



# Electrochemical study of the corrosion of different alloys exposed to deaerated 80 °C geothermal brines containing CO<sub>2</sub>



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## ABSTRACT

Corrosion of metallic engineering materials accounts for problems during geothermal operation in the Upper Rhine Graben (URG). Herein, we study the electrochemical behaviour of various metal alloys in an 80 °C simulated geothermal environment by using potentiodynamic polarisation and open-circuit potential measurements. Two different natural geothermal waters from URG geothermal sites were used for the experiments. The measurements reveal spontaneous passivation to be a key process for all alloys. This ennoblement protects more noble alloys from significant corrosion (e.g. titanium gr. 2, alloy 625) and brings less noble alloys to failure, mostly due to pitting corrosion (e.g. 316L).

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## 1. Introduction

Geothermal energy can contribute a significant portion of electricity to the future energy mix [1]. However, technical challenges towards a viable use of these virtually infinite resources have remained unsolved so far. In Germany and France, the Upper Rhine Graben (URG) offers favourable conditions for geothermal utilization and several projects producing electricity in binary-type power plants (e.g. Soultz, Bruchsal and Landau) have emerged in the last decades. One major obstacle is corrosion of materials and components in contact with corrosive high-temperature geothermal fluids [2,3]. Especially, production pumps are prone to suffer irreparable damage which leads to extensive downtime periods. The prediction of material behaviour in such environments is challenging due to the complex chemistry, the presence of dissolved gases, varying temperatures, and flow conditions [4]. With increasing size of future geothermal power plants, corrosion engineering will receive increased attention.

This research relies on two geothermal sites in the URG: Soultz-sous-Forêts (France) and Bruchsal (Germany). With the kind permission of the operators, GEIE (Soultz) and EnBW AG (Bruchsal), we were authorized to sample brine from the process stream for the laboratory experiments. The brines are extracted from deep

water saturated rock formations. In the case of Soultz, the brine is produced from a 5 km deep borehole penetrating the granitic basement. Bruchsal produces brine from a 2.5 km deep borehole in the Buntsandstein formation [5]. The brines can be classified as Na–Ca–Cl brines with a total dissolved solid content of approx 97 g l<sup>-1</sup> (Soultz) and 123 g l<sup>-1</sup> (Bruchsal), respectively. The presence of CO<sub>2</sub> in these brines leads to a pH < 5, while O<sub>2</sub> is virtually absent. The redox potential  $E_h$  of the brines is below –200 mV vs. SHE [5–7]. Even though both brines are considered to be genetically related, they have unique characteristics in terms of composition [5,6]. In the URG, the brines are usually produced with 120–160 °C, cooled to about 70–80 °C and reinjected into the same rock formation. To sum up, these factors set up a corrosive environment which challenges passive alloys, including stainless steels. To give an example, Pfennig and Bäßler showed that substantial corrosion occurred on 13% Cr alloys in 60 °C CO<sub>2</sub>-saturated brine [8].

In a previous study, various test metals (stainless steels, Ni alloys, and titanium gr. 2) have been exposed to an 80 °C in situ environment in Soultz in order to evaluate and quantify the corrosion behaviour [7]. Most metals remain unaltered and the coupons show only negligible weight loss, or even weight gain. Others alloys, however, show features of corrosion. For example, 316L stainless steel was obviously challenged and some coupons showed pitting corrosion after few days of exposure. Given these results, the following question came up: how do these metals react

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