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Hydrothermal activity on the southern Mid-Atlantic Ridge: Tectonically- and volcanically-controlled venting at 4–5°S

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ABSTRACT

We report results from an investigation of the geologic processes controlling hydrothermal activity along the previously-unstudied southern Mid-Atlantic Ridge (3–7°S). Our study employed the NOC (UK) deep-tow sidescan sonar instrument, TOBI, in concert with the WHOI (USA) autonomous underwater vehicle, ABE, to collect information concerning hydrothermal plume distributions in the water column co-registered with geologic investigations of the underlying seafloor. Two areas of high-temperature hydrothermal venting were identified. The first was situated in a non-transform discontinuity (NTD) between two adjacent second-order ridge-segments near 4°02′S, distant from any neovolcanic activity. This geologic setting is very similar to that of the ultramafic-hosted and tectonically-controlled *Rainbow* vent-site on the northern Mid-Atlantic Ridge. The second site was located at 4°48′S at the axial-summit centre of a second-order ridge-segment. There, high-temperature venting is hosted in an ~18 km^2 area of young lava flows which in some cases are observed to have flowed over and engulfed pre-existing chemosynthetic vent-fauna. In both appearance and extent, these lava flows are directly reminiscent of those emplaced in Winter 2005–06 at the East Pacific Rise, 9°50′N and reference to global seismic catalogues reveals that a swarm of large (M 4.6–5.6) seismic events was centred on the 5°S segment over a ~24 h period in late June 2002, perhaps indicating the precise timing of this volcanic eruptive episode. Temperature measurements at one of the vents found directly adjacent to the fresh lava flows at 5°S MAR (Turtle Pits) have subsequently revealed vent-fluids that are actively phase separating under conditions very close to the Critical Point for seawater, at ~3000 m depth and 407 °C: the hottest vent-fluids yet reported from anywhere along the global ridge crest.

1. Introduction

Thirty years after the first discovery of submarine hydrothermal venting (Corliss et al., 1979), less than 10% of the global mid-ocean ridge crest has been investigated, systematically, for high-temperature hydrothermal activity (Baker and German, 2004). In the South Atlantic Ocean, for example, the only sites of hydrothermal activity that had been reported, prior to this study, were along the East Scotia Ridge (German et al., 2000). The highest priority of this work, therefore, in concert with a parallel study of the DFG (Priority Program 1144 "From Mantle to Ocean"; Devey et al., 2005) was to conduct first systematic investigation for hydrothermal activity anywhere along the southern Mid-Atlantic Ridge. The motivation for our study was two-fold: first, to investigate the types of geologic setting that can host hydrothermal activity along the slow-spreading southern MAR; second, to characterise sites of venting and any chemosynthetic communities they might host along this previously unexplored ridge-section.

While it has been long established that the incidence of hydrothermal activity along a Mid-Ocean Ridge, on average, is proportional to ridge-spreading rate (e.g. Baker et al., 1996; Baker and German, 2004), our prior work had also shown that the incidence of venting along different sections of the slow-spreading northern MAR can also vary, at a constant spreading rate, in response to different neovolcanic and/or tectonic controls (German and Parson, 1998). In particular, near the Azores (MAR 36–38°N) an "excess" of hydrothermal venting was identified in the non-transform discontinuities (NTDs) between adjacent second-order ridge-

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segments, distant from any sites of recent neovolcanic activity (German et al., 1996). One such site, which has subsequently been investigated in detail, is the Rainbow hydrothermal field at 36°15′N — a particularly large, high power (~0.5 GW) and long-lived high-temperature vent-site (Fouquet et al., 1998; Cave et al., 2002; German et al., submitted for publication). Hosted in ultramafic rocks that have been uplifted from the mantle in this tectonically-controlled setting, the vent-fluids at Rainbow are unusually enriched in both metals (notably Fe, Cu) and the dissolved

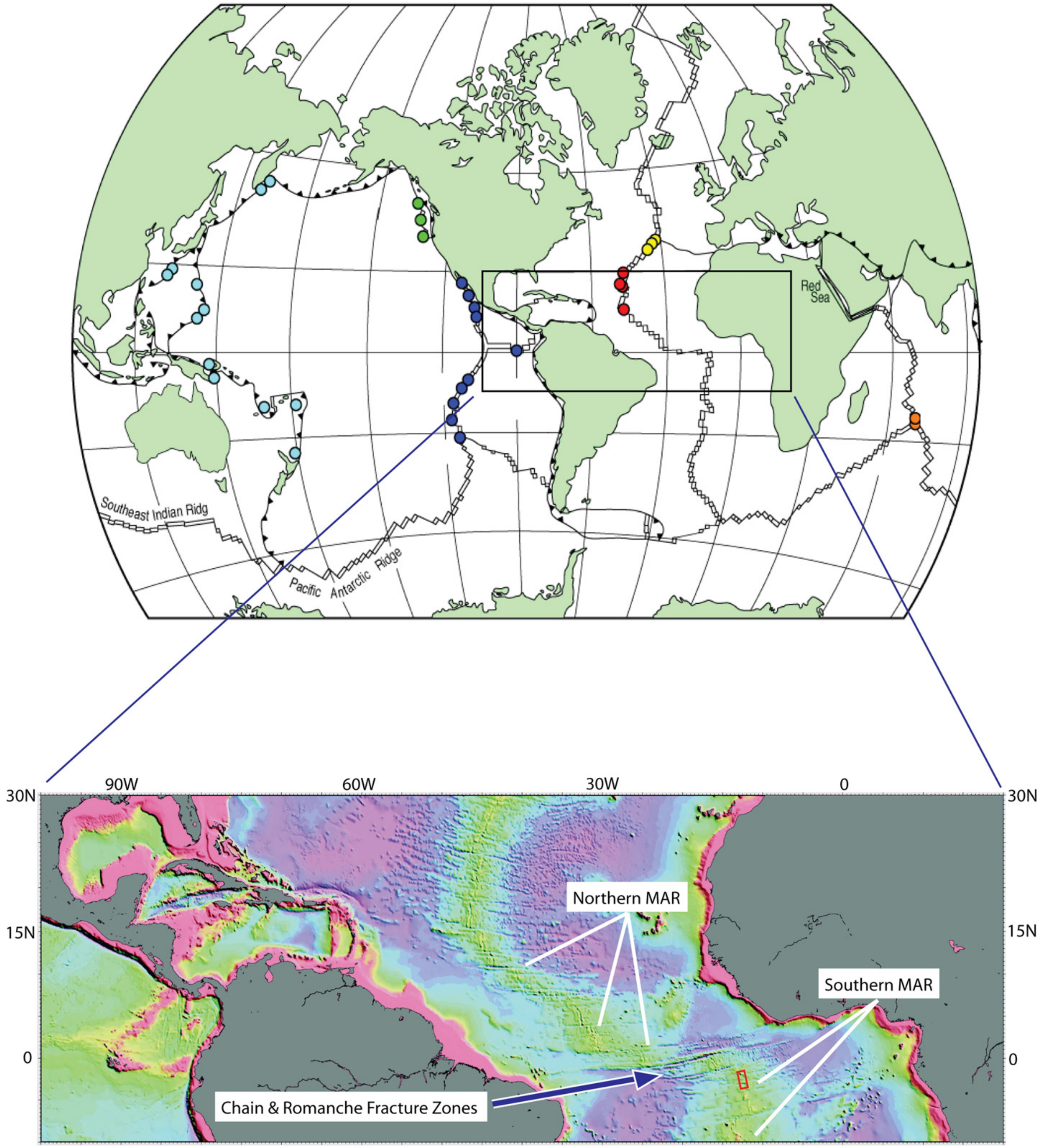

Fig. 1. *Upper panel*: map of the global ridge crest (after Van Dover et al., 2002) showing locations of individual vent-sites that had been visited by submersible prior to this study. Different coloured symbols denote six different biogeographic provinces: pale blue = SW Pacific; green = NE Pacific; dark blue = East Pacific; yellow = Azores; red = northern Mid-Atlantic Ridge; orange = Central Indian Ridge. *Lower panel:* Bathymetry of the Atlantic Ocean floor as interpreted from satellite altimetry [46] showing the marked offset from the northern MAR to the southern MAR across the equatorial (Chain & Romanche) fracture zones. The study area for this project is outlined in red, between 3° and 7°S, immediately south of the equatorial fracture zones. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)