Field evidence for unstable thermal-convective transport in a fault controlled geothermal system

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The Borax Lake Known Geothermal Resource Area comprises a group of approximately 175 thermal vents, located along the trace of a north-south trending normal fault in the Alvord Basin of southeast Oregon. As part of a larger interdisciplinary study of the Alvord Basin hot springs, we have been collecting time series temperature data from selected springs in the Borax Lake system since May 2004. On the basis of these data, we tentatively divide the springs into three categories: Type I springs demonstrate steady temperatures with only slight excursions due to environmental forcing (e.g., diurnal temperature fluctuations), and are assumed to result from advective heat and mass transfer along high-permeability pathways within the Borax Lake fault. Type II springs are characterized by two or more metastable states that apparently constitute quasi-steady limit cycles, between which temperature may shift in response to as yet unidentified perturbations within the system. Type III springs also show more than one metastable temperature state, but additionally evince non-periodic, high-frequency fluctuations of an unstable nature.

We attribute the behaviors of Type II and III springs to unstable thermal-convective heat and mass transfer processes acting within the Borax Lake fault. Thermal-convective instability has been studied under laboratory conditions since the 1970s, and has been hypothesized to exist in fault controlled geothermal systems on the basis of numerical simulations of idealized domains. An evaluation of the thermal behavior of springs along the Borax Lake fault provides important information about the properties and processes of the active fault zone, and offers the opportunity to study unstable transport regimes at the field scale in a fault-controlled geothermal system.

Cation-exchange patterns in groundwater in coastal lowlands of the Western Netherlands

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The displacement of fresh groundwater by saline groundwater and vice versa leads to cation exchange reactions. It is generally stated that first a Na-HCO_3 fresh type arises during freshening followed by a Mg-HCO_3 fresh type, while a Ca-Cl_2 saline type arises during salinization. Here, fresh Ca-HCO_3 and saline Na,Mg-Cl groundwater are assumed to be the two end members.

Over 3000 groundwater analyses were collected in the western part of the Netherlands from the Holocene toplayer and Pleistocene aquifer units below, to test whether or not such simple end members can explain the cation-exchange patterns observed. The results indicate that the freshening pattern not only happens in fresh groundwater but in saline groundwater ($Cl > 10{,}000$ mg/l) as well. Saline patterns for fresh groundwater were also observed. More generally, all kind of cation exchange patterns were observed for the various salinity classes. This implies that groundwaters having a wide variety of composition are regionally displaced. The cation-exchange patterns observed were phenomenally reproduced by 1-dimensional reactive transport modelling using PHREEQC-2. Here, carbonate and redox chemistry were also taken into account.

The observations confirm recent paleohydrological research that buoyancy-driven groundwater flow following transgressions in coastal lowlands has occurred in addition to hydraulically driven flow. Here, various types of infiltrating surface water occur in an estuarine or deltaic environment due to mixing of fresh water with seawater.