Investigating the formation of the active TAG hydrothermal mound using observational, petrographic and geochemical data

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Introduction

During Leg 158 of the Ocean Drilling Program in October-November 1994, the active TAG hydrothermal mound (~26°10′N on the Mid-Atlantic Ridge) will be drilled to investigate the structure and processes involved in the formation of a large, mature hydrothermal deposit on a slow-spreading mid-ocean ridge. It is likely that these drilling operations will significantly impact the subseafloor circulation system and result in major changes in the fluid flow pathways. These in turn will affect the morphology of the hydrothermal deposits, and the distribution of different types of venting activity. With appropriate characterization of the structure before, during, and after drilling, this perturbation and the subsequent response and recovery can be used to better constrain some of the physical properties of the hydrothermal system. An international effort is underway to conduct such studies, with participation from U.S., British, and Japanese investigators.

During two submersible programs in 1986 and 1990, we documented the surficial distribution of the various types of venting activity on the active TAG hydrothermal mound. In addition, we have completed detailed petrographic and geochemical studies of a comprehensive suite of solid samples collected during a number of submersible dives. From these two sets of data, we have deduced patterns of flow and seawater/hydrothermal fluid interactions within the mound, thereby characterizing the hydrothermal system prior to drilling.

Geologic setting

The TAG hydrothermal field lies at the mid-point of a 40 km long ridge segment that extends from about 25°55′N to 26°17′N. At about 26°10′N, the east wall forms a broad salient that reduces the width of the valley floor from about 9 km to 6 km. The TAG hydrothermal field is located at the base of this salient and extends over an area of at least 5 × 5 km along the eastern median valley wall. It consists of presently active low and high temperature zones, as well as a number of relict deposits. The active high temperature mound lies on oceanic crust at least 100,000 years old, based on present sea floor spreading rates, and is located about 2.4 km from the neovolcanic zone at a water depth of ~3660 m. It is a large, mature deposit of varying mineralogy that is venting fluids with a wide range of temperatures and two distinct, but related, chemistries. It is completely covered with hydrothermal precipitates; no basalts have been observed on the mound surface or on talus slopes.

Patterns of fluid flow derived from submersible observations, petrographic and geochemical studies

PA schematic cross-section derived from submersible observations, together with the inferred fluid flow within the mound derived from the mineralogical and geochemical data, are shown in Figure 1. High temperature (363°C) black smoker activity is strongly focused, and localized in a cluster of chimneys on top of a conical edifice. The high f_{S_2}–f_{O_2} black smoker mineral assemblage (chalcopyrite, pyrite, and amorphous Fe-oxide intimately intergrown with anhydrite) is a reflection of the low H_2S concentration in the fluid. The conical edifice is composed of massive sulphide crusts, which form from black smoker fluid pooled within the edifice, interspersed with blocks of corroded massive anhydrite, produced by mixing of black smoker fluid with seawater entrained into the edifice. Trace element data (e.g. enrichment in Co and Se but not in Zn, Au, Cd, or Pb) support the conclusion that all three sample types form from black smoker fluid that has been

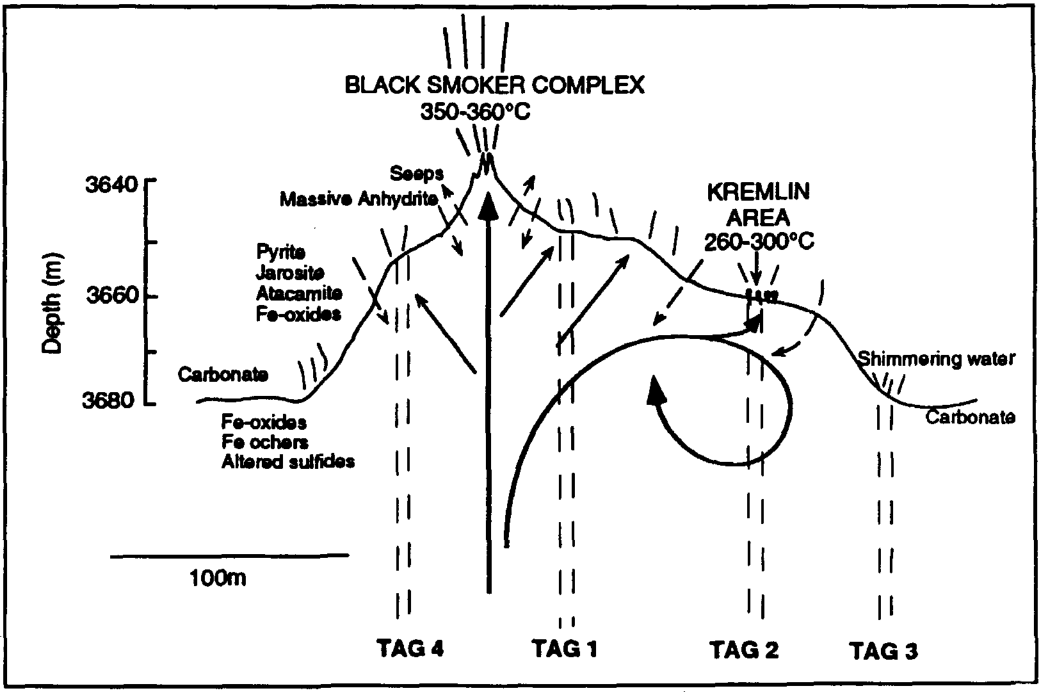

FIG. 1. Schematic cross section of the active TAG hydrothermal mound derived from submersible observations. The fluid flow pattern within the mound is deduced from petrographic and geochemical studies. Also shown are the relative positions of holes to be drilled during ODP Leg 158.

cooled conductively to varying extents and/or mixed with seawater.

Fluids exhibiting lower temperatures (250–300°C) and less vigorous flow rates emanate from many small (1–2 m) chimneys concentrated in an area (~50 m in diameter) in the southeast quadrant of the mound. These 'Kremlin'-like spires are composed dominantly of low-Fe sphalerite with minor amounts of chalcopyrite, pyrite and amorphous silica. They are similar mineralogically and chemically to blocks of sulphide-rich samples found on the surface of the mound. Enriched in Zn, Au, Cd and Pb, these blocks of sulphide and the white smoker chimneys form from black smoker fluid that has been modified by mixing with entrained seawater, precipitation of significant amounts of sulphide and sulphate within the mound, and dissolution of sphalerite which results in remobilization of some trace elements. The steep outer walls of the mound expose deposits formed during previous hydrothermal episodes and include ocherous material and massive sulphides with outer oxidized layers, which show evidence of hydrothermal reworking and recrystallization.

Drilling plans and objectives

Drilling at the TAG hydrothermal mound will allow this model of seawater entrainment and ongoing zone refinement within the deposit to be tested. A transect of four holes are planned to investigate the nature of fluids, deposits, and altered crust in the near-surface part of the hydrothermal system (Figure 1). At least one hole (most likely TAG-2) will penetrate into the stockwork zone underlying the surface deposit. Drill holes are planned close to the black smokers and in the 'Kremlin' area, where both the mineralogy of the deposits and the fluid chemistries are distinct. A third location of drilling will be on the outer edge of the mound where the older deposits are exposed and diffuse, low temperature fluids emanate in discrete areas. A fourth site will be located on the western side of the mound in a region where low conductive heat flow suggests local entrainment of seawater.