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Discovery of new hydrothermal vent sites in Bransfield Strait, Antarctica

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Abstract

We carried out a search for hydrothermal vents in the Central Basin of Bransfield Strait, Antarctica. The ZAPS (zero angle photon spectrometer) chemical sensor and instrument package (Oregon State University), OFOS (ocean-floor observation system) camera sled and TVG (TV-grab) (GEOMAR) were used to explore the water column and underlying seafloor. These operations were supplemented with a series of dredges. Hydrothermal plumes over Hook Ridge at the eastern end of the basin are confined to the E ridge crest and SE flank. The plumes are complex and sometimes contain two turbidity maxima one widespread feature centered at 1150 m and a smaller, more localized but broad maximum at 600–800 m. We traced the source of the shallower plume to a sunken crater near the ridge crest using sensors on the ZAPS instrument package. Subsequently two TV-grabs from the crater brought back hot, soupy sediment (42–49°C) overlain by hard, siliceous crusts and underlain by a thick layer of volcanic ash. We also recovered chimney fragments whose texture and mineralogy indicate venting temperatures in excess of 250°C. Native sulfur and Fe-sulfides occur in fractures and porous layers in sediment from throughout the area. Pore water data from the crater site are consistent with venting into a thin sediment layer and indicate phase separation of fluids beneath Hook Ridge. The source of the deeper plumes at Hook Ridge has yet to be located. We also explored a series of three parallel volcanic ridges west of Hook Ridge called Three Sisters. We detected water column anomalies indicative of venting with the ZAPS package and recovered hydrothermal barites and sulfides from Middle Sister. We spent considerable time photographing Middle Sister and Hook Ridge but did not identify classic vent fauna at either location. We either missed small areas with our photography or typical MOR vent fauna are absent at these sites.

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1. Introduction

Bransfield Strait is a narrow marginal basin that separates the South Shetland Islands from the Antarctic Peninsula (Fig. 1). The Bransfield Strait consists of three subbasins: Eastern, Central, and Western. Recent (< 300,000-yr-old) volcanism in the rift zone produced mainly basalt and basaltic andesite with scattered occurrences of high-silica rock [1,2].

There have been several previous reports of hydrothermal activity in Central Basin. Manganese concentrations up to 7 nM and corresponding δ^3He > 7 were measured in the water column of the eastern Central Basin [3,4]. Further evidence from this time included hydrothermal alteration of sedimentary organic matter [5–7] similar to that associated with the Guaymas Basin hydrothermal site [8]. In addition, qualitative analysis by electron microprobe of sediments recovered from a high heat flow area indicated the presence of Fe sulfide, Fe–Zn sulfide, Fe–Zn–Cu sulfide, Zn chloride, and Fe and Zn oxides [9,10]. High and variable heat flow has also been reported for Central Basin (150–600 mW/m^2) [10].

In 1995 our group carried out a systematic search for hydrothermal activity in Central and Eastern basins [11–15]. We found clear indications of activity in both basins and isolated two venting areas in Central Basin: Hook Ridge, and Three Sisters. We measured anomalously high manganese concentrations (13 nM) over Hook Ridge that coincided with a large turbidity anomaly. We also found areas of high turbidity over Middle Sister and recorded a temperature anomaly of 0.025°C. Subsequent investigations during cruise ANT-XV/2 of the RV *Polarstern* in 1997–98 recovered hot sediment (24°C on deck), iron sulfides and silica crusts from the top of Hook Ridge [16].

The present study extended the investigations at Hook Ridge and Three Sisters using the ZAPS instrument package (Oregon State University) in combination with the OFOS (ocean floor observation system) camera sled and the TV-guided grab sampler (TVG) from GEOMAR. We used water column anomalies detected with the ZAPS

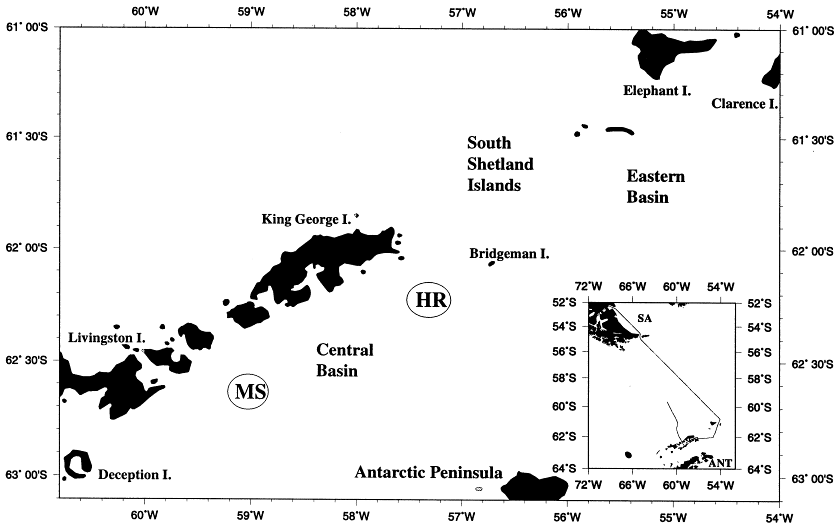

Fig. 1. Map of Bransfield Strait showing the NBP99-04 cruise track. Most of the time was spent just west of Bridgeman Island at Hook Ridge (HR). We also spent several days at Middle Sister Ridge (MS). Shown in the blow-up is the location of Bransfield Strait relative to South America and the Antarctic Peninsula.

package to backtrack to sites of venting and recovered hydrothermal products from these sites using the dredge and TVG to document exact locations. We then photographed the areas with OFOS.

