Low Temperature Methane Formation from the Hydration of Forsterite.

A. Neubeck[1], D.T. Nguyen[1], N. G. Holm[1], [1] Department of geology and geochemistry, Stockholm University, anna.neubeck@geo.su.se, duc.nguyen@geo.su.se, nils.holm@geo.su.se

Introduction

Hydrocarbons are known to be formed through the Fischer-Tropsch Type or Sabatier reactions in hydrothermal systems (Charlou 2002; Holm 1998; Rushdi A. 2001), but the temperatures used are often higher than at least 100°C. (McCollom 2009). Hydrocarbon formation in lower temperature environments would expand the plausible sites for the existence and growth of microbial communities and possibly also the abiotic formation of organic compounds. Therefore we have tested the potential abiotic H_2 and CH_4 production in a mixture of forsterite and water at temperatures ranging from 30°C to 70°C.

Discussion

We have analyzed the methane and hydrogen formation coupled to the hydration of forsterite in three different temperatures, 30°C, 50°C and 70°C. In all temperatures, there is a consistent and temperature dependent release of methane into the headspace of the reaction cells, fig.1.

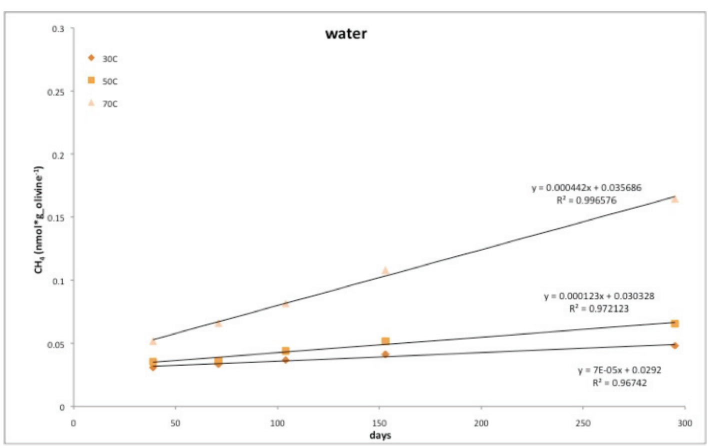

Fig. 1. Methane accumulation in the headspace as a function of time at 30°C, 50°C and 70°C.

Even at temperatures as low as 30°C there is a clear methane release already after one month of incubation and hydrogen was found in all bottles after termination of the experiments, fig.2. This indicates that reactions coupled to the hydration of natural forsterite are forming or releasing methane and hydrogen at very low temperatures. Therefore, environments in which methane and hydrogen may be released and thus also

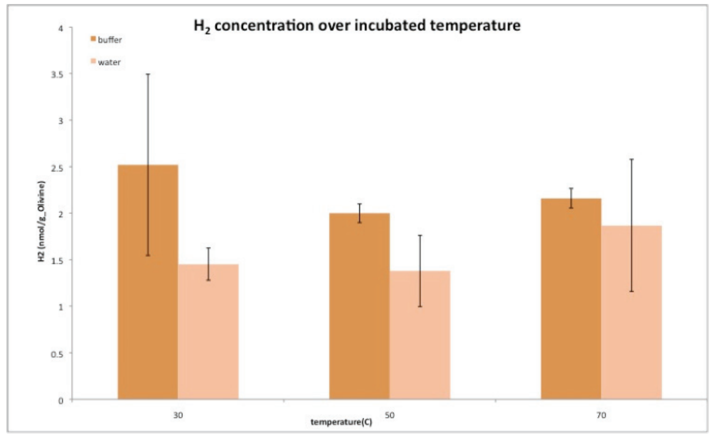

Fig 2. Hydrogen accumulation in the headspace of the olivine hydration reaction bottles.

sustain the growth of certain microorganisms, might be more widespread than previously thought. Also, reactions such as the Fischer-Tropsch type or Sabatier reaction may have a great potential for hydrocarbon formation in natural, forsterite-rich systems at near surface conditions. The reaction pathways for the methane release are still not known, but magnetite and chromite present in the samples are most likely to be catalyzing any organic compound formation.

Dry crushing experiments have been performed parallel to the olivine hydration experiments, in order to test the idea that methane is already stored inside the olivine crystal structure. Material such as aluminum, stainless steel, plastic and copper where used as crushing tubes and methane were detected in all tubes. However, blank crushing with aluminum tubes showed least methane accumulation in the headspace with concentrations an order of magnitude less than the crushing tubes with olivine samles inside. A total disintegration of the olivine occurs already after a couple of minutes of crushing but the methane accumulation continues (fig. 3), indicating a formation of methane rather than a release from the olivine crystal structure itself. These results support the idea that methane is formed also in the reaction vessels. SEM-EDS and Raman analyses of the samples have not shown any stored carbon in between the olivine grains, excluding the possibility of methane storage in the olivines.

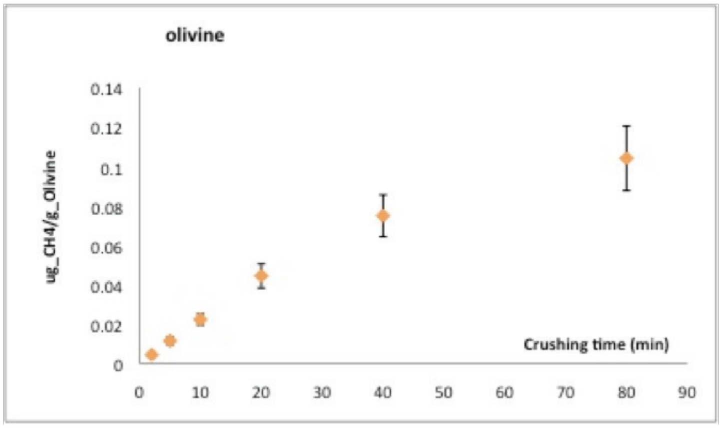

Fig. 3. Methane is found after dry crushing of a) olivine sand samples in aluminum tubes sealed with rubber septa and flushed with N_2 gas.

Conclusions

We have seen that methane is likely to be formed as a product when olivine is hydrated even at temperatures as low as 30°C. Dry crushing experiments, Raman and SEM-EDS analyses supports the idea that methane is formed and not released from the olivine crystals even though the reaction mechanism is still unknown. This would expand the possible environments for the abiotic formation of organic compounds or for the survival and growth of microoorganisms using methane or hydrogen for their metabolism.

Implications

This study shows that interactions between water and olivine result in the release of significant amounts of hydrogen and methane, the latter corresponding to olivine dissolution rates, at temperatures ranging from 30 to 70 ºC. This has important implications regarding several aspects. First, regarding questions about early life on Earth this study shows that high quality electron donors (H_2 and CH_4) can be released when water interacts with very common minerals also at temperatures suitable for living cells, and not just at temperatures above 100 ºC as previously reported. This substantially expands the range of environments suitable for chemosynthetic organisms on the early Earth. Furthermore, if the release rates shown in this study are representative of natural conditions, there may be a much more widespread and extensive subsurface biogeochemical cycling of hydrogen and methane than previously believed.

References

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