Hydrocarbon-bearing spilitized gabbro xenoliths from Sicily: Evidence for a fossil abyssal-type hydrothermal system

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Some tholeiite gabbro xenoliths from tuff-breccia deposits in the Hyblean area (Sicily, Southern Italy) exhibit mineralogical and geochemical evidence of various degrees of hydrothermal alteration. In some cases, no traces of igneous minerals were left. Hence, the chemical composition of such a metasomatic rock shows higher contents in alkalis, Zr, Hf, U, Th, volatiles and lower CaO, MgO, FeO with respect to the pristine gabbro. Under optical microscope, these deeply altered rocks exhibit a lot of tiny vesicles with an opaque core and a double clayey shell. The core mostly consists of carbon (measured by VP-SEM-EDS). Five representative samples, cleaned up by hydrogen peroxide and sulfuric acid, have been selected for thermal decrepitation and bulk gas analyses by quadrupole mass spectrometry. All samples display the same EI-DPMS spectra. These have series of peaks differing in 14 mass units due to loss of methylene groups (-CH_2), possibly induced by a fragmentation process typical for saturated aliphatic and aliphatic-aromatic hydrocarbons. FT-IR spectra of investigated xenoliths exhibit several bands peculiar of vibrations of aliphatic hydrocarbons. These high-molecular-weight hydrocarbons were probably produced via Sabatier/Fischer-Tropsh-type synthesis that occurred within the high-temperature section of a serpentinite-hosted hydrothermal system. Hydrocarbon micelles were first transported by a strongly reactive supercritical aqueous fluid, which underwent phase separation during cooling. The inferred circulation-type system closely resembles those associated with the modern abyssal hot-vents, therefore representing a further proof for the original oceanic nature of the Hyblean unexposed basement. With a much broader interest, this study has reference to the baffling problem of the abiogenic vs. biogenic origin of organic compounds from oceanic hydrothermal systems, dealing with the tantalizing passage from abiotic to biologic domain.

Concentration fronts in the dissolution of entrapped gas

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Entrapped gas in otherwise water-saturated porous media, resulting from a fluctuating water table or from indigenous processes such as methanogenesis leading to the formation of volatile compounds, is fairly common in groundwater bodies. When the formation is flushed with water in gas equilibrium to the atmosphere, the entrapped gas is dissolved. Typically, this process is a combination of inter-phase mass transfer at the gas-water interface, diffusion through a boundary layer, and advective-dispersive transport. Under many typical field conditions the kinetics of inter-phase mass transfer play only a minor role in comparison to advection.

In the limit of pure advection coupled to local gas equilibrium, concentration profiles exhibit a characteristic behavior of hyperbolic systems: A disturbance in the composition of the dissolved gases is split into several fronts of concentration changes, each traveling with a characteristic velocity through the domain. The number of fronts equals the number of dissolved-gas components. The concentration of an individual compound (e.g., dissolved nitrogen) may increases at intermediate times (e.g., when concentrations of dissolved oxygen decrease), although the final concentration is lower than the initial one. This behavior stems from the competition of the dissolved gases in the partitioning into the gas phase. Quite obviously, a partitioning system affected by transport does not behave like a closed system.

Because local equilibrium depends on hydrostatic pressure, spatial orientation of flow is important in the behavior of dissolution fronts. Downward flow can lead to almost uniform gas dissolution over large depths, horizontal flow creates constantly moving dissolution fronts, whereas upward flow can lead to intermediate gas accumulation in the upper part of the formation. Thus, results of experiments performed in vertical columns may not directly be transferred to field situations with predominantly horizontal flow.

Inter-phase mass trasfer kinetics smears the distinct fronts, but the general behavior remains. Continuous changes in concentration, rather than distinct fronts, can result from kinetic mass transfer, but also from continuously changing boundary conditions, dispersion, or varying equilibrium conditions along the flow path.