

Using direct-current and complex electrical conductivity to monitor biogeochemical redox reactions

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Direct-current electrical conductivity measurements can be correlated across scales to changes in chemical concentrations due to redox reactions if reaction stoichiometries are understood. In batch experiments, reaction rates for dissimilatory iron reduction calculated from geophysical and geochemical changes were similar to within $\pm 25\%$. In flow-through reactors, initial conductivity changes corresponded to changes in fluid chemistry. However, under iron-reducing conditions a three-fold increase in electrical conductivity (0.02 S/m – 0.06 S/m) was recorded over 10's of cm. after 11 weeks. An even larger increase (0.02 S/m – 1.2 S/m) was recorded under nitrate-reducing conditions. Models based on percolation theory are consistent with the measured conductivity increase if biofilms are 33 times more conductive than pore fluid. To confirm this hypothesis we performed electrochemical experiments that involved growing iron reducing bacteria directly on an electrode surface. Preliminary data from these experiments demonstrate a thousand-fold increase in the DC electrical conductivity of respiring biofilms. Similar column experiments are being run while collecting complex conductivity measurements (an alternating-current method) in an attempt to further characterize this phenomenon.

Mineral precipitation from geothermal brines during reservoir activities – Example Groß Schönebeck (Germany)

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Between 2001 and 2009 various reservoir operations have been conducted at the two geothermal wells of Groß Schönebeck (North German Basin) to increase fluid production and injectivity. Simultaneously, fluid samples have been collected (at 4100-4235 m depth) and analyzed for their chemical composition. The aqueous phase is nearly saturated with calcium, sodium and chlorine, which represent altogether 98 % of its salt content. During fluid production the initial (reservoir) pressure and temperature conditions (~ 150 °C and ~ 45 MPa) change, causing shifts in the chemical equilibrium of the fluid. Consequently, various minerals such as sulfates or silicates are oversaturated and their precipitation in pipes of the geothermal plant or in the pores of the reservoir can be expected. In addition, other minerals could be formed due to slight changes of pH- and redox conditions (e.g. iron-, manganese-, or lead- hydroxides).

In this study, changes in fluid chemistry were related to geothermal reservoir activities (engineering). It was found that concentration variation of most elements (e.g. Na, Ca, K, Cl, Li) over time was mainly due to dilution of the formation fluid with filtered freshwater used for water-frac stimulations or injection tests. However, iron, lead, barium, sulfate and bicarbonate concentrations did not correlate with dilution indicating that precipitation-, dissolution-, and/ or redox reactions took place.

Direct evidence for scaling induced by well operations was found for the element lead (Pb), which occurs normally in the unprocessed Groß Schönebeck fluid in concentrations of about 0.8 to 1 mM. During pumping tests, redox conditions in the vicinity of the pump changed and Pb concentration decreased dramatically (< 0.0002 mM). Additionally, a grey scale consisting mainly of native lead and laurionite (Pb (OH)Cl) as identified by X-ray diffraction, precipitated on the pump.