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The Chemical and Thermal Stability of Proppants under Geothermal Conditions

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Enhanced geothermal system (EGS) reservoir fracture creation and management may require the use of proppants to maintain fracture conductivity. Hydraulic fracturing accompanied by the addition of proppant is a common procedure in the oil and gas industry. In contrast, the use of proppants by the geothermal industry has been limited. A variety of proppants are available, and the most commonly used include silica sand, ceramic, resin coated sands, and bauxite. These solids remain in newly formed fractures to keep them open. In geothermal systems, proppant will need to withstand high temperatures, acidified fluids, acid treatments, and cleanouts while maintaining fracture performance. Thus, the performance of proppants in geothermal reservoirs must be understood to avoid costly mistakes in the creation and maintenance of EGS reservoirs.

A series of static experiments have been conducted at 200-230^{o}C using 30/60 sintered bauxite proppant. The proppant consists of corundum with minor quartz, hematite, and chlorite. Some experiments included granite as the proxy for geothermal reservoir rock. Deionized (DI) water, DI water spiked with silica, and produced fluid from the Raft River Geothermal Field have been used for the fluid phase. The experiments were run for periods up to two months.

X-ray diffraction (XRD), scanning electron microscope (SEM), and QEMScan analyses were performed on the proppant before and after testing to evaluate textural, mineralogical, and compositional changes that occurred as a result of water-rock-proppant interactions. Only minor changes were observed. These changes include dissolution textures on corundum mineral faces (Fig. 1) and deposition of amorphous silicates, aluminosilicates, and aluminum oxides/hydroxides (Fig. 2).

During three of the first five experiments, concerns related to pressure vessel leakage arose. Loss of steam will alter the water chemistry and may also result in mineral precipitation. The sixth experiment was conducted with modified experimental setup to remove the possibility of fluid leakage. Ongoing static experiments will be conducted using this modified setup.

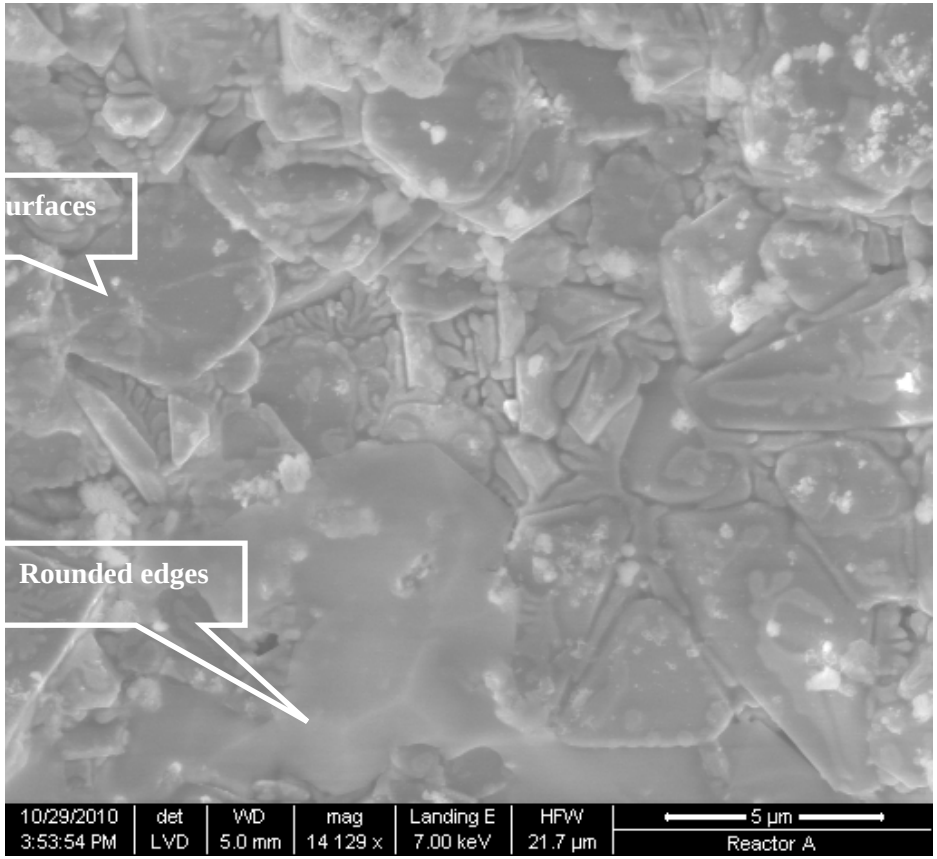

Figure 1: SEM image of dissolution textures, including etched surfaces and rounded edges of corundum crystals, on the surface of sintered bauxite proppant. This proppant came from a reaction of produced water from Raft River and proppant at 230^{o}C after 5 weeks.

Figure 2: (a). SEM image of sintered bauxite proppant after reaction with deionized water at 200°C for 10 weeks. (b). Detail of aluminum oxide/hydroxide and amorphous aluminosilicate precipitated on the surface of proppant in (a).

Batch modeling was used to investigate the dissolution of corundum and the saturation of gibbsite, boehmite, and diaspore at different temperatures. PHREEQC (Parkhurst and Appelo, 1999) and Geochemist's Workbench (Bethke, 2008) are used for the batch geochemical modeling; TOUGHREACT (Xu et al., 2004) is used for 1D reaction path modeling. In both cases, the Lawrence Livermore National Laboratory (LLNL) and THERMODDEM (Blanc et al., 2007) databases are used, since they are two available databases with information for the aluminum oxides/hydroxides (corundum, gibbsite, boehmite, and diaspore) for the temperature range of interest.

In the batch models, corundum and deionized water were reacted at temperatures from 0° to 300°C. The saturation of gibbsite, boehmite, and diaspore were calculated for this temperature range. For the initial batch models, corundum is dissolved when equilibrated with deionized water, and no other aluminum oxides or hydroxides are significantly saturated at 200 to 300°C. The modeled results are consistent with the observed experimental results at 200-230°C indicating dissolution of the proppant. These models will be extended to include granite, and geothermal water. For the geothermal water, the composition of produced water from the Raft River geothermal system will be used.

For the 1D reaction path modeling using TOUGHREACT, fluid with a composition of produced water from the Raft River geothermal system flows through bauxite proppant filled fractures in granite. The setup is based on McLin et al., 2006. Preliminary results indicate that the sintered bauxite proppant may be chemically stable at this temperature, with this fluid chemistry, and with these flow conditions. Ongoing models will vary temperature, porosity and permeability, fluid chemistry, and proppant mineralogy to predict a range of geothermal reservoir environments.