2. Methods

Dissolved and total Mn and Fe were measured on the ship by flow-injection analysis (FIA) [17]. Dissolved Mn was also determined in situ using an oxidation coupling method [18] and a ZAPS (zero angle photon spectrometer) fiber optic spectrometer [19]. ZAPS is a fixed-filter instrument that couples a photomultiplier tube and xenon flash lamp through a short (18 cm) bifurcated bundle of fused silica fibers potted in stainless steel tubes. The fiber assembly is external to a pressure case that holds interference filters, xenon lamp, flash power supply, PMT detector, and signal processing board. ZAPS was configured as a flow-through chemical sensor by attaching a flow-cell (50-cm path length) and two chemical cartridges in tandem to the threaded end of the bifurcated fiber assembly. The first cartridge was filled with periodate embedded in acrylic beads. The second cartridge held diethylaniline (DEA) immobilized in a microporous fluorocarbon substrate. The first cartridge added the oxidizing agent and also served to filter the sample stream. In this method reduced Mn enhances the oxidative coupling of DEA by periodate yielding yellow color proportional to its concentration. Color was monitored by its absorption at 470 nm with the flash lamp set at 700 V and the PMT at 400 V. At these settings the cell blank was < 0.08 V or $< 2.0 \pm 0.1\%$ of the signal at full absorbance. The instrument was calibrated in the laboratory before and after the cruise.

A custom-built, magnetically coupled pump pulled water through the cartridges and flow-cell at 50 ml min^{-1}. This rate was high enough to replace water in the cartridges and optical cell every few seconds. The detection limit of the chemical sensor was 0.1 nM. This sensitivity allowed us to detect the smallest of plumes and even the dissolved Mn enrichment associated with the surface mixed layer, as shown in Fig. 2.

A microprocessor on the ZAPS signal board sent data to a specially designed 'power bottle' that contained the system's power supply, data packaging circuits, and modem. The circuits in this bottle package data from ZAPS, the CTD, and other sensors. The modem transmitted the data packets to the ship through the conducting cable to a specially constructed deck unit that disseminated data to three locations: real-time display, primary storage, and backup archiving. The deck unit supplied the instrument package with 500 W of power and encodes digital commands to the ZAPS instrument.

The rest of the ZAPS instrument package consisted of a 12-place rosette holding 1.7-l Niskin bottles, SeaBird 911*plus* CTD, Chelsea nephelometer, and Simrad altimeter. The CTD provided T, depth, and conductivity data at ± 0.002°C, ± 1 dbar, and ± 0.003 ppt, respectively, as determined by calibration at SeaBird.

The towed OFOS system is a camera sled used to observe the ocean floor and map geological and biological features. For this project, the system consisted of four lamps (24 V, 150 W), monochrome video camera (OSPREY OE 1323), Benthos still camera (372-A) and Benthos flash system (383-RH/380-RH). Power was supplied by two deep-sea batteries (12 V, 230 Ah) providing energy for about 15 h. A Seabird 25 CTD was also deployed with the system. The sled was towed at 0.5–1.0 knots.

The TVG is a hydraulic claw capable of sampling 1.8 m^2 of seafloor with a penetration up to 50 cm. The TV-grab was equipped with an online video camera (OSPREY SIT monochrome TV camera) and four lamps (24 V, 150 W) allowing the operator to see the sampling location. The TVG was opened and closed by hydraulic pressure also powered by two deep-sea batteries (12 V, 230 Ah). The energy supply allows opening and closing up to six times during a 6-h seafloor observation.

Temperature of sediment recovered with the TVG was measured by inserting a thermometer into the mud as soon as possible after the grab arrived on deck. Subcores were taken with plastic tubes and the pore waters separated with a Teflon® squeezer in an inert atmosphere. Sediment pH was determined with a glass electrode inserted into the sediment before squeezing, compared with buffers prepared in artificial seawater. Silica, sulfide, ammonia, and iron were measured using standard spectrophotometric techniques with some modification for the high-sulfide content. Chloride and sulfate were measured by ion chromatography.

3. Results

The chemical sensor on the ZAPS instrument package provided real-time data that correlated well with shipboard measurements of dissolved Mn as shown in the top-left panel of Fig. 2. As shown in the top panel, Mn plumes usually mimicked turbidity plumes. But at lower Mn concentrations the turbidity anomaly was small and not well defined, as illustrated in the bottom panel. Mn proved to be a useful tracer even at low concentrations where turbidity anomalies were difficult to detect. These results illustrate the usefulness of chemical sensor data for hydrothermal exploration.

