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Modelling the Massive Scaling Phenomena in Upper Mahiao and South Sambaloran Using Solveq/Chim-XPT

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ABSTRACT

Massive mineral deposition along geothermal Fluid Collection and Re-cycling System (FCRS) facilities has caused losses in the operation of Upper Mahiao and South Sambaloran sectors in Leyte Geothermal Production Field due to recurring shutdowns conducted to remove these deposits. It is important to provide the proper mitigating measure to prevent such occurrence and this can be done by understanding the process by which this massive scaling forms. Geochemical modelling software like SOLVEQ and CHIM-XPT are useful tools to model and understand the process by which mineral deposition occurs.

Results of the simulation using the software showed that the modelling was able to match the identity of most of the deposits that were observed in the field and the mechanism by which massive scale formation occurred. Modelling simulation showed that massive deposition in Upper Mahiao two-phase header was due to the mixing of the acidic (pH = 3.7) amorphous silica-supersaturated fluid, from Well 2D with the less acidic (pH=6) fluid from Well 1D. The resulting fluid was supersaturated with amorphous silica but with a less acidic pH of 5. The increase in pH resulted to faster oligomerization that caused massive scale formation. Separation of the branch-lines was recommended to prevent the massive scaling. While for the case of South Sambaloran, the massive deposition in Separator 6 brine line, based on the simulation, was due to the flashing of the brine. Flashing caused amorphous silica to become supersaturated and form massive deposits.

1. INTRODUCTION

Formation of mineral deposits along the FCRS facilities is detrimental to geothermal operation. Massive deposition restricts the flow of fluid and cleaning these deposits will require shutting down of the well or the entire facility. It was observed that massive scaling occurs when two or more geothermal fluids coming from production wells mixed in a common two-phase header.

1.1 Massive Scaling in Upper Mahiao

In Upper Mahiao, massive deposits were documented in March 2010 at the two-phase header where Well 1D (~3.0 MWe) and Well 2D (~5.8 MWe) mixed. The deposits extended ~60 meters downstream of the mixing point and almost completely blocked an 18 meter section of the two-phase header. Individual branch lines of each of these wells were relatively clean.

The scales were composed primarily of iron sulfides/oxides (magnetite and pyrrhotite) embedded in thin multi-layered amorphous silica based on petrographic analysis (Rosell, 2010).

1.2 Massive Scaling in South Sambaloran

Recurring flooding of Separator 6 was reported since March 2009. This was due to the mineral deposits that cause blockages along the brine line and other components downstream of the separator vessel (Sabenicio, 2011).

The discharge from Wells 4D, 5D and 10D with a combined output of ~30 MWe were mixed in a common two-phase header and directed to Separator 6. Both Wells 4D and 5D were dry wells while Well 10D contained minimal brine, approximately 2-4 kg/s (Sabenicio, Angcoy, & Rosell, 2011).

The deposits were reported to be corrosion products, illitized rocks, smectite scales, amorphous silica which were deposited in layers, rimmed and cemented by amorphous silica (Sabenicio, 2011).

2. METHODOLOGY

It is important to understand how and why massive mineral deposits form along the pipelines and other FCRS facilities. Understanding the process by which these minerals deposit can help develop the proper course of action and mitigating measures to prevent recurrence. Geochemical modelling software like SOLVEQ-XPT and CHIM-XPT can help provide a better understanding of how the chemical species present in the geothermal fluid interact during mixing or boiling. For a given temperature, pressure, and total composition of a chemical system, CHIM computes the compositions of the aqueous, solid, and gas phases at equilibrium. While SOLVEQ is used primarily as a work horse for processing water analyses of all types, but useful also for certain types of geochemical process modeling (Reed, Spycher, & Palandri, 2012).

2.1 Geochemical Modelling Using CHIM-XPT

The modelling assumes an isolated system. In an isolated system, the enthalpy of the well discharge is that of the aquifer fluid.(Arnorsson & Stefansson, 2005)

The modeling work started with simulating the reservoir fluid of each well. The reservoir fluid was then boiled to branch line temperature and two-phase header temperature. The result from the two-phase header boiling was used for the mixing simulation. The fluids from the wells that were connected to the two-phase header were then mixed. The resulting mixed fluid was then boiled at an incremental temperature from the header temperature to the separator vessel temperature or even down to 100°C.

The resulting predicted minerals were then compared to the scales identified by the petrographic analysis. This study was limited only in modelling the likely minerals that will deposit and not the quantity because the amount of minerals that will deposit could be dependent on the kinetics of deposition which was not part of the scope of this study.

3. RESULTS AND DISCUSSION

3.1 Upper Mahiao Modelling Result

Well 1D modelling was able to replicate the formation of magnetite and amorphous silica scales that were identified in actual scale samples. But for Well 2D, only amorphous silica formed based on the model wherein actual scales had magnetite, sulfides and chalcopyrite. The mixed fluid model which represents the fluid in the two-phase header matched the magnetite and amorphous silica scales that deposited in actual scales, except for pyrrhotite.

It was noted that both Well 2D branch line modeled fluid and the two-phase header modeled fluid have potential for amorphous silica scaling but it was only in the two-phase header where massive mineral deposition was documented. This could be because of the difference in the pH. The Well 2D fluid had more acidic fluid, pH ~ 3.6, while the mixed fluid at the two-phase header has pH of ~5.

The increase in pH at the two-phase header could have caused amorphous silica to develop into scales. According to Iler (1979), the oligomerization rate is more rapid at neutral pH. The oligomerization of silica monomers is the first step in forming complex precipitates. As pH increases towards 7, the decrease in the activity of H^+ and the increase in un-protonated $Si\text{-}O^-$ groups on the colloidal surfaces naturally leads to an increased sensitivity of polymerization to ionic strength and silica concentration (Icopini, Brantly, & Heaney, 2005). The slightly higher pH of the mixed two-phase header fluid could have increased the rate of oligomerization of silica monomers thus causing more deposition.

3.2 South Sambaloran Modelling Result

The simulated boiling of Well 10D from the reservoir up to the branch line showed potential for magnetite and pyrite deposits but not with amorphous silica until boiling reached 192°C. Well 10D had a branch line temperature of ~198°C and based on the simulation, there was no potential for amorphous silica deposition at this temperature. The simulation results matched the deposits observed in the field.

However, significant amount of deposits composed of amorphous silica and halite were observed at the Well 10D stub-in section. This is the section where the fluid coming from Well 4D mixed with Well 10D fluid. The modelling of the Well 10D and 4D mixing showed potential for pyrite and Al-free-chlorite deposits but not for amorphous silica when the two fluids completely mix. But it was observed that at the initial stage of mixing, at lower mixer fraction, amorphous silica did deposit. It is likely that non-homogenous mixing occurred at the stub-in section and caused amorphous silica to deposit.

Mixing of the fluid from Well 5D with the mixture of Wells 4D and 10D showed potential for pyrite and Al-free-chlorite deposits but not amorphous silica. However, the boiling of the mixed fluid from Well 4D, 10D and 5D from two-phase header temperature of 191°C down to 179°C showed potential for pyrite deposition throughout the boiling run and potential for amorphous silica deposition from 182-180°C.

The result of the modelling of the mixed fluid showed that massive scale deposits in Separator 6 could be due to the flashing of the fluid entering the separator vessel that caused the temperature to drop to 179°C. Because of the potential for amorphous silica deposition, this initiated the cementation of suspended solid carried by the dry wells which was reported to be greater than 5ppm as total suspended solids. It was also evident by the identity of these deposits which was reported as corrosion products, illitized rocks, smectite scales, amorphous silica which were deposited in layers, rimmed and cemented by amorphous silica (Sabenicio, 2011).

4. CONCLUSION

SOLVEQ-XPT and CHIM-XPT are very useful geochemical modelling software that can help geochemists in understanding the process or processes of mineral deposition along FCRS facilities. Better understanding of how and why these minerals form can help in developing the proper mitigating measures.

Based on this investigation of the massive scaling phenomena in Upper Mahiao, the change in pH could have triggered the massive deposition in the two-phase header, when the acidic-amorphous silica-supersaturated fluid from Well 2D mixed with the neutral fluid from Well 1D. While for the case of South Sambaloran, massive deposition in Separator 6 brine line was due to the flashing of the brine which caused amorphous silica to become supersaturated and deposit as scales.

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