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Hydrothermal fluid emanations from the submarine Kick'em Jenny volcano, Lesser Antilles island arc

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Abstract

Little is known about the role of island arcs as hydrothermal sources to the ocean when compared to the extensive research that has been carried out on hydrothermal systems at spreading ridges, although increasingly more work is being done on intraoceanic arcs. Here, we present fluid geochemistry data from the Kick'em Jenny (KeJ) submarine volcano of the Lesser Antilles island arc. Discharge of diffuse hydrothermal fluid was discovered on the southwestern flanks of the volcano. Hydrothermal input into the water column was recognized from CH_4 and trace-metal anomalies in water-column profiles in a depth range of 500–700 m. Samples collected directly on the seafloor also showed evidence for hydrothermal emissions where Mg and Cl were depleted in the fluids compared to ambient seawater, while CH_4 and several trace metals were enriched. The chemical composition of these samples, including O and H isotope data, suggests that the fluids are a mixture between a condensed vapor phase derived from a phase-separated hydrothermal fluid, which was conductively cooled in the sub-surface, and seawater. Increased dissolved organic carbon (DOC) concentrations of the fluids also indicate interaction with the sediment layer through which the fluids percolated. Although the volcanic crater could not be sampled directly due to safety concerns, δ^3He and some trace-metal values in seawater samples indicate fluid input containing a mantle component, probably from a hot, focused-flow source in the crater region around 200–300 m depth.

Keywords: Lesser Antilles; island arc; Kick'em Jenny volcano; submarine hydrothermal venting; fluid geochemistry

1. Introduction

Hydrothermal activity at mid-ocean ridges (MOR) has been the focus of many geochemical investigations since the discovery of seafloor hydrothermal systems in 1977 (e.g., von Damm, 1995). These hydrothermal fluxes play a significant role in the oceanic budgets for many dissolved metals (e.g. Sr, Fe, Mn). By contrast, much less is known about the role of seafloor hydrothermal activity along submarine volcanic arcs in terms of the element budgets of the ocean. A number of studies report on the compositions of arc-related hydrothermal mineral deposits (e.g., Glasby et al., 2000; Glasby and Notsu, 2003; Petersen et al., 2002),

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but little has been published about the chemistry of fluids. Available data are mostly from Pacific sites (e.g., de Ronde et al., 2001; 2003a,b; 2005; Gamo et al., 1997; Ishibashi and Urabe, 1995) and suggest that vent fluids produced by submarine volcanism and hydrothermal activity in intraoceanic arcs and back-arc systems differ in composition from those originating at MORs, and may represent an important source of gases and trace metals to the ocean. Eruptive activity together with hydrothermal discharge has also recently been described for a submarine arc volcano along the Mariana intraoceanic arc (Embley et al., 2006). Moreover, with exception of some plume survey work done along the Lihir island arc offshore Papua New Guinea (de Ronde et al., 2003a,b) and for Kavachi volcano of the Solomons island arc (Baker et al., 2002) little work has been done on submarine volcanoes and vents of the submerged portions of island arcs.

The focus of this study was to determine the composition of hydrothermal fluids from the Kick'em Jenny (KeJ) submarine volcano, which is located at the southern part of the Lesser Antilles (Fig. 1a). Widespread submarine volcanic activity along the Lesser Antilles island arc is well documented (e.g., Polyak et al., 1992; Devine and Sigurdsson, 1995). However, little information is available about submarine venting of hydrothermal fluids along this arc. Shallow-water hot springs are known along the coasts of some of the islands, such as Dominica, St. Lucia and Montserrat (Johnson and Cronan, 2001), although very little information is available for deeper waters (i.e. Polyak et al., 1992).

In an attempt to provide more information on submarine hydrothermal venting along the Lesser Antilles island arc, a research cruise with the German vessel *R/V Sonne* (SO 154, CARIBFLUX) was carried out in January/February 2001, covering four separate locations between Montserrat and Grenada (Halbach et al., 2002; Fig. 1a). Although no focused-flow hydrothermal vents were directly sampled during the expedition, evidence for hydrothermal components in the water column was detected and hydrothermal precipitates (e.g., ferromanganese crusts) collected (Frank et al., 2006). In the areas offshore Montserrat, Dominica and St. Lucia, only limited evidence for hydrothermal activity was noted in the water column, including slight increases in CH_4 concentrations and reduced Cr(III) species (Sander et al., 2003). The best evidence for hydrothermal emissions was noted close to the KeJ submarine volcano, northwest of Grenada. This volcano is located on the western slope of the Lesser Antilles island arc, where oceanic crust is subducted westward under the Caribbean plate. Hydrothermal activity has been observed on the crater floor of KeJ (Devine and Sigurdsson, 1995; Wishner et al., 2005). Bacterial mats and focused venting, (up to 70 °C), commonly accompanied by gas bubbles, occur at a depth of 250 m at the summit, although were not observed on the flanks of the volcano. No chemical data is available from these earlier investigations.

The summit crater of KeJ could not be mapped and sampled during the CARIBFLUX cruise due to safety concerns, as a result of increased seismic activity associated with the volcano. However, we detected significant input of hydrothermal fluids into the water column over the flanks of the volcano and also found indications of hydrothermal fluid venting from the crater region. Here, we present for the first time geochemical data on the hydrothermal fluids emanating from KeJ volcano. The unusual composition of the hydrothermal fluids together with evidence for a significant hydrothermal signal in the water column around KeJ volcano support the view that hydrothermal activity associated with submarine volcanic arcs – including both the submarine portion of island arcs and the more commonly studied intraoceanic arcs – may play an important role in the fluxes of various elements to the ocean, with notable differences in the chemistry of the venting along these arcs when compared to MOR systems (see e.g., von Damm, 1995).

2. Geologic setting and sampling sites

The basement to the Lesser Antilles consists of Eocene MOR-type basalts and sedimentary rocks of several km thickness (Eocene and Oligocene volcaniclastics), which were formed during Tertiary age spreading of the Grenada basin. These rocks are overlain by volcanic rocks of the modern island arc (Speed et al., 1997). Outcrops of sedimentary rocks occur at the northern coast and shelf of Grenada, and along the western shelf slope.

The location of KeJ north of Grenada (Fig. 1a) is possibly controlled by faults (Sigurdsson and Sheperd, 1974). The steep western flank of the island arc is characterized by N–S-trending, deeply penetrating normal faults caused by the uplift of the Lesser Antilles Platform, relative to the Grenada Basin in late Miocene (with initial volcanism due to the onset of subduction).

Observations made of the ocean floor during SO 154 by camera tows showed several faults with offsets up to 10 m along the southern flank of KeJ. These faults are either related to local stresses during volcano formation, or have been formed due to oblique subduction of the oceanic crust. Outcrops of basaltic dikes and massive rocks were also observed.