GEOPHYSICAL RESEARCH LETTERS, VOL. 24, NO. 19, PAGES 2351-2354, OCTOBER 1, 1997

Acoustic mapping of diffuse flow at a seafloor hydrothermal site: Monolith Vent, Juan de Fuca Ridge

P. A. Rona,[1] D. R. Jackson,[2] T. Wen,[2] C. Jones,[2] K. Mitsuzawa,[3] K. G. Bemis,[1] and J. G. Dworski[2]

Abstract. Diffuse flow of hydrothermal solutions commonly occurs in patchy areas up to tens of meters in diameter in seafloor hydrothermal fields. It is recognized as a quantitatively significant component of thermal and chemical fluxes, yet is elusive to map. We report a new acoustic method to detect and map areas of diffuse flow using phase-coherent correlation techniques. The sonar system was modified to record phase information and mounted on DSV SEA CLIFF. The submersible occupied a stationary position on the seafloor and the transducer scanned the seafloor surrounding Monolith Vent, a sulfide edifice venting black smokers, at a nominal range of 17 m at a depth of 2249 m on the Juan de Fuca Ridge. Patchy areas of uncorrelated returns clearly stood out from a background of returns that exhibited ping-to-ping correlation. The areas of uncorrelated returns coincided with areas of diffuse flow as mapped by a video survey with the Navy's Advanced Tethered Vehicle (ATV). Correlated returns were backscattered from invariant seafloor. Uncorrelated returns were distorted by index of refraction inhomogeneities as they passed through diffuse flow between the seafloor and the transducer. The acoustic method presented can synoptically map areas of diffuse flow. When combined with standard in situ measurement and sampling methods the acoustic mapping will facilitate accurate determination of diffuse thermal and chemical fluxes in seafloor hydrothermal fields.

Introduction

Observations of seafloor hydrothermal fields reveal that thermal and chemical transfer from the oceanic lithosphere into the water column occurs by discrete and diffuse flow of aqueous solutions [Converse et al., 1984; Little et al., 1988]. A major component of discrete flow is the focused discharge of high-temperature hydrothermal solutions from individual vents as point sources, such as black smoker-type venting from mineralized chimneys. Thermal and chemical fluxes from such discrete sources can be determined by direct measurements [Converse et al., 1984; Macdonald et al., 1980] and compositional analysis of fluid samples [Edmond et al., 1979]. Diffuse flow is the disseminated discharge of lower-temperature hydrothermal solutions through areas of the seafloor. It is ubiquitous at low intensity throughout at least half the area of ocean basins [Mottl and Wheat, 1994; Schultz and Elderfield, 1997], and at higher intensity in seafloor hydrothermal fields. Quantitative assessment of diffuse flow is important because the cumulative thermal and chemical flux through areas of the seafloor may equal or exceed that of associated black smokers and other discrete sources. However, fluxes from diffuse flow have remained elusive to map because flow velocities and fluid temperatures are low, fluids are generally transparent lacking suspended particulate matter detectable by transmissometer-type instruments, and discharge occurs in irregular, patchy areas that are meters to tens of meters in dimension.

We report initial results of a new acoustic method to detect and map diffuse flow in seafloor hydrothermal fields. Monolith Vent, a massive sulfide edifice venting multiple black smokers associated with areas of diffuse flow was selected for the present study. The site lies at a depth of 2249 m at 44°59.431'N, 130°12.081'W near the 020°-trending spreading axis of the north Cleft segment of the Juan de Fuca Ridge [Lupton et al., 1991; Embley and Chadwick, 1994; Koski et al., 1994; Feely et al., 1994]. The method we applied to map diffuse flow around Monolith Vent also has the potential to measure temperature fluctuations [Jackson and Dworski, 1992] and flow velocities within the diffuse flow. This is beyond the scope of the present paper.

Prior Work

Prior methods to map the areal distribution of diffuse flow in seafloor hydrothermal fields comprised observation of shimmering water and measurement of temperature anomalies recorded along near-bottom traverses by a submersible, towed instrument sled, and remotely operated vehicle [e.g., Rona and Trivett, 1992]. Information on diffuse flow recorded by these methods is limited to individual tracklines. The acoustic method presented in this paper delineates whole areas of diffuse flow as a basis for mapping of the diffuse flow field. Supplemental information about temperature, flow rates, and chemistry of the diffuse flow is needed to estimate thermal and chemical fluxes. Standard in situ methods may be employed to make these spot measurements [Little et al., 1988; Schultz et al., 1992, 1996; Rona and Trivett, 1992; Trivett and Williams, 1994] within the framework of the acoustic map.

Methods

An existing sonar system (Mesotech model 971) with a frequency of 330 kHz, pulse duration of 100 microseconds, and transmit source level of 220 dB re 1 mPa @ 1 m was modified to image hydrothermal plumes [Rona et al., 1991] and record amplitude and phase information. The sonar original fan-beam transducer head was replaced with one providing a conical beam shape (1.7° full width at half maximum). The time-varied gain function was reprogrammed to increase sensitivity, and a second transducer rotation unit was added to train the sonar in 1.7° elevation steps in addition to 0.9° azimuthal steps. The receiver electronics were redesigned with timing circuitry to

[1]Institute of Marine and Coastal Sciences and Department of Geological Sciences, Rutgers University, New Brunswick, N.J.
[2]Applied Physics Laboratory, University of Washington, Seattle
[3]Japan Marine Science and Technology Center (JAMSTEC), Yokosuka

Paper number 97GL02504.
0094-8534/97/97GL-02504$05.00