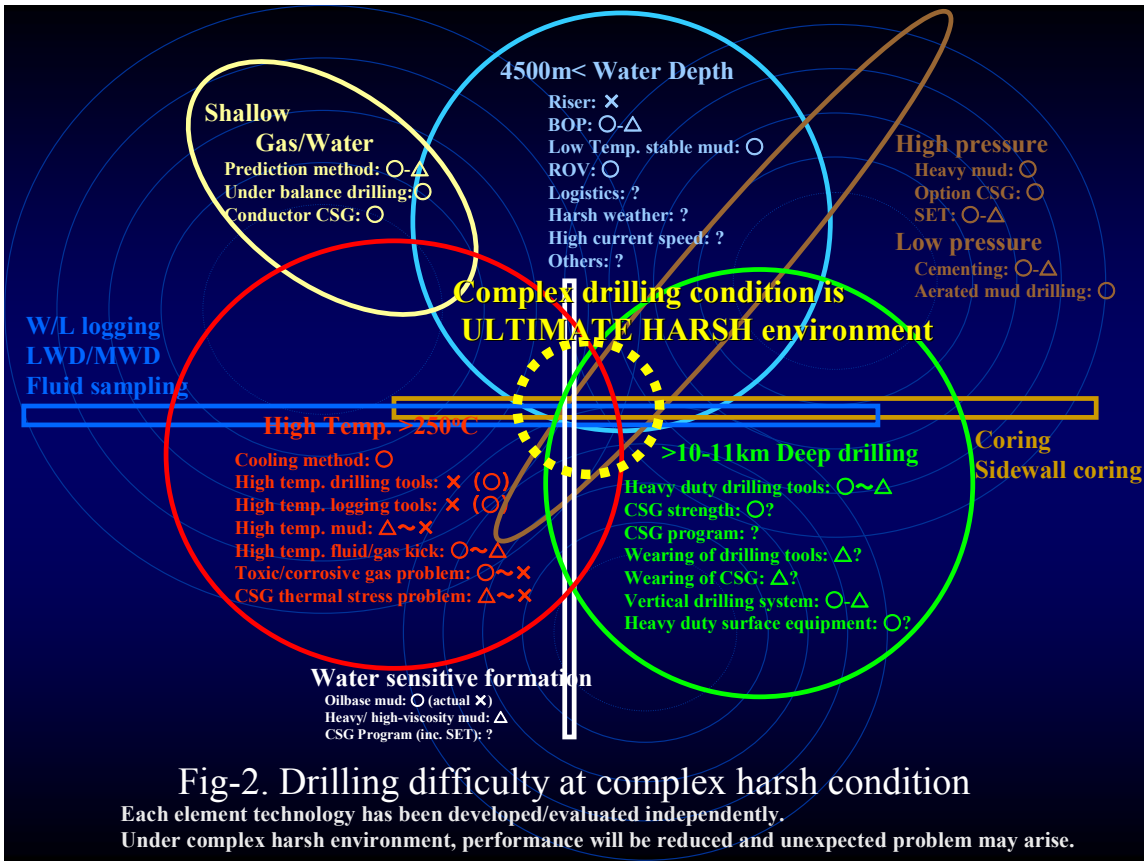


Fig-2. Drilling difficulty at complex harsh condition

Each element technology has been developed/evaluated independently.
Under complex harsh environment, performance will be reduced and unexpected problem may arise.

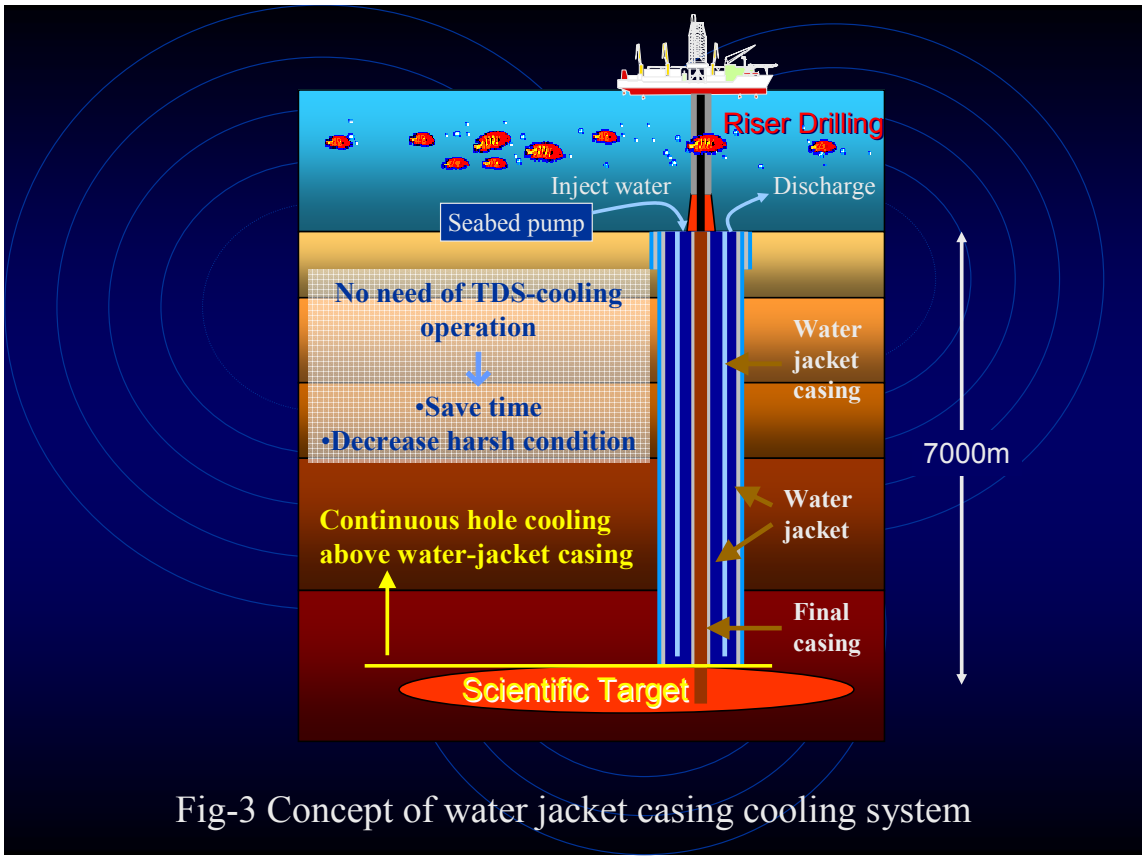


Fig-3 Concept of water jacket casing cooling system