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Investigating and quantifying natural H_2 emissions within the Fe-rich Kansas Precambrian granitoid crust, through high resolution microscopy and tomography

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Natural hydrogen (H_2) generation has long been believed to only occur during serpentinization of ultramafic to mafic rocks at mid-oceanic ridges. Nevertheless, several studies have shown that H_2 could also be emitted in the middle of continents, within ancient cratonic basements. Here we report the study of drill cores from the H_2-emitting DR1-A well (Kansas, USA). In this area, the Precambrian granitoid basement rich in ferromagnesian minerals produces high levels of H_2.

Petrographic observations of samples from a depth of 452 m within the basement show fractured olivine distributed in a matrix of amphibole, pyroxene, feldspar, quartz, and oxides. As revealed by SEM, these Fe-rich olivines (fayalite, Fe_2SiO_4) are crosscut by veins filled with two types of phyllosilicates, associated with iron oxides. XANES spectroscopy at the Fe L-edge showed that these phases contain both ferrous and ferric iron: the external part of the veins exhibits almost 30% of ferric iron versus only 20% for the center part. Transmission electron microscopy investigations conducted on ultrathin FIB sections extracted across these veins show Fe-phyllosilicates structurally related to chlorites. Although rare in such geological context, the presence of fayalite and chlorite with a heterogeneous but significant ferric iron content strongly suggests water-rock interactions leading to the local generation of H_2.

However, an alternative explanation would be the trapping of H_2 by the Fe-rich phyllosilicates composing the external veins and having crystallized at high temperature. In fact, as shown by XCT, SEM-EDS, µRaman and NanoSIMS, the external veins are restricted to fayalites crystals while the central veins propagate throughout the entire matrix, strongly suggesting a two-stages history. The further interactions of the external phyllosilicates with subsequent infiltrating fluids could have been responsible for the release of molecular hydrogen. Post-processing of XCT data combined with XANES data allow to estimate the volume fractions of those Fe(III)-rich phases, and thus to quantify the potential H_2 production associated to those phyllosilicates. The present findings have important implications for exploring similar Precambrian granitoids present in every continent that might correspond to potential natural H_2 production sites.