

Geochemistry of borehole fluids: Example of Hole 504B

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Fluid circulation through the upper parts of the basalts of Layer II of the oceanic crust has often been postulated to occur from evidence of low heatflow or from the geochemical composition of the pore fluids of the overlying sediments. The latter often show that diffusive communication between Layers I (sediments) and II (basalts) must occur. Actual evidence for these fluids has been difficult to obtain, but obtaining such information is an important aspect of the fluid sampling programs in oceanic boreholes. In this report we concentrate on evidence obtained from repeated efforts of fluid sampling in Hole 504B in the area of the Costa Rica Rift, carried out over a number of years towards these purposes.

Regional pore fluid studies in the area of Site 504 have been carried out in detail at several occasions in this area, the results of which suggest that indeed fluids circulate in the upper portion of the basement on a large scale basis, keeping a

relatively constant chemical composition, acquired as a result of water-rock interactions at moderate temperatures [Mottl, 1989]. A typical example from this survey is presented for the pore water distribution of dissolved calcium and magnesium in Site 677 [Mottl, 1989]. The concentration depth profiles indicate a component of laterally advected fluids, characterized by increased calcium and decreased magnesium concentrations. In addition, the pore fluids just above basement, in a zone of consolidation and hence reduced diffusive communication, indicate sharp changes in composition, caused by release and leakage from the circulating fluids in the underlying basalts. There are many more instances of this phenomenon from other sites drilled both during DSDP and ODP.

As indicated above, the real problem has been to obtain, in a direct manner, samples of the fluids that are proposed to circulate through basement. Hole 504B has been revisited over a number of years to make an attempt towards the sampling of basement formation fluids. The problem, of course, in Hole 504B, is that the temperature logs taken at many occasions indicate that bottom seawater flows into the formation over at least the upper 100 meters of Layer II, thus preventing the sampling of basement formation fluids. Particularly in the more fractured portions of the upper part of Layer II, underpressures cause this fluid transport into the formation. Studies of the permeability of basement at greater depths, however, have indicated that the deeper horizons of Hole 504B are almost sealed, thus allowing at best diffusive communication with formation fluids. Much of the earlier work on the geochemistry of the borehole fluids in Hole 504B has been summarized by Mottl and Gieskes [1990]. At that time it was argued that some of the observed compositional changes with depth were the result of potential diffusive exchange with the basement formation waters. This was supported by low concentrations of originally introduced surface water tritium concentrations. Subsequent work, however, has indicated that this may not be the case and that most of the observed changes in the chemical composition of the borehole fluids (originally surface seawater) are due to reactions occurring in the deepest part of the borehole, presumably between borehole fluids and basaltic rubble that has fallen into the hole [Magenheim *et al.*, 1995]. As the hole was deepened almost every time after reentry exercises, temperatures in the bottom of the hole increased and this allowed reactions to cause slightly different changes in the chemical composition of the borehole fluids [Magenheim *et al.*,

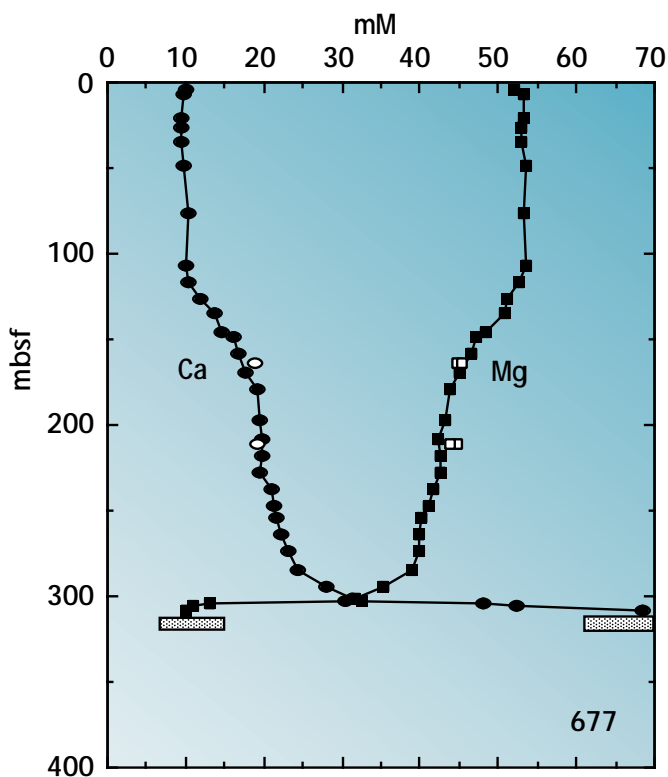


Figure 1. Pore water chemistry, Site 677: Costa Rica Rift Flank. Curvature around 180-200 mbsf is probably due to lateral advection of fluid; near basement change in calcium and magnesium are the result of diffusive exchange with fluids circulating in the top of Layer II.

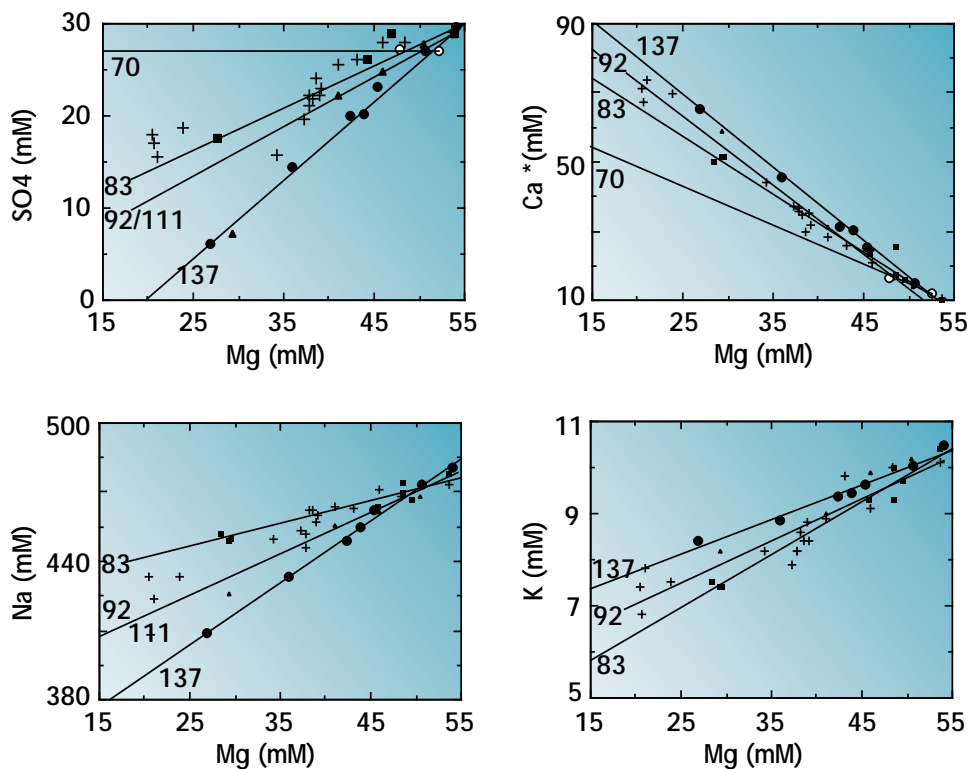


Figure 2. Comparison of element vs. Mg mixing lines of borehole fluid components from Hole 504B (c.f., Magenheimer et al., [1995]).

1995]. As concentration gradients are difficult to establish in the Hole 504B borehole fluids, mainly as a result of sampler problems at high temperatures as well as downhole mixing problems during sampling, correlations between decreases in magnesium concentrations and those of other components demonstrate these observations, as is shown in Figure 2 [Magenheimer et al., 1995]. In addition to considerations of potential diffusive exchange with the formation, a second process that may affect the chemical composition of the borehole fluids will be downhole mixing with bottom waters, a process that can be aided by the inherent instability of many downhole fluid columns as a result of negative density gradients [Magenheimer and Gieskes, 1996].

The results of these surveys, therefore, have shown that indeed large scale changes in the chemical composition of basement fluids must occur, especially at elevated temperatures. Direct sampling of these formation fluids, however, has not yet been

achieved. This remains a primary objective of future borehole fluid studies. Until now only in boreholes in which it has been demonstrated that fluid expulsion from basement causes outflow of fluids into the ocean (much in the manner of hydrothermal vents) can samples be obtained that will have a strong component of basement formation fluids. This has been accomplished recently both during ODP Legs 168 and 169. Data from these drilling legs are still being analyzed, but their information will be of great importance in the quest for more information on basement formation water compositions.

References:

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