Seawater-rock interaction at high temperature/pressure conditions in deep-sea hydrothermal systems: A thermodynamic approach

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In order to study seawater-rock interaction in deep-sea hydrothermal systems, hydrothermal fluids have been collected from various vent fields on Mid-Oceanic Ridges (MOR). Since the first observation of vent fields at the Galapagos Rift in 1977 (Corliss *et al.*, 1979), numerous sites has been discovered and sampled by submersible (Cyana, Nautile, Alvin, Shinkai) on the Mid-Atlantic Ridge (MAR), on the East Pacific Rise (EPR) and in Back-Arc Basins and Troughs of West Pacific (Fig. 1). Fluid chemistry is strongly influenced by the nature of the geological setting such as the influence of the spreading rate i.e. slow (MAR), fast (north EPR) and ultra-fast (south EPR), but also hot spot influence (Azores), volcanic/tectonic activity, magmatic contribution, sedimentary influence and rock types i.e. acidic volcanic rock (PacManus, Vai Lili in BAB), basalts (MOR) or ultra-mafic rocks (Rainbow, Logatchev on the MAR). Recent investigations led by McCollom and Shock (1998), predict fluid-rock interactions in the lower oceanic crust via thermodynamic models of hydrothermal alteration. Their conclusions were that a more extensive circulation in the lower ocean crust may occur under temperature around 700°C. The

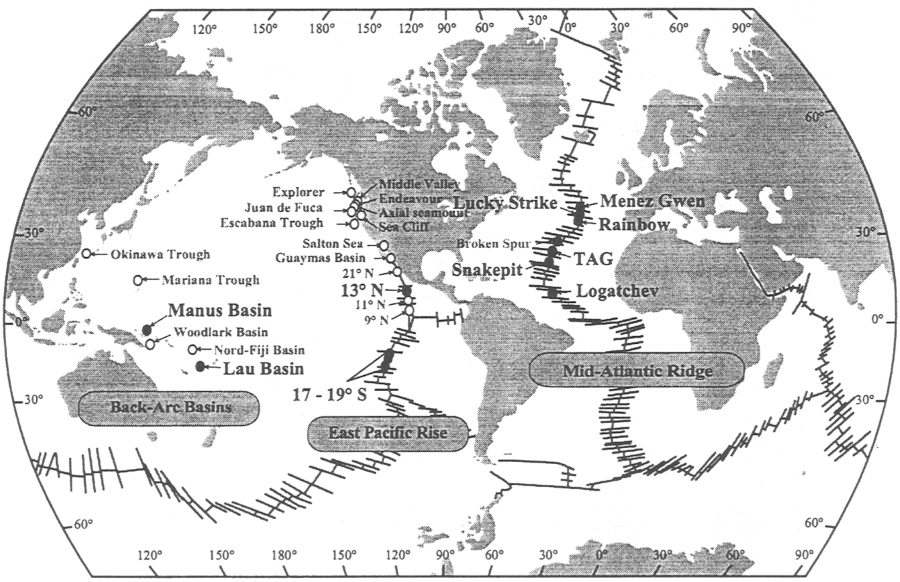

FIG. 1. Deep-sea active hydrothermal systems on Mid-Oceanic Ridges and in Back-Arc Basins.

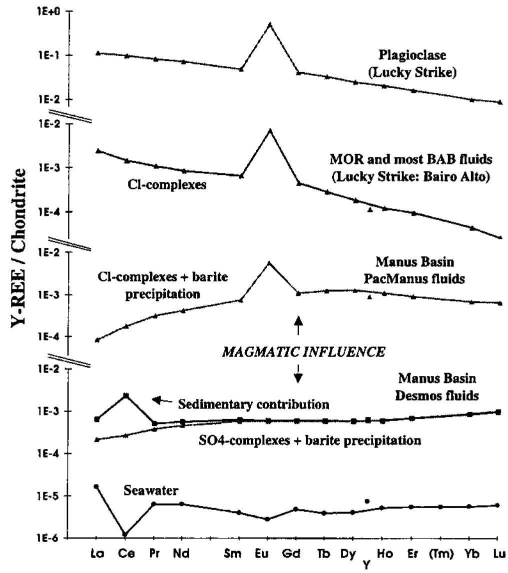

FIG. 2. Chondrite normalized *REE* (REE_N) and Yttrium patterns in fluids from Desmos (Manus), PacManus (Manus), MOR and some BAB fluids. Plagioclase REE_N pattern is given for comparison.

