Forms of organic carbon at depth

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Abstract

In the subsurface, carbon has been largely assumed to exist as CO_2 for decades, though a few studies have shown that deep fluid-rock metamorphic reactions could generate other forms of carbon such as methane [1,2]. Over recent years, field and petrographic studies have revealed more diverse forms of organic carbon in sub-seafloor or subduction zones including organic acids [3] and condensed carbonaceous matter (CCM) [4,5].

In this study, we investigated the effect of pressure and water-rock ratio on the transformation of organic acids during the widespread serpentinization reaction of forsterite between 300 and 400°C. Experiments were performed in an externally heated diamond anvil cell and monitored in situ by Raman spectroscopy to characterize the kinetics of reactions between 1 and 40 kbar. Quenched products were analyzed by a suite of high-resolution analytical methods including but not limited to Raman and infrared mapping, XPS, SEM-EDX and TEM to characterize the variable composition of CCM, and structural relation with minerals.

Synthetic forsterite was chosen as the starting mineral in order to avoid focusing on redox reactions due to the ferrous iron content of olivine. Our study shows the rapid formation of CCM of variable composition and the lack of methane among products. The reaction kinetics is strongly influenced by pressure. The dehydration of the system by the serpentinization reaction contributes to carbon transformation by condensation as previously observed under lower pressure conditions in sub-seafloor [4]. Our results differ from those obtained for reaction between fayalite and aqueous acetate [6] that led to an organic composition very close to that obtained in the absence of the mineral phase, namely immiscible hydrocarbons [7,8]. Altogether, these studies highlight the wide range of organic compounds potentially occurring in sub-seafloor or subduction zones.

References

[1]Holloway (1984) Geology 12: 455–458.

[2]Vitale Brovarone et al. (2020) Nat Commun 11: 3880

[3]Frezzotti (2019) Nat Commun 10: 4952

[4]Andreani et al. (2023) Nat Commun 14: 347

[5]Debret et al (2022) Sci. Adv. 8, eabo2397

[6]Tao R. et al., (2025) GCA 395 : 64–76

[7]Huang F. et al., (2017) Nat Commun 8: 15798

[8]Huang J. et al. (2023) Chem Geol 630: 121489