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Deep Submarine Gas Vents in the Aeolian Offshore

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Abstract. Consistent results, concerning the detection of deep submarine hydrothermal vents, were obtained during two cruises (1991 and 1996) offshore from the Aeolian Islands, by CTD profiling from sea surface down to seafloor, and water-sampling casts. In 1991 an echo sounder showed a wide plume at a depth of about 800 m, within which water samples displayed anomalies in He and NH_4^+ content, suggesting also the presence of a water-vapour phase. The latter, in 1996, was remarkably observed as a horizontally diffusing plume at about 350 m. Near-plume casts were characterised by high CO_2 and CH_4 and low O_2 concentrations in seawater, disturbed light transmission profiles, and false bottom outputs appearing at ~300-350 m down to the seafloor from the rosette-mounted altimeter. No significant temperature/salinity anomalies were noted during either events. These preliminary results show the presence of deep hydrothermal activity, over an area where, one century ago, the occurrence of submarine eruptions was detected.
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1. Introduction

Submarine hydrothermal activity offshore from the Aeolian volcanic islands (Southern Tyrrhenian Sea, Italy) is known to occur at shallow depths (down to 50 m; e.g. Italiano and Nuccio, 1991 and references therein). In the present paper we introduce data from different types of observation which provided evidence for deeper submarine hydrothermal activity off the Eastern coast of Vulcano island, at depths down to 800 m. In this area, between 1888 and 1892, several submarine eruptions broke the telegraphic cables that linked the island of Lipari with the Northern Sicilian coast (De Fiore, 1916). The eruptions occurred during and after the last eruptive period of Vulcano island (1888-1890). Echo sounder anomalies were recorded in the area in 1988, during a period of the volcanic activity on the Island (unpublished data). In the present paper we report further evidence of such a deep activity.

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2. Methods

Two cruises by RV Bannock and RV Urania were conducted in 1991 (February) and 1996 (October), respectively. The positions of the sampling stations are shown in figure 1.

The surveys were performed by down-to-bottom (max.793 m) CTD and water sampling casts. Seawater was collected in 2 and 10-L Niskin-type bottles mounted on a rosette sampler fitted with a Hydrolab CTD in 1991 and, in 1996, with a Seabird CTD, a Seatech 0.25-m path length transmissometer and a Datasonics altimeter.

The water samples collected in 1991 were submitted on board analyses of NH_4^+ by ion selective electrode (Orion), and laboratory analyses of He by mass spectrometry (Leybold). The water samples collected in 1996 (AC3, AC4 and AC5, Fig.1) were submitted to head-space equilibration method (Etiope, 1997) and analysed on board by a TCD-equipped micro-GC (Chrompack) for free CO_2, CH_4, O_2, and Ne. The GC precision from air replicate analyses was within ± 7%.

3. Results and discussion

The investigations carried out in 1991 revealed the existence of some echosound anomalies off-shore from the Eastern coast of Vulcano Island, as in 1988. The widest one (about 500 m in diameter) was located at a depth of 794 m. (V5, Fig. 1), and it was detected by a high frequency (28 kHz) fish-finder echo-sounder (Koden CVS 8805), while the low frequency sub bottom (Atlas Deso 10) always recorded the sea-bottom profile.

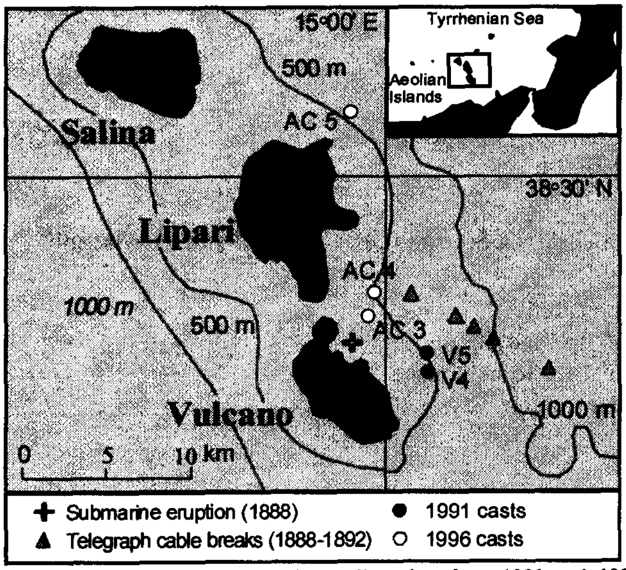

Fig. 1. Location of the reported sampling sites from 1991 and 1996 surveys. Data on the submarine eruptions are from De Fiore (1916).

No anomalies have been recorded by the CTD but some water samples showed significant high concentration of NH_4^+ (Tab. 1).

Table 1.
Extracted data from the 1991 and 1996 surveys. 1991 data after Francofonte *et al.*, (1992). NH_4^+ in µmol L^{-1}, dissolved gas concentrations in ml L^{-1} (STP). Seawater data, from a reference, non-active site (AC5) are shown for comparison.