major objective of this work is to study hydrothermal processes by analysing the chemistry of collected fluids and by inserting the obtained data in models of thermodynamic prediction (SUPCRT92, EQ3/6). This work is conducted on acidic (pH 2 to 4) and hot (250–360°C) fluid samples collected during many diving cruises on the MAR between 14°N and the Azores: Logatchev (14°45′N) and Snakepit (23°N) during MICROSMOKE cruise (1996), TAG (26°N) during ALVIN CRUISE (1993), Rainbow (36°14′N) during FLORES cruise, Lucky Strike (37°17′N), Menez Gwen (37°50′N) during DIVA1 (1994) and FLORES (1997) cruises conducted these last years. These cruises were part of the FARA (French American Atlantic Ridge) program and the European AMORES program. Fluids were also collected on the EPR at 13°N during the CYATHERM cruise (1982) and in three active areas on the 17–19°S section of the EPR during the NAUDUR cruise (1993). In back-arc system, fluids were also sampled from Vai Lili field in Lau Basin during NAUTILAU cruise (1989) and from three new active sites (Vienna Woods, PacManus and Desmos) in the Manus basin during the MANUSFLUX cruise (1996) as part of French-Japanese cooperation. Major and minor elements in fluids are determined by Ion Chromatography, ICP/AES and Atomic Absorption Spectrometry. Firstly, fluid chemistry is directly controlled by seawater-rock interaction at high temperature (T) and pressure (P) conditions (> 380°C, 90 to 500 bar). Secondly, hydrothermal fluids can undergo phase separation process which alters gas, major and minor element levels in fluids compared to the initial seawater. Phase separation process can produce either metal-rich brines (TAG, Rainbow, 17–19°S, EPR zone), or a gas-enriched and metal-(low)enriched vapour phase (Menez Gwen, Lucky Strike and 17°–19°S, EPR zone). In this environment, complementary studies are led on the geochemical behaviour of the traces and Rare earth elements (*REE*) analysed by ICP/MS. Trace element levels in fluids are strongly depending on rock types i.e. high siderophile/chalcophile abundances in PacManus and Vai Lili fluids linked to ultra-acidic rock context. Yttrium which behaves like Holmium, and *REE* concentrations in most fluids would be affected by an interaction of fluids with plagioclase phenocrysts in any rock type environment (Douville *et al.*, 1997). This trend seems to be well establish since most fluids and plagioclase display similar chondrite normalized *REE* (REE_N) patterns which are enriched in *LREE* compared to heavy and show a positive Eu anomaly (Fig. 2). Thermodynamic calculations given by EQ3, predict a *REE* speciation in most fluids dominated by Cl-complexation at high T, P conditions in harmony with this pattern shape. Some processes such as sedimentary contribution (Desmos) or magmatic contribution i.e. baryte precipitation (PacManus) and SO_4-complexation (Desmos), directly modify REE_N patterns. Model predictions are in good agreement with these phenomena. However, chemical properties of fluids seem directly depending on interaction of the seawater with minerals i.e. plagioclase, olivine, orthopyroxene, epidote..., in the lower oceanic crust, strongly controlled by the temperature. Supplementary works are necessary by using phase diagrams of coexisting minerals at P and T, which will give informations on the validity of theoretical and petrologic hypothesis previously predicted about deep-sea hydrothermal seawater-rock interaction.

References

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