Scaling potential during (CO_2) degassing in geothermal installations

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ABSTRACT

Several geothermal doublets in the Netherlands co-produce CO_2 and to a lesser extent methane with the targeted hot water. This occurs since the produced water degasses upon pressure release at the surface. As the gas is no longer dissolved, a new chemical equilibrium must be formed which may cause mineral precipitation (scaling) within the geothermal installation. A geochemical evaluation of geothermal water was performed to match and predict the scaling potential for Dutch geothermal doublets. We had the unique opportunity to use water and gas composition data of actual geothermal projects, providing us with case studies for the different target reservoirs in the Netherlands. The performed simulations indicate that doublets containing dissolved CO_2 have high scaling risks for carbonate precipitation. It is therefore advisable to take measures to keep the CO_2 in solution or re-introduce CO_2 or another pH decreasing agent during degassing.

1. INTRODUCTION

Geothermal energy in the Netherlands has been growing rapidly over the last decade, including several low enthalpy geothermal projects developed for greenhouse heating. The geothermal reservoirs in the Netherlands can contain significant amounts of CO_2 and dissolved methane. During water production the pressure reduction causes a decrease of gas solubility in the produced water and consequently degassing. Several operators separate and remove CO_2 together with methane, since the methane is a valuable resource. The removal of CO_2 causes a disruption of the chemical equilibrium and invokes a pH increase, which can result in the unintentional precipitation of various mineral phases. Mineral precipitation can severely decrease the functionality of a geothermal doublet and scaling is already observed in some of the Dutch doublets, indicating its relevance to geothermal operations in the Netherlands. This study focusses on understanding and quantifying the effect of CO_2 removal. Geochemical simulations can help identifying the processes involved in scaling. Insight in the process of scaling may point to possible preventive or remediation measures.

2. METHODS

The software PHREEQC (Parkhurst and Appelo, 1999) is used to simulate the scaling potential as a result of depressurization and CO_2 degassing of the water. The scaling potential is defined as the mineral precipitation reactions required to re-establish the chemical equilibrium of the water after it is disturbed by the changing pressure. These models use the Thermoddem database (http://thermoddem.brgm.fr).

We used the measured water composition for the main formation water constituents. The CO_2 is calculated from the gas water ratio, the CO_2 content in the co-produced gas and the CO_2 partial pressure. We used data from seven geothermal doublets of the Netherlands. The data is not reported due to confidentiality of the data, but the CO_2 concentrations for the studied doublets range from 1 to 8 mmol/l. The pressure decrease is modelled as the driving force for and CO_2 degassing during production. CO_2 degassing is close to instantaneous so degassing is simulated first and mineral precipitation next without contact with CO_2 (assuming removal of the CO_2 in a separator tank).

2. RESULTS

The main mineral phases to form during CO_2 degassing are carbonates, with minor amounts of ferrihydrite, silica and barite (Figure 1). The carbonates that form are dolomite and siderite. Note that the type of carbonate formed also depends on the temperature, for example at low temperatures calcite will probably form instead of dolomite. This means that the design of the installation and the relative location of the gas separator and heat exchanger also affect the nature of scaling. The glass phases indicate a that silica has a tendency to precipitate. In reality this means that an amorphous silica gel may form, possibly containing several (metallic) elements.

The spread in mineral precipitation for the different doublets indicates that the scaling potential is strongly location specific and dependent on the original formation water composition (pH) and the original amount of dissolved CO_2. The amount of carbonate scaling will not just depend on the amount of CO_2 present but more specifically on the amount of CO_2 degassing. The amount of CO_2 degassing is in turn

controlled by the CO_2 partial pressure and hence depends on the pressure release. Many geothermal installations have the possibility of keeping the doublet under a certain amount of pressure. Therefore insight into the change in precipitation with pressure could help determining an optimal installation pressure. Figure 2 shows that scaling increases with pressure decrease with maximum scaling potential at the total pressure release to 1 bar. For some minerals it appears that a slight pressurization can prevent their formation.

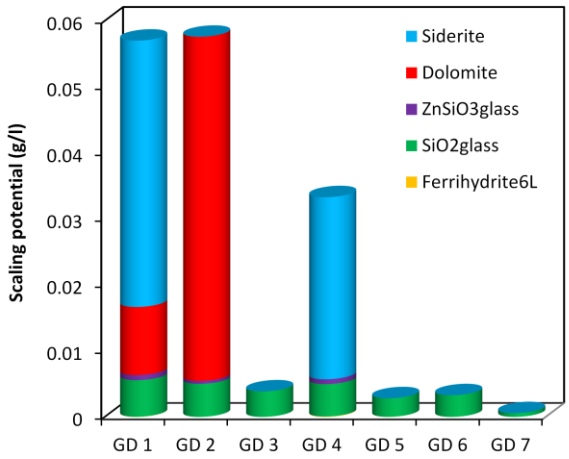

Figure 1: The scaling potential due to degassing as predicted by geochemical modelling for 7 geothermal doublets

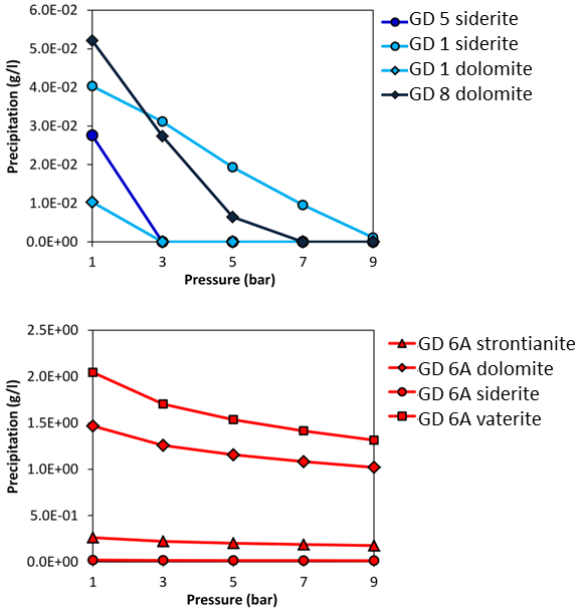

Figure 2: Carbonate scaling due to degassing, given for different pressures.

3. DISCUSSION AND CONCLUSIONS

CO_2 degassing and the related pH increase cause a significant risk for carbonate scaling. When CO_2 is kept in solution this risk will be largely reduced. This could be done by *not* or only partially degassing the water or alternatively CO_2 or an acid can be used to re-acidify the water. If degassing can be prevented depends on the bubble point of the gas, the temperature decrease and the pressure that can be contained within the doublet system. The findings of our study indicate that in the design of installations it is important to evaluate the effects of degassing, in particular in view of the trade-off between potential benefits of degassing (e.g. production of associated gas) vs scaling risks.

The predicted amount of scaling is sensitive to the location specific chemistry. To accurately predict scaling it is important to calibrate the model with detailed measurements of scaling samples and the water chemistry. Combining simulations with observations of scaling by the operators provides an excellent opportunity to build an applied model for predictions of possible problems. This will aid the development of preventive and remediation measures for flow reductions and contributes to a best practice for geothermal operations.

The chemical changes in the water due to temperature and pressure changes, degassing and subsequent scaling may cause additional chemical reactions upon injection in the reservoir. This may require, and affect, soft stimulation of the reservoir, on which research is currently ongoing.

REFERENCES

Parkhurst, D.L., Appelo, C.A.J., 1999. User's Guide to PHREEQC (Version 2) – A Computer Program for Speciation, Batch Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. Report 99-4259. US Geological Survey Water-Resources Investigations.

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