1991 survey

Site	Sampling depth (m)	T (°C)	pH	NH_4^+	He
Vulcano - V4	689	13.8	8.2	30.0	1.3 x 10^{-4}
Vulcano - V5	792	13.8	8.1	78.8	n.d.*

1996 survey

Site	Sampling depth (m)	T (°C)	pH	CO_2	O_2	CH_4
Vulcano - AC3	338	13.9	7.6	73.2	1.0	7.4 x 10^{-3}
Vulcano - AC4	350	13.9	8.2	18.2	1.2	4.1 x 10^{-3}
Lipari - AC5	473	13.8	8.2	0.4	3.4	*n.d.

*n.d.: not detected (value below the detection limit: 10^{-4} ml L^{-1} for CH_4 and $4x10^{-5}$ ml L^{-1} for He)

Helium anomalies (concentrations above the equilibrium value with atmosphere) were recorded at another deep site (V4; depth = 689 m) which showed lower echo-sounder anomalies.

In 1996 another event was remarkably observed on the same type of echo sounder in the same area, a plume diffusing horizontally at about 350 m water depth. Even though no significant temperature/salinity anomalies were found, the AC3 and AC4 casts (Fig. 2) were characterised by disturbed light transmission profiles, as well as by false bottom outputs appearing at 300-350 m down to the seafloor from the rosette-mounted altimeter. For comparison data collected in a reference cast AC5 (non-active site offshore from Lipari Island) are shown in figure 3. In the gas concentration profiles of figures 2 and 3 the broken lines represent the ASW (Air Saturated Water, i.e. the theoretical dissolved gas concentration based on the assumption that the atmosphere is the sole source of the gas in question and that equilibrium conditions prevail) values calculated from the potential temperature and salinity at each depth by using solubility data (Atkinson and Richards, 1967; Konig et al., 1964; Weiss, 1970). Values close to the ASW level are shown in the Aeolian offshore by the inert gas Ne throughout the water column and by the shallow CO_2 samples. The highest free CO_2 concentration (74 ml L^{-1}) has been measured in the AC3 near-bottom sample (≈ 350 m), while pH values do not show substantial variations throughout the water column. Strong undersaturation of O_2 occurs in the samples taken just below the thermocline (about 40 m).

The ASW level of methane in seawater is, from Henry's law, 4.6 x 10^{-5} ml L^{-1} (STP) at 20°C and 38‰ of salinity, derived from equilibration with atmospheric air having 1.4 ppm of CH_4. As the GC detection limit for this gas is 2-3 ppm (by the method used), the detected CH_4 would result from processes other than the solution of air. CH_4 has been detected in the AC3 near-bottom samples and in the AC4 sample at -350 m from surface, the same water depth where the highest CO_2 value is recorded. In the AC3 and AC4 Aeolian casts the O_2 profile shows stronger deviations from equilibrium just in correspondence with the CO_2 peaks. Considering the large dilution effects by seawater, higher concentrations of the detected gases should occur at the seafloor emission points.

4. Concluding remarks

Two geochemical surveys suggested the occurrence of hydrothermal activity off-shore of the Eastern coast of Vulcano Island, at depths greater than those of known manifestations. Evidence for deep fluid vents is given by echosounder anomalies associated with high CO_2, CH_4, He, NH_4^+ and low O_2 seawater concentrations, disturbed light transmission profiles, and by false bottom altimeter outputs. The dissolved gas concentrations suggest their origin from volcanic fluids typically detected at the active crater of Vulcano Island. It will be important to discover the areal extension, distribution, episodicity and chemistry of the deep submarine hydrothermal activity of the Aeolian arc for a better understanding of the Tyrrhenian basin geodynamics. More comprehensive and multidisciplinary exploratory surveys should be the object of researches for future years.

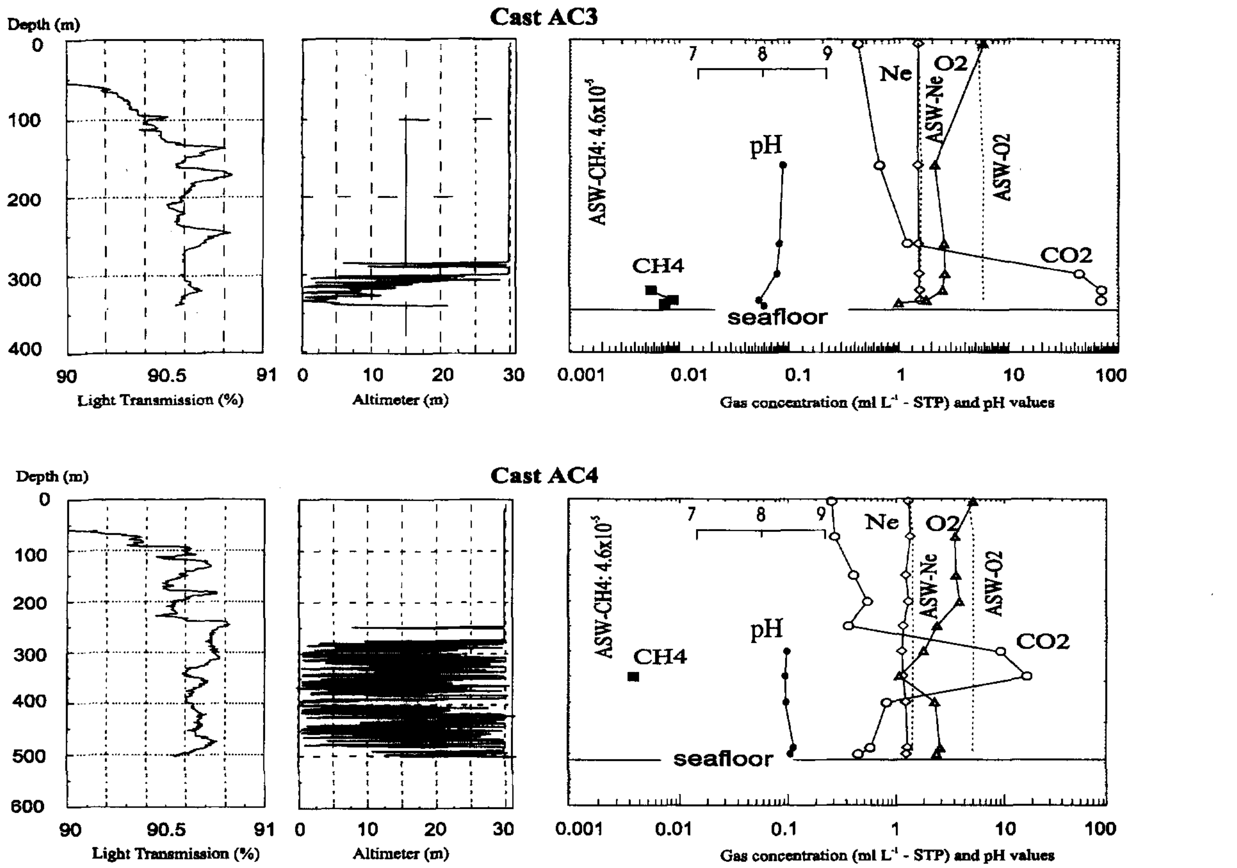

Fig. 2. Light transmission, altimeter output profiles, seawater gas concentration and pH from AC3 and AC4 casts. Altimeter is designed to indicate a constant value of 30 m until CTD distance above the seafloor is less than this value. Very high concentrations of CO_2 and CH_4, and strong O_2 undersaturations, are coincident with false bottom outputs appearing at 300-350 m down to the seafloor from the rosette mounted altimeter. CH_4 values in the other samples are below the detection limit (10^{-4} ml L^{-1}).

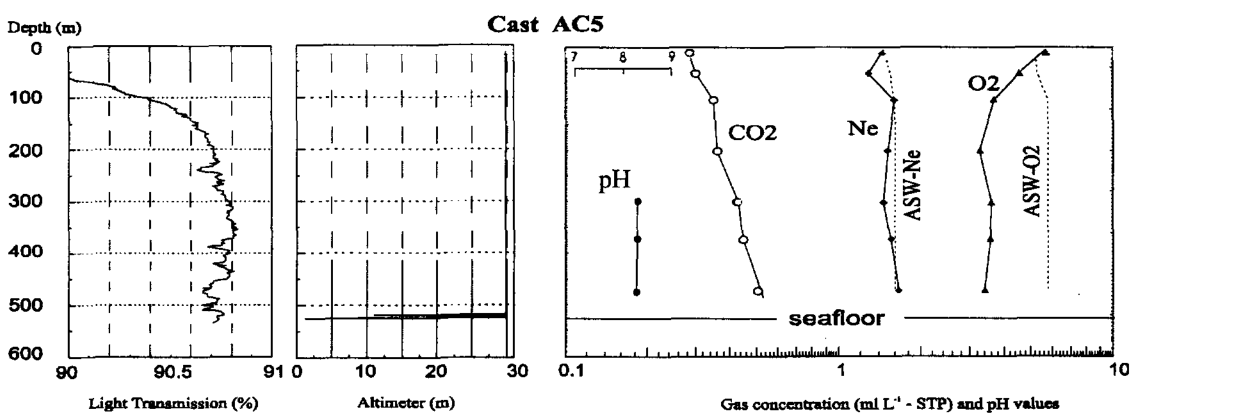

Fig. 3 Light transmission, altimeter output profiles, seawater gas concentration and pH from AC5 reference cast in a non-active site.

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