Shipboard measurements of dissolved and total

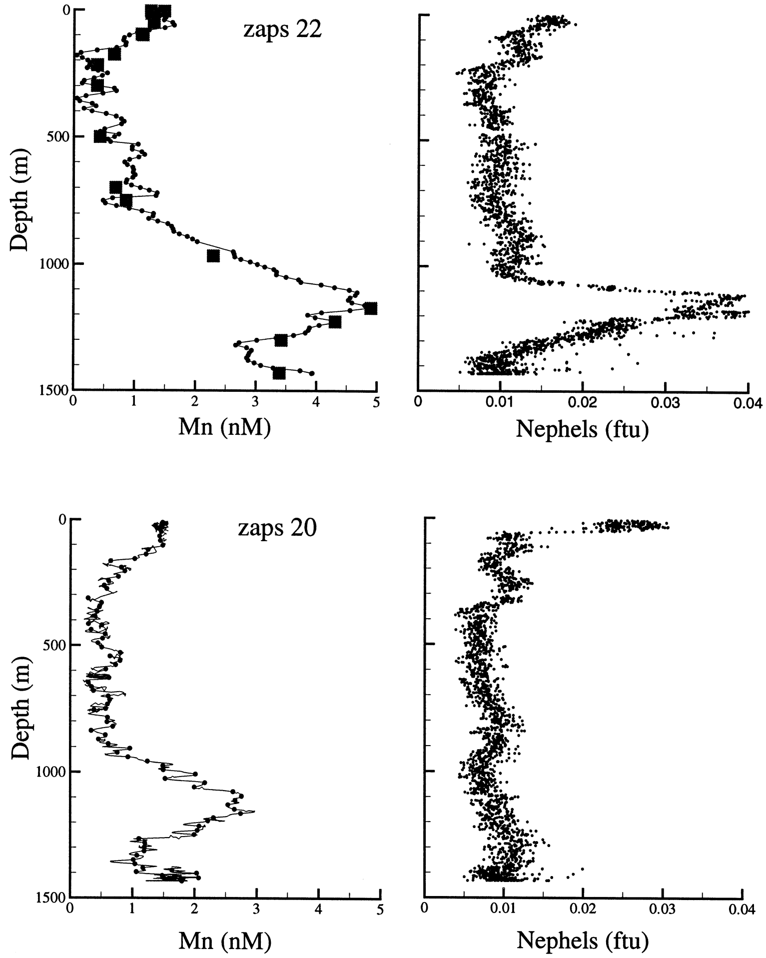

Fig. 2. Mn profiles produced with the ZAPS chemical sensor at two stations in the 'elbow' area at Hook Ridge. Also shown are the associated nephel profiles. Nephels are given as ftu. The shaded symbols in the top-left panel are dissolved Mn concentrations determined on the ship by FIA. Mn proved to be a reliable tracer of hydrothermal input even when the plume contained very little turbidity, as shown in the bottom panels.

Table 1
Results of Fe and Mn analyses done on the ship by FIA for samples from below 1000 m. The particulate fraction was calculated from measured total and dissolved levels

Area (ZAPS Sta. No.)	Latitude/longitude (deg., min.)	Depth (m)	Total Fe (nM)	Diss Fe (nM)	Part Fe (nM)	Total Mn (nM)	Diss Mn (nM)	Part Mn (nM)
Hook Ridge								
4	62°12.00'S	1302	19.1	2.51	16.6	1.04	–	–
	57°17.02'W	1224	28.0	3.92	24.1	1.58	–	–
5	62°12.50'S	1559	21.8	8.77	13.1	5.04	3.94	1.10
	57°17.00'W	1545	24.2	7.04	17.2	4.99	4.24	0.75
		1270	13.5	3.51	9.9	3.94	2.73	1.21
		1270	15.5	2.98	12.5	3.95	2.90	1.05
		1175	17.4	2.16	15.2	4.34	3.09	1.25
		1145	15.4	2.25	13.1	4.80	3.19	1.61
		1000	15.8	2.65	13.2	3.75	2.43	1.32
10	62°12.76'S	1468	26.0	10.4	15.6	4.80	3.93	0.87
	57°15.72'W	1350	10.4	2.57	7.9	3.60	2.95	0.65
		1215	11.6	8.25	3.4	4.45	3.63	0.82
		1215	18.0	3.06	15.0	4.82	3.79	1.03
		1150	14.9	3.47	11.4	4.83	3.65	1.18
		1108	15.2	2.57	12.6	4.77	3.81	0.96
		1108	27.6	2.5	25.1	4.64	3.67	0.97
22	62°12.69'S	1430	37.5	12.56	24.9	4.59	3.39	1.20
	57°15.55'W	1300	128.3	6.66	121.6	6.57	3.42	3.15
		1226	24.4	8.81	15.6	5.11	4.31	0.80
		1186	33.9	8.19	25.7	5.92	4.90	1.02
31	62° 11.80'S	1408	16.0	4.93	11.1	4.07	2.91	1.16
	57°15.48'W	1264	18.6	5.46	13.1	5.10	3.73	1.37
		1138	15.1	10	5.1	5.63	4.89	0.74
		1138	27.9	10	17.9	6.22	4.46	1.76
		1096	5.4	0.7	4.7	1.59	1.32	0.27
39	62°11.59'S	1045	66.6	3.66	62.9	5.58	3.23	2.35
	57°16.59'W	1038	42.6	11.3	31.3	11.33	9.58	1.75
		1038	49.6	3.09	46.5	5.27	3.17	2.10
44	62°11.51'S	1428	40.2	8.93	31.2	5.09	3.45	1.64
	57°14.48'W	1320	37.3	5.52	31.8	4.62	3.10	1.52
		1200	33.4	5.47	27.9	5.38	3.81	1.57
		1100	23.8	5.84	18.0	6.43	4.99	1.44
Middle Sister								
48	62°40.40'S	1199	35.3	4.57	30.7	4.54	3.46	1.08
	59°05.50'W	1152	32.9	4.64	28.3	4.65	3.48	1.17
		1083	43.6	3.69	39.9	3.65	1.87	1.78
49	62°42.00'S	1252	39.4	5.77	33.6	4.25	3.12	1.13
	59°10.75'W	1200	28.7	5.62	23.1	3.76	2.83	0.93
		946	32.2	3.49	28.7	1.97	1.14	0.83
65	62°38.65'S	998	23.0	5.77	17.2	12.52	11.89	0.63
	59°00.00'W	966	19.2	8.61	10.6	23.45	22.26	1.19
		965	29.3	3.78	25.6	15.60	13.70	1.90
		950	20.1	5.71	14.4	14.75	13.06	1.69

