Problem Solving process in SAGD Project

Here is a synopsis of the problem and problem solving process encountered at an Operator's SAGD Project.

Problem

The operator experienced a large number of mud rings in the Clearwater formation during the enlargement of the intermediate hole from 311mm to 444.5mm. The mud rings were not encountered during the drilling of the pilot hole (311mm) but were constantly encountered while running the hole opener to 444.5mm.

Problem Solving Process

Composite samples of the Clearwater formation were recovered and tested at the Q'Max Lab. The CST tests revealed that the Clearwater formation in this area is mostly composed of smectitic clays, extremely water sensitive and with very fast hydration rates. The CST scored 2154 sec. For comparison, other well known water sensitive formations in Western Canada score much less (i.e. Old Man shale @ 400 sec; Milk River shale @ 200 sec; Lea Park shale @ 162 sec; Fort Simpson shale @ 87 sec; etc.). The well known Gumbo shale in the GOM scores at ~850 sec. Consecutive CST tests with Clearwater and Q'Max's Maxdrill amine demonstrated its highly inhibitive properties by reducing the CST to 18 sec.

Operational reviews determined that the mud rings formed were Type A Mud Rings. This kind of mud ring forms in the presence of fast hydrating clays/shale, fast rates of penetration cumulated with inadequate hole cleaning. In such situations the bit/hole opener generates large cuttings, ribbon-like in appearance. These cuttings hydrate fast on their surface and, if not removed from the hole in due time, will coil to form 1 – 1.5 inch balls, while rolling on the bottom of deviated holes. Then they will start sticking to each other and to the drill string, thereby creating mud rings that are wet inside.

A drilling fluid can influence the formation of such mud rings by two distinct processes:

1. Chemical & mechanical inhibition; and
2. Hole Cleaning

The chemical and mechanical inhibition required by the Clearwater formation were addressed by the use of the Q'Max's MaxDrill System, an inhibitive amine/PHPA fluid designed for extremely water sensitive formations.

Chemical Inhibition – as discovered through the CST testing and further shown in this field application, 5-6 L/m^3 MaxDrill amine reduced the hydration of the Clearwater formation by 99.2%.

Mechanical Inhibition – in order to further reduce the coiling and sticking effect of the ribbons created during drilling, an anionic PHPA (Q'Max's Hyperdrill 247) was mixed in concentrations of up to ~3 kg/m^3.

However, even employing this very inhibitive water based mud to its best capabilities, did not result in completely alleviating the formation of mud rings in the large hole (444.5mm). It was determined that proper inhibition was achieved with the MaxDrill System, due to the fact that mud rings were not formed in the 311mm pilot hole. The cost/benefit ratio did not justify excess usage of inhibitors. As such, the hole cleaning in large, deviated holes was approached in a scientific manner.

The three forces that act upon the ribbon, or ball, of clay are: **G** gravity, **B** buoyancy and **F** friction. In a deviated hole, between ~30° and ~65°, **G**ravity pulls a particle down and to the lower side of the hole. **B**uoyancy pulls it up and to the upper side of the well. **F**riction also pulls it up in the direction of the flow. Because the force of gravity is typically at least twice as much as the buoyancy, the particles ends up rolling around the bend on the lower side of the hole. On connections when the flow stops, a turbidity flow phenomenon takes place and the cuttings found between ~30° and ~65°, avalanche toward the bottom hence forming a mud ring.

In order to clean the hole properly, the **B** and **F** forces have to overcome the **G** force. To increase the **B** force, the mud density has to be increased. However, it has a limited effect on hole cleaning and there are unwanted side effects associated with drilling with high density fluids through clays and unconsolidated sands. In order to increase the **F** force three things can be done: **1**) increase the pump output OR **2**) increase the fluid rheology OR **3**) do both.

For this specific operation, the method with the best cost/benefit ratio was determined to be an increase in the pump output. However, the operator felt they were restricted by the available rig equipment which produced only 3 m^3/minute of flow, therefore generating a maximum of 20m/min annular velocity around the bend. Hydraulics modeling on hole cleaning showed extremely low cuttings transport ratios.

Numerous techniques had been tried by the Operator. They employed running consecutive polymer viscosified pills, amine/PHPA inhibitive pills, sawdust pills, fiber pills, low visc–hi visc pills, etc. and they all had limited success. Further increases in mud rheology with Brookfield rheometer readings in excess of 100,000 cPs at 0.3 RPM had limited success also.

A new round of hydraulics modeling pointed again to a hole cleaning issues due to lack of annular velocity. The operator agreed to, and brought in, an extra pump, therefore increasing the pump output to ~4.4 m^3/min and the annular velocity to ~30 m/min around the bend. In conjunction with a slight increase in the fluid's low end rheology, this approach completely alleviated the formation of mud rings for the last three large holes.

This should help in dealing with similar situations. When drilling similar holes (444.5mm and larger) off-shore and in the Arctic, 4 m^3/min is typically the minimum acceptable for pump output.