Deep-Sea Drilling Project Leg 92

Advection in the East Pacific

from the Leg 92 staff

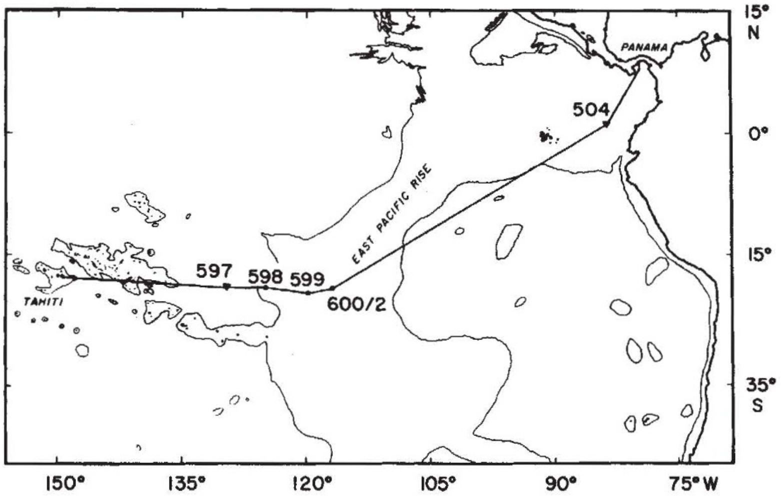
ADVECTION of seawater through oceanic crust probably continues for millions of years after the formation of the crusts at mid-ocean ridges. The history of advection is recorded in the alteration sequence of the crust itself, in the chemistry of hydrothermal exhalations and pore waters in deep-sea sediments, and in the hydrothermal component of the sediment column. Drilling and experiments conducted during Leg 92 of the Deep-Sea Drilling Project were designed as a multidisciplinary study of past and present hydrogeological processes that accompany the alteration of basalt by seawater. Nineteen holes were drilled at sites which form an east–west transect across the western flank of the East Pacific Rise at 19°S (see the figure). Borehole water samples were collected and several experiments conducted in Hole 504B, previously drilled through 1 km of basalt crust near the Costa Rica Rift during DSDP Legs 69, 70 and 83.

The best record of the alteration of the crust itself came from Hole 597C which was drilled in 25.8-Myr-old crust at the now extinct fast-spreading Galapagos Rise. At this site 91 m of basalts were drilled (with 48.5 m of recovery) which were olivine-poor to olivine-free ferrobasalts characteristic of fast-spreading ridges. The site was the most successful drilled on crust from a fast-spreading ridge, probably because of the high ratio of massive flows to pillow basalts.

A study of the sequence of vein and vesicle infilling and basalt alteration revealed that the crust had undergone several stages of fluid advection and concomitant alteration. The first stage was probably deuteric and is characterized by a pale-blue trioctahedral smectite. The second stage of alteration was non-oxidative and is characterized by a dark-green smectite, by pyrite and native copper, and by other replacement minerals tentatively identified as celadonite, talc and chlorite. The final oxidative stage of alteration is dominated by calcite, oxyhydroxides and smectite.

One site, 600, was selected on the basis of high heat-flow values characteristic of advection in the hope that it would provide sediment samples whose pore waters showed evidence of advecting fluids. Unfortunately neither Site 600 nor any of the others revealed any unequivocal evidence of pore-fluid advection.

Evidence for advection of hot seawater through the crust is recorded in the sediment column. Clearly the sites accumulated hydrothermal phases while near the ridge crest at rates somewhat different from modern rates. The sediments at all the sites are dominated by calcareous nannofossil ooze with varying amounts of non-carbonate fraction which, except in the near-surface sediments of Sites 597 and 598, is made up of smectites, iron oxyhydroxides, amorphous material and reddish-yellow semi-opaque objects ('RSOs'). This assemblage has been found in other Pacific sediments and has been shown to be formed by the deposition and diagenesis of particulate matter of hydrothermal origin. The proportion of this hydrothermal assemblage increases downhole at all sites and a rough estimate of its mass flux based on the stratigraphy and physical properties of the sediments suggests that hydrothermal accumulation rates near the East Pacific Rise were greatest 4.5–8 and 21–25 Myr ago and that before the Pliocene, the hydrothermal accumulation rate was about twice that of the present. This accumulation could be controlled by differences in hydrothermal output at the ridge crest or by local to regional distribution processes.



Map of the East Pacific Rise showing the positions of the drilling sites used in Leg 92.

A full understanding of advection requires detailed knowledge of the heat flow and permeability of the oceanic crust and their changes in time and space. It also depends on a knowledge of the chemical changes that occur when seawater and basalt react at various temperatures. These aspects of hydrothermal processes were examined when Leg 92 returned to Hole 504B, the deep basement hole near the Costa Rica Rift. Temperature profiles and water samples were taken while the borehole waters were still undisturbed. The former document the decreasing flow rate of water downhole to an underpressured acquifer in the uppermost 100 m of basalt. Since Leg 83 (November 1981), the rate has decreased from 25 m h^{-1} to 2–3 m h^{-1}. The temperature at the bottom of the hole is 155–165°C.

The borehole waters provide a natural laboratory for the evaluation of reactions at elevated temperatures. Chemical analyses on board showed the linear relationship between decreasing Mg and increasing Ca when the latter is corrected for anhydrite precipitation using the sulphate concentration. The analyses further confirmed that the reaction is also balanced by Na and K which are removed during alteration reactions. Unfortunately, since the borehole was contaminated with bentonite drilling mud, many of the reactions could represent the alteration of bentonite as well as the alteration of basalt.

Several downhole experiment programmes addressed the relationship between crustal fracture density and distribution and hydrothermal flow. On a regional scale, an oblique seismic experiment was carried out in which the *Challenger* clamped a borehole seismometer in the hole while a second ship carried out both radial and circular shooting pattern. The experiment detected anisotropy from the seismic wave arrivals which appears to be related to crustal inhomogeneities.

On a smaller scale, a multi-channel sonic tool was used to study sonic velocities and waveforms in Layer 2A (which encompasses the underpressured zone). This work showed that the shape of the waveforms was related to differences in the amount of fracturing in the rock which had previously been detected by a borehole televiewer in the same interval. □

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