Fe and Mn by FIA (Table 1) showed that water below 1000 m was generally enriched in these elements. This result is consistent with the pervasive venting in Bransfield Strait [13,15]. In general most of the Mn was dissolved and most of the Fe was particulate as one would expect given the relatively rapid oxidation kinetics of Fe.

The exploration of Hook Ridge began with N–S and W–E transects of stations across and along the main rift axis using the ZAPS instrument package (Fig. 3). No plumes were detected north of the ridge summit (ZAPS stations 1 and 2) but anomalies began to appear at the ridge crest (sta. 3) and increased in size moving down the south

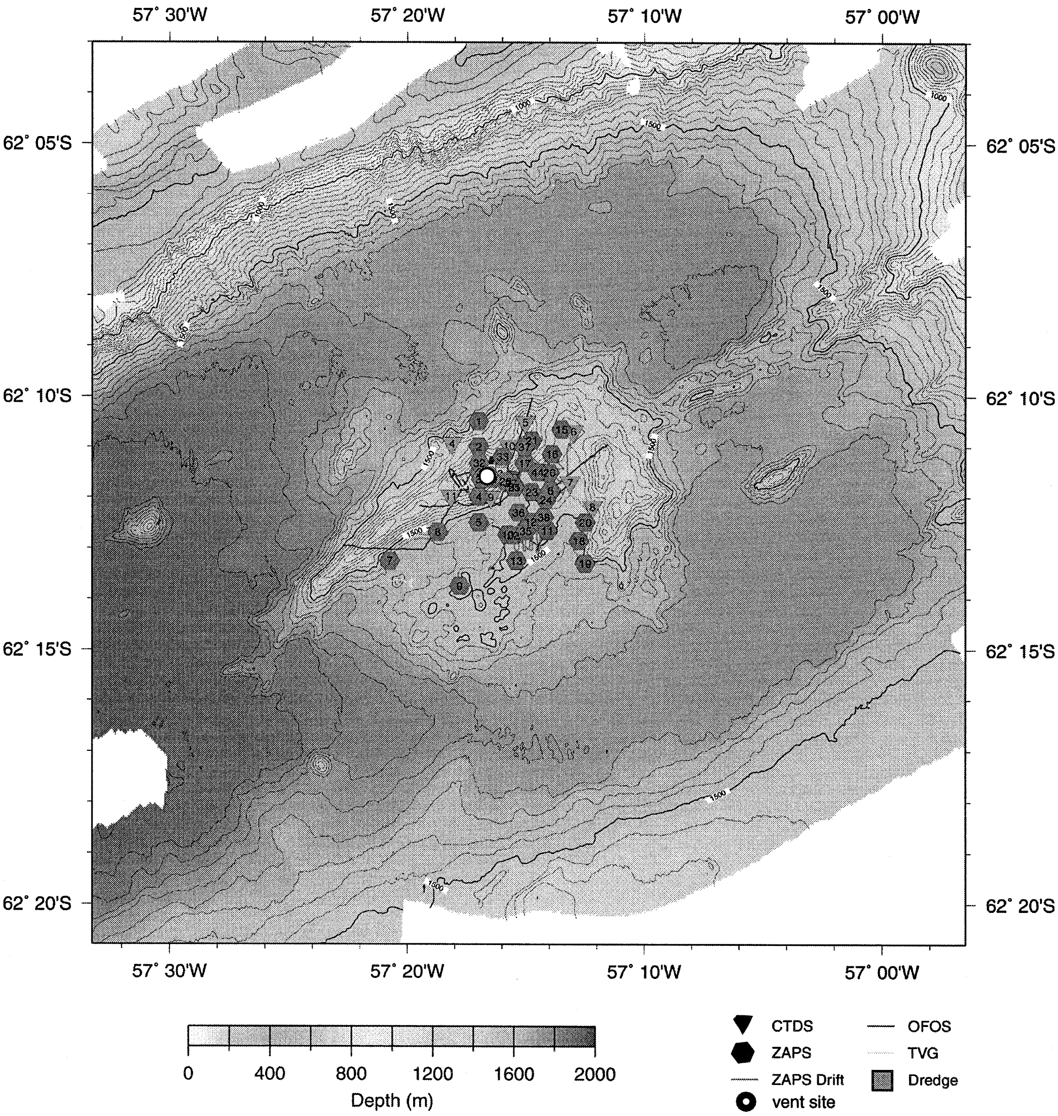

Fig. 3. Multibeam map of Hook Ridge showing ZAPS, OFOS, CTD, TVG, and dredge operations. Hook Ridge is made up of two volcanic features that form the north and east boundaries of a plateau. The along-axis ridge runs SW–NE with a lateral feature trending SE. Most of the operations were carried out at the intersection of these sections in an area we call the 'elbow'. This area lies along the main rift axis characterized by the linear topographic high associated with Bridgeman Island that lies just off the map to the NE.

flank. Two ZAPS stations were then occupied along the southern flank of the ridge (stas. 7 and 8) plumes increased in amplitude moving east. This crossing pattern of ZAPS stations isolated the most robust plumes at the intersection of the two ridge segments (the 'elbow'). The rest of our work at Hook Ridge focused on this area.

