IMPROVEMENT OF TC5RD PERMEABILITY INDUCED BY STEAM CONDENSATE INJECTION: MODELING THE CONDENSATE-ROCK INTERACTION USING CHIM-XPT

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ABSTRACT

Steam condensate reinjection well TC5RD in Southern Negros Geothermal Production Field initially has low permeability and did not attain the required reinjection capacity. However the acceptance increased by ~38 kg/s in a period of ~5 months since it was commissioned. Geochemical modelling using the CHIM-XPT software was conducted to investigate the role of mineral dissolution in the permeability improvement in TC5RD. At less than one gram rock titrated, there was an observed steep increase in $SiO_{2(aq)}$ and Na^+ concentration indicating quartz and silicate mineral dissolution from the andesitic host rock. Total molality of $SiO_{2(aq)}$ changed from $4.74x10^{-5}$ to $6.80x10^{-3}$ (mol/kg solution). Major dissolution happen at lower titrated rock mass and this likely occurs at the section of the rock near the open hole section where the condensate and host rock first interact in the reservoir. Subsequent injection of condensate could have induced more dissolution of the quartz and silicate minerals from the rock which further initiated increase in permeability.

Keywords: CHIM-XPT, permeability, reinjection, condensate, dissolution, SiO_2

1. INTRODUCTION

TC5RD was drilled to accommodate the reinjection of the condensate coming from the 112.5 MWe Palinpinon 1 powerplant in Southern Negros Geothermal Production Field. The open hole section intersected the Okoy Sedimentary Formation (OSF) which was characterized to be calcareous and fossiliferous siltstone with intercalations of few andesite dikes/lavas. The initial acceptance of the well was 19.0 kg/s, operating at the maximum well head pressure (WHP) set at 1.2 MPag. It was observed that after 7 days of continuous condensate injection, the WHP decreased by 0.2 MPag. After ~5 months operation the acceptance of the well increased to 57.0 kg/s and the WHP became vacuum.

The case of TC5RD was similar to that tested in Geysers USA and Salak geothermal fields wherein the reinjection of steam condensate showed permeability improvement through time. Although not conclusive, initial field investigations conducted showed rapid dissolution of quartz [1] and opening of new and existing cracks with injection of steam condensate [2].
Bahian conducted water-rock interaction experiment using a high temperature plug-type flow through simulator by reacting a representative core sample from Okoy Sedimentary Formation and representative Palinpinon 1 condensate. The result showed that there is a rapid dissolution of silica in the andesitic rock which creates vugs, fractures and void spaces (Fig. 1).

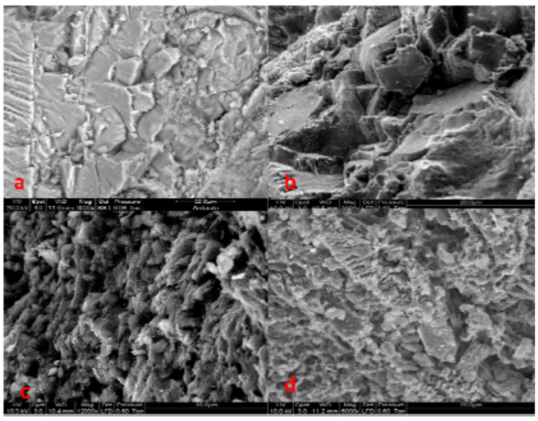

Fig. 1. Scanning electron micrograph of rock matrix (a) unreacted (b,c,d) reacted

Equilibrium concentration of $SiO_{2(aq)}$ in the solution has reached 400 ppm, from an initial concentration of 0.79 ppm. Na^+ and K^+ were also quickly released into the solution resulting to increased levels of Na^+ and K^+ ions in the effluent samples. The thermal and the chemical effects were also evaluated by Aqui [4] using a number of established correlation equations which relates permeability with porosity, mineral dissolution-precipitation reactions and stresses. Thermal cracking or contraction of the rock matrix was found to have little contribution to the over-all permeability [4].

It is important to understand the net effect of mineral dissolution and precipitation that could influence the permeability. In this study, CHIM-XPT was used to model the likely mineral dissolution and precipitation that occurred when the Palinpinon 1 powerplant condensate reacted with the reservoir rock of the Okoy Sedimentary Formation and compare the result with what was observed on the studies conducted by Bahian (Bahian, 2012) and Aqui (Aqui, 2012).

2. METHODS

CHIM-XPT is a FORTRAN program for computing multi-component heterogeneous chemical equilibria among solids, gases, and an aqueous phase. CHIM-XPT computes the chemical equilibrium assemblage at minimum Gibbs free energy [5]. In this study, it was used to model mineral dissolution and formation by water-rock titration.

The modeling run was done as a water-rock titration where the reactant rock is incrementally added to the condensate. Rock titration run was done in three incremental runs from 0.01 to 0.1, 0.1 to 1.0, and 1.0 to 10 grams of rock titrated. The rock composition consists of 48.97wt% SiO_2, 19.21% Al_2O_3, 6.73% CaO, 3.74% MgO, 1.74%Na_2O, 0.56% K_2O, 0.06% FeS, 3.48% FeO, 1.93% Fe_2O_3, and 13.56% CO_2. The actual measured temperature of the reservoir of 230 ^oC was used in the simulation.

3. RESULTS AND DISCUSSION

The modelling was conducted to evaluate the changes in the concentration of dissolved components in the condensate and the formation of secondary minerals. At titrated rock mass less than 1, simulation showed steep increase in $SiO_{2(aq)}$ and Na^+ concentration (Fig. 2). This indicates the dissolution of quartz and silicates from the host rock. Total molality of aqueous silica changed from 4.74×10^{-5} to 6.80×10^{-3} mol/kg of solution. As the titrated rock mass increased, concentration of $SiO_{2(aq)}$ reached a plateau and quartz become saturated (Fig. 3).

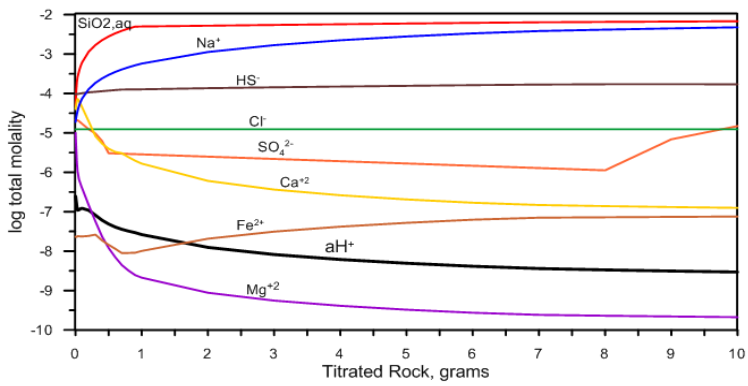

Fig. 2. Concentration of aqueous species at incremental rock titration

Even with the formation of quartz, the major forming mineral, at higher titrated rock mass , which could indicate a re-deposition of the SiO_2, the $SiO_{2(aq)}$ concentration did not drop.

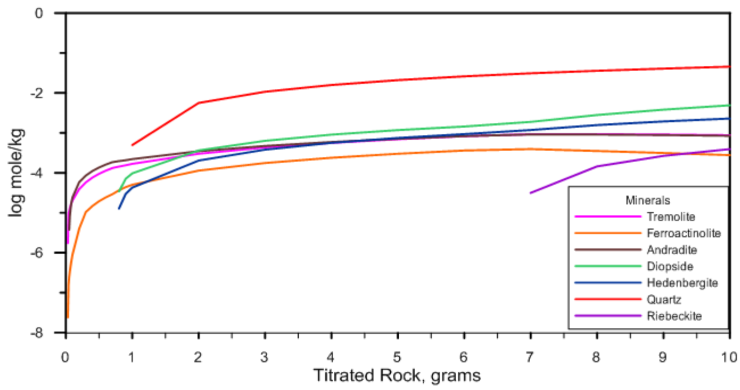

Figure 3: Minerals species saturation in solution at incremental rock titration simulated from ions concentrations in solution at equilibrium

Based on the result of the modelling, major dissolution happen at lower titrated rock mass and this occurs at the section of the rock near the open hole where the condensate and host rock first interact in the reservoir. Then as the fluid travels further along the fractures, there is lesser dissolution. However, subsequent injection of condensate could have induced more dissolution of the quartz and silicate minerals from the rock that further initiated increase in permeability.

4. CONCLUSION

Water-rock interaction modelling of Well 5 reservoir rock with Pal 1 condensate is consistent with the studies conducted by Bahian [3] and Aqui [4]. As the $SiO_{2(aq)}$ undersaturated condensate fluid travels along the reservoir, the rapid dissolution of quartz and silicate minerals created void spaces thus increasing permeability. This was indicated by a steep increase in $SiO_{2(aq)}$ concentration. Consequently, as the injected condensate dissolves more rock further in the reservoir, it created new flow paths that could have channelled connections with the existing major fractures in the reservoir. This was manifested by the vacuum attained by Well 5.

Condensate injection is a future viable option for improving the permeability of geothermal wells. Modelling the water-rock interaction, using CHIM-XPT, between condensate and the host rock is a helpful tool to evaluate the net effect of steam condensate injection in reservoir permeability by understanding the process of mineral dissolution and precipitation.

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