Hydrogen generation during peralkaline granite hydrothermal alteration

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Hydrogen (H_2) can be produced by different reaction processes occurring naturally in the Earth's crust. The bests known are (i) serpentinization of ultramafic rocks, (ii) radiolysis of water, and (iii) activity of certain fermentative bacteria. However, this gas may also be present in a significant amount in peralkaline intrusive plutons (e.g. Lovozero/Khibiny in Kola, Ilimaussaq in Greenland, Strange Lake in Canada)[1,2]. Fluid inclusions may contain up to 40 mol% H_2, and the Kola super-deep borehole is known for its high H_2 production[3]. Based on petrographic observations, hydrothermal alteration of Fe(II)-bearing amphibole (arfvedsonite) has been proposed as the source of H_2 in this context, but this is yet to be irrefutably demonstrated.

To study H_2 generation during alteration of peralkaline granites, we performed hydrothermal experiments on pure arfvedsonite (arfv.) and natural granite (20 wt% arfv.) from Strange Lake. We used gold capsules and a Ti flexible reaction-cell rocking autoclave to investigate the effects of temperature (up to 400°C), chlorinity and pH. Numerous blanc experiments were conducted to quantify background H_2 generation due to Au/Ti oxydation, diffusion through reaction cells, and release of naturally entrapped H_2 from fluid inclusions or that occluded in granite/arfv. Solid by-products were charcterized by FEG-SEM, XRD and STXM-XANES.

H_2 concentration increased over time during alteration of granite or pure arfv. at T>280°C. After about 15 days of reaction at 350°C/500 bar, 30 mmol H_2/kg_{rock} were produced by the water-granite system (W/R=1). H_2 generation increased with T and pH, but not with chlorinity. Granite alteration produced more H_2 than arfv. alone, possibly because its dissolution provides the required conditions for secondary minerals (e.g. phyllosilicates) to precipitate, thus enhancing arfv. dissolution. After reaction, arfv. displayed clear dissolution features. Characterization of alteration by-products is in progress, but STXM-XANES analysis at the Fe $L_{2,3}$-edges already reveal oxydation of arfv. structural Fe(II). Clearly, peralkaline granites are an excellent source rock for H_2 generation, representing a favorable geological environment for H_2 exploration.

[1]Salvi and Williams-Jones (1992). Eur. J. Min., 4, 1155-1174.
[2]Potter et al. (2013). Lithos, 183, 114-124.
[3]Ikorsky et al. (1999). Geol. J., 107, 145-152.