Available online at www.sciencedirect.com

ScienceDirect

Procedia Earth and Planetary Science 17 (2017) 344 – 347

Procedia Earth and Planetary Science

15th Water-Rock Interaction International Symposium, WRI-15

Unraveling the formation of large amounts of calcite scaling in geothermal wells in the Bavarian Molasse Basin: a reactive transport modeling approach

Christoph Wanner[a,1], Florian Eichinger[b], Thomas Jahrfeld[c], Larryn W. Diamond[a]

[a]*Rock-Water Interaction Group, Institute of Geological Sciences, University of Bern, Baltzerstrasse 1+3, CH-3012 Bern, Switzerland*
[b]*Hydroisotop GmbH, Woelkestr. 9, D-85301 Schweitenkirchen, Germany*
[c]*renerco plan consult, Herzog-Heinrich Str. 13, D-80336 München, Germany*

Abstract

Results from reactive transport simulations performed for the geothermal plant in Kirchstockach, located in the Bavarian Molasse Basin in southern Germany, are presented to unravel the formation of calcite scaling. Simulation results successfully predict the calcite scaling profile observed along the production well if supersaturation with respect to calcite is specified for the model water leaving the pump at 800 m depth. This observation is in good agreement with a previous study suggesting that gas exsolution (i.e., boiling) occurring at the pump due to an unwanted pressure drop is the most likely driver for the formation of those calcite scalings.

Peer-review under responsibility of the organizing committee of WRI-15

Keywords: Scaling; calcite; geothermal energy; reactive transport; boling

1. Introduction

The carbonate-dominated Malm aquifer in the Bavarian Molasse Basin in southern Germany is being widely exploited and explored for geothermal energy[1-3]. Owing to karstification, the fracture spacing and permeability is high enough for continuous water extraction. Therefore, some 40 wells have been drilled in the greater Munich area over the last 10 years. Typical flow rates are between 30 and 130 L s^{-1} and the production temperatures reach up to 150 °C. Despite these favorable reservoir conditions, the use of many of the wells for heat and power production is

* Corresponding author. Tel.: +41316314023; fax: +41316314843.
E-mail address: wanner@geo.unibe.ch

Peer-review under responsibility of the organizing committee of WRI-15
doi:10.1016/j.proeps.2016.12.087

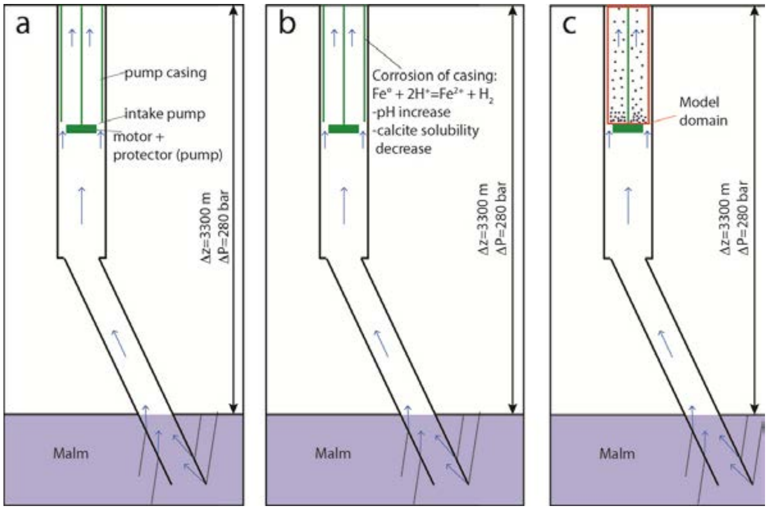

Fig. 1. Scenarios of the formation of calcite scaling: (a) linear decompression scenario in which calcite precipitation occurs only due to the solubility decrease associated with the linear pressure decrease of ca. 280 bar as the thermal water is pumped from the Malm aquifer to the surface. (b) Corrosion scenario in which calcite precipitation is induced by corrosion of the casing and the associated pH increase and calcite solubility decrease. (c) Boiling scenario in which calcite precipitation is caused by gas exsolution from the produced thermal water due to a localized pressure drop, most likely located within the centrifugal pump. Scenario c also shows the section of the well for which reactive transport model simulations were performed.

highly challenging. The main difficulty, especially in the deep (>3000 m) boreholes with temperatures >120 °C, is that substantial amounts of calcite-dominated scaling are hindering the proper operation of the pumps within the wells and of the heat exchangers at the surface. In a previous study[4] we presented an extensive dataset from the geothermal plant in Kirchstockach, which was collected during the production period between December 2014 and March 2015. Based on chemical analyses of wellhead water samples, chemical and mineralogical analyses of scaling collected along the uppermost 800 m of the production well, and gas analyses of fluid inclusions identified in calcite crystals we postulated three scenarios that can explain the formation of the calcite scaling (Fig. 1). The scenarios were evaluated by performing geochemical speciation calculations taking into account the pressure dependence of calcite solubility. The calculations suggested that the boiling scenario, where gas exsolves at the pump due to an unwanted pressure drop, is the most likely driver for scale formation[4]. For this contribution we present results from reactive transport model simulations performed for the three scenarios to further test the three scale formation scenarios.

2. Model setup

Reactive transport model simulations were performed for each scaling scenario (Fig. 1) using the code TOUGHREACT V3[5]. Simulations were run for the section of the production well located above the pump. Since the pump was situated at a depth of 800 m during the studied production period, the vertical extent of the model is 800 m (Fig. 2a). The temperature was kept constant at 135 °C, corresponding to the long-term average wellhead temperature. At the upstream model boundary the pressure was fixed to 18 bar, corresponding to the pressure under which the geothermal plant is being operated at the surface. Within the well a hydrostatic pressure distribution was defined yielding a pressure of about 90 bar at the downstream model boundary. To be able to simulate that scaling formation only occurs at the surface of the casing a 2D radial mesh was defined (Fig. 2b). In doing so, the production well was discretized into 7 radially concentric grid cylinders. The radial discretization further allowed the definition of a parabolic velocity distribution $v(r)$ across the well according to the Poiseuille equation:

$$v(r) = \frac{1}{4\eta} \cdot \frac{\Delta P}{\Delta z} (R^2 - r^2) \quad (1)$$