It became apparent after more detailed work in the elbow area that there are actually two plume depths at Hook Ridge the large, focused plume that we originally identified at 1150 m and a small but broad anomaly centered at 700 m (Fig. 4). We noticed that the intensity of the shallow plume increased as we moved toward the ridge crest. While always subtle, the shallow turbidity plume was most distinct at stations on the southern flank of the ridge like sta. 28 shown in Fig. 4. During one series of ZAPS operations, we followed the increasing intensity of the shallow plume to the summit of Hook Ridge but found that the plume disappeared once we moved north of 62°11.60'S.

Subsequent photographic reconnaissance with OFOS revealed a depression near the summit resembling a partially collapsed crater. We carried out carefully navigated ZAPS lowerings and determined that there was a Mn anomaly above the depression (Fig. 5). There were few nephels associated with this anomaly but there was somewhat more turbidity near the bottom. In general, plumes over the crater were consistent with the small size and depths of the 700 m turbidity anomaly indicating that the shallow plume over the southern flank originated at the crater vent site.

TS data from the summit showed that there was anomalously warm water coinciding with the depth range of the Mn anomaly and that the salinity in this layer was the same as bottom water (Fig. 6). These results are consistent with a large body of buoyant water rising from the crater. These findings were supported by readings

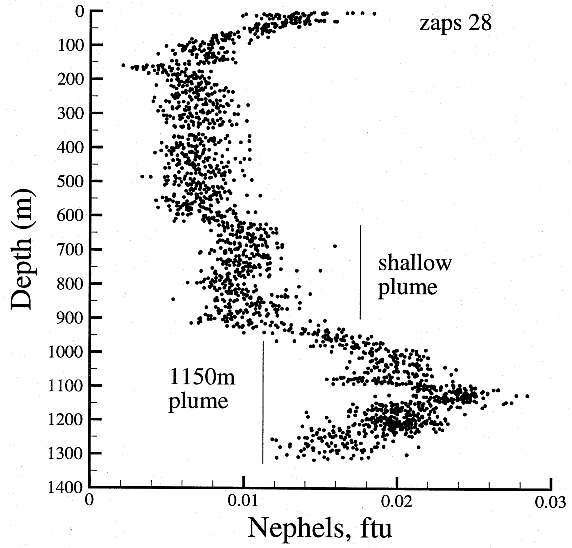

Fig. 4. Nephel profile from the southern flank of the main ridge section at Hook Ridge, just south of the 'crater vent site' showing the presence of two water column plumes. The shallow plume appears to be produced by venting at the summit site while the deeper plume probably indicates a deeper yet undiscovered site.

