Two methods for temperature measurement in super-hot geothermal systems based on synthetic fluid inclusions

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Super-hot geothermal systems are promising targets for near future geothermal exploration either for direct fluid exploitation or as potential reservoirs of Enhanced Geothermal Systems. Although reservoir conditions assessment is crucial for the evaluation of the geothermal resources, temperature measurement is still a major challenge in super-hot systems since their extreme conditions (i.e. very-high temperature, possible presence of aggressive fluids) preclude the use of conventional logging methods. During two EU projects (i.e. IMAGE (FP7) and the DESCRAMBLE (H2020)) two methods based on fluid inclusions synthesis were developed for in-situ measurements of very high-temperature (i.e. ≥400°C). Synthetic fluid inclusions are produced by trapping fluid within pre-fractured minerals, free of natural fluid inclusions, placed in a gold capsule together with an aqueous solution. Laboratory tests showed that fluid inclusions in quartz form in a relatively short time (down to 48 hours) if an alkaline-saline solution (0.4 M of NaOH + 10 to 20 wt.% NaCl) is used. In the first method synthetic fluid inclusions in quartz chips are produced within gold capsules placed inside a micro-reactor containing a volume of de-ionised water in such amount that the density of water in the micro-reactor has the critical value. Under these conditions, the trapping temperature of synthetic inclusions can be computed by the intersections between inclusion isochores, determined through microthermometry, and the critical isochore of water. Thus, if the micro-reactor is kept for at least 48 hours at the depth of measurement in a geothermal well, the trapping temperature of fluid inclusions formed in capsules would correspond to the well temperature at that depth. The second method consists in the production of fluid inclusions in gold capsules in direct contact with the environment of the geothermal well. Under the conditions of the super-hot systems characterized by relatively low pressure (such as the deepest part of the Larderello-Travale geothermal system in Italy), pressure-temperature conditions would cause fluid immiscibility in the gold capsule (i.e. the saline-alkaline fluid splits in a high-salinity liquid and a low-salinity vapor). In this case, the trapping temperature of both high-salinity and low-salinity inclusions is equal to their homogenization temperature. Laboratory tests demonstrated that the trapping temperatures of fluid inclusions produced by both methods can provide a good estimate of the experimental temperatures. Two field tests following the first method were performed in geothermal wells of Krafla (Iceland) and Larderello-Travale (Italy).
characterized by measured temperature at the test depth of 336°C and 249°C, respectively. These tests showed that synthetic fluid inclusions trapping temperatures closely approach the temperature measured using conventional methods. Finally, a field test was also attempted in the Venelle 2 (Larderello-Travale) geothermal well characterized by super-hot conditions. Trapping temperatures of fluid inclusions formed at 2900 below ground level (b.g.l.) by both methods resulted compatible with independent measurement by an electronic device which gave 444°C at 2810 m b.g.l..

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