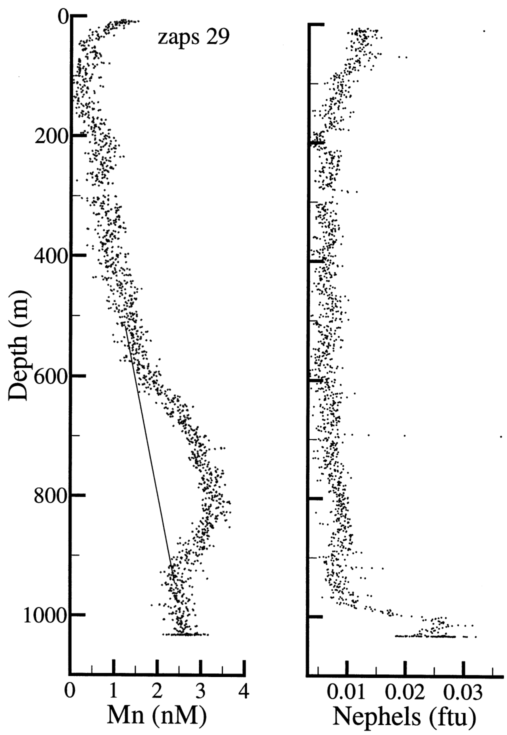

Fig. 5. Dissolved Mn and turbidity profiles from directly over the 'crater vent site' at Hook Ridge. Most of the turbidity at this site is located near the bottom in the depression. The small Mn anomaly is associated with a fleetingly small turbidity anomaly (700–900 m) but this depth range is associated with significant T and TS anomalies as shown in Fig. 6.

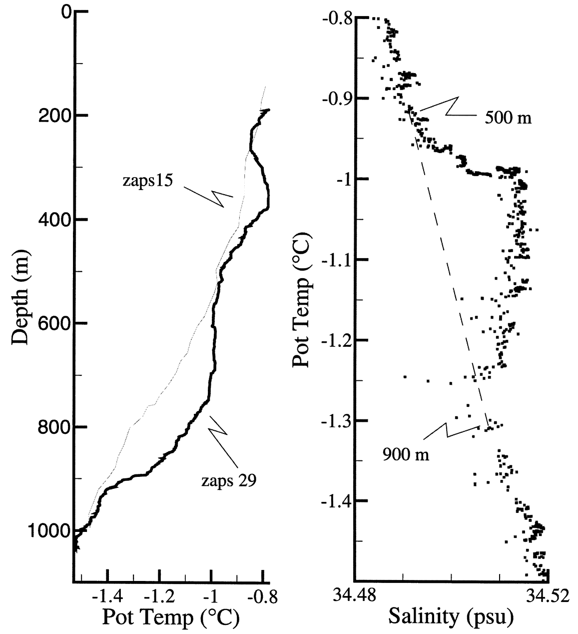

Fig. 6. Profile of potential temperature at ZAPS sta. 29 above the 'crater vent site'. Shown for comparison is the profile at nearby sta. 15 also on the ridge crest but not above the crater. The TS plot in the right panel shows that the salinity in the anomaly is consistent with entrainment of bottom water in a buoyant plume.

from the CTD mounted on the OFOS camera sled that recorded temperature anomalies up to 0.3°C above the white siliceous crusts found in the crater.

We took two TV-grabs at the southern margin of the crater. The grabs recovered hot, soupy sediment capped by hard, siliceous crust. Temperatures in these sediments recorded on deck were 42.0–48.5°C. These sediments were twice as hot as those measured by Bohrmann et al. [16] in a TVG collected 1 km to the west of this site. In a companion paper [20] we suggest that the 'crater' site discovered on this cruise and the 'Polarstern' site [16] are part of the same hydrothermal system connected through a subfloor brine reservoir. We subcored these hot sediments and separated pore waters for chemical analyses (Fig. 7). Pore water chemistry at the crater site (TVG 68) is distinctly different when compared to a nearby reference station also taken on the ridge axis (TVG 27).

After leaving Hook Ridge, we spent several days investigating the Three Sisters area (Fig. 8). Turbidity plumes were detected near the ridge crest of Middle Sister during several ZAPS lowerings. We documented the presence of active venting from one topographic high of Middle Sister with temperature anomalies recorded by thermistors on OFOS and the ZAPS sled. We also detected a Mn anomaly with the chemical sensor (Fig. 9). A dredge at this site recovered hydrothermal minerals including sulfides and barite.

4. Discussion

4.1. Hook Ridge

Hook Ridge consists of two main sections: one trending SW–NE along the axis of the rift and an adjoining orthogonal section at the eastern terminus of the main section (Fig. 3). These orthogonal features form the north and east boundaries of a broad plateau that in turn forms the western end of a regional high that shoals east to Bridgeman Island.

There was always a turbidity plume in the elbow area at about 1150 m but the size of this anomaly varied with location and time. The larger turbidity plumes at Hook Ridge (0.04 formazine turbidity units (ftu)) are approximately half the size of plumes over the TAG mound on the Mid-Atlantic Ridge measured with the same instrument [21]. We also found that there was relatively little dissolved Mn associated with even the largest of these turbidity plumes (Table 1). In general, the amount of Mn in the Hook Ridge plumes is low when compared to other MOR systems. For example, large plumes at Hook Ridge have a maximum reading of 0.04 ftu and contain 5 nM of dissolved Mn. Neutrally buoyant plumes over the TAG hydrothermal mound on the Mid-Atlantic Ridge, on the other hand, typically have a nephel reading of about 0.08 ftu [21] and 40 nM of Mn [22]. These results suggest that the Mn/particle ratio is four times lower in Bransfield Strait than at TAG.

On the other hand, plumes at Hook Ridge are relatively turbid. This observation is consistent with the high levels of particulate iron (e.g. sta.

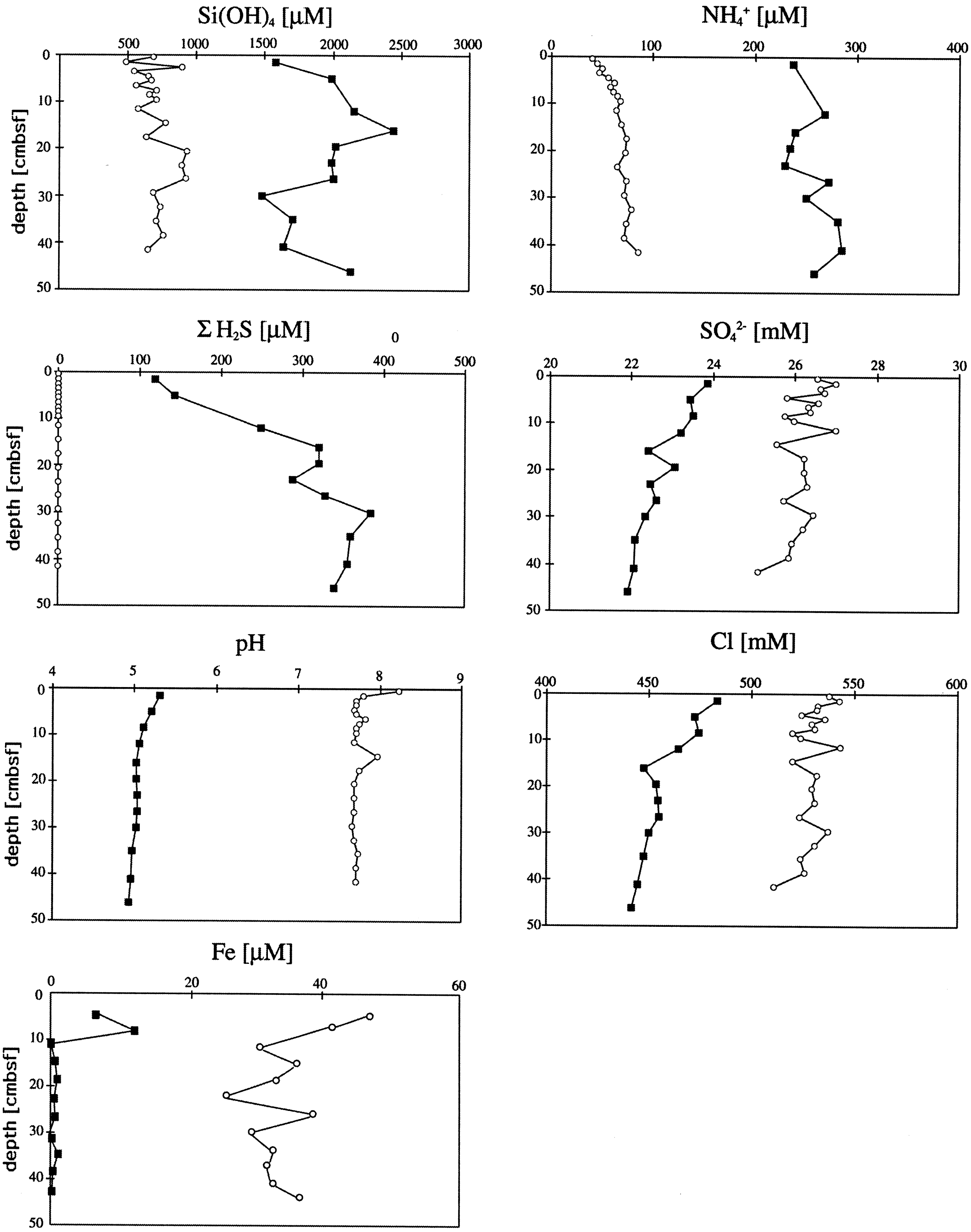

Fig. 7. Profiles of chemical parameters dissolved in pore water from two subcores taken from the TVG at Hook Ridge. The solid symbols represent data from a grab taken at the 'crater vent site' (TVG 68) while the open symbols represent a nearby reference site (TVG 27). Data from the 'crater site' are consistent with the influence of vent fluid.

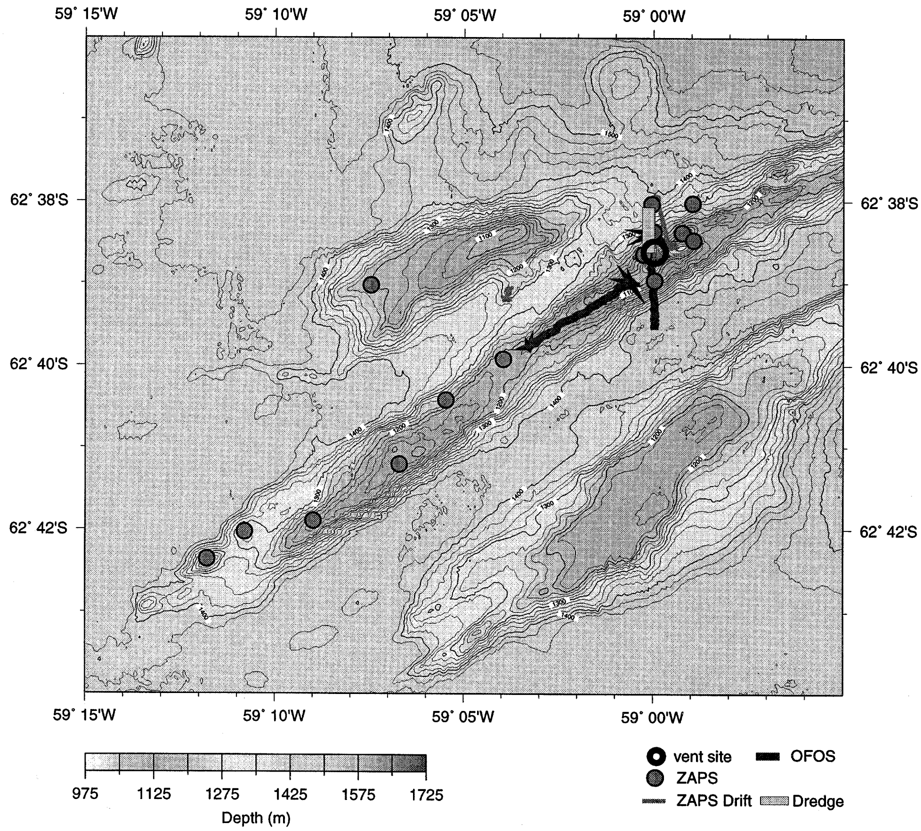

Fig. 8. Multibeam map of Three Sisters showing operations at Middle Sister carried out during NBP99-04 and the location of the vent site.

22 in Table 1). We know that the fluids emanating from the summit of Hook Ridge are reasonably hot because sediments recovered from the crater were 42–48.5°C on deck. Variations in the Mn/Fe could also reflect differences in substrate. Rhyolite, for example, is known to be common in Bransfield Strait volcanics [1,2] whereas such silica-rich rocks are rare on mid-ocean-ridges.

It is quite plausible that the sediment-hosted field at the summit crater would produce the low-turbidity plume over the site (Fig. 5). The summit is too shallow, however, to produce the deeper plumes without significant downwelling. We conclude that there is at least one additional deeper vent site at Hook Ridge in addition to the 'crater' and 'Polarstern' ridge crest sites.

The effects of hydrothermal circulation at the summit of Hook Ridge are apparent in sediments recovered with the TVG (Fig. 7). Pore waters in sediments recovered from the 'crater' site (TVG 68) and from a reference site also on the ridge (TVG 27) were distinctly different even though the biogeochemical conditions in the overlying water column that determine sediment diagenesis like productivity and bottom water oxygen concentration were the same. We, therefore, attribute differences in these cores directly to hydrothermal activity in the crater. Hydrothermal fluids are silica-rich, acidic, and reducing compared to seawater. The presence of hydrothermal fluid would explain the higher silica, ammonia, and hydrogen sulfide as well as lower sulfate and pH in the crater core. Fe concentrations were also lower in the pore fluids of the core influenced by hydrothermal fluid – apparently titrated out by free sulfur. The gleaning of vent fluid Fe by uptake in sediments would explain the low turbidity of the summit plume (Fig. 4).

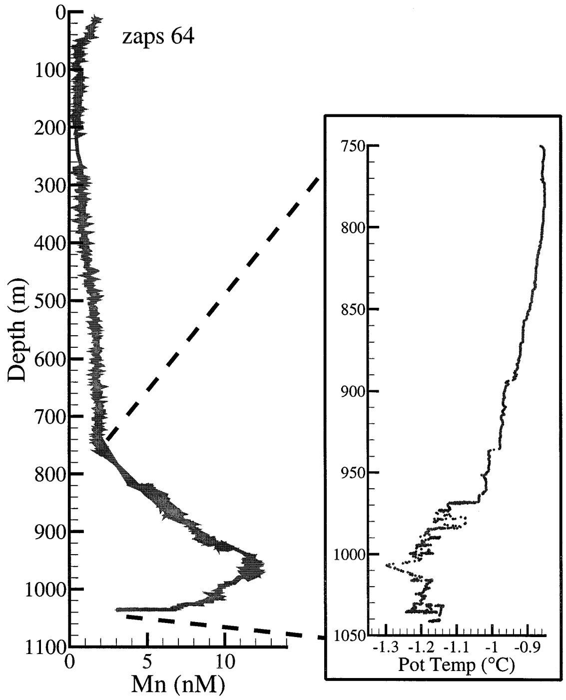

Fig. 9. Profiles of Mn (from the chemical sensor) and temperature from a station next to the Middle Sister vent site. Notice that the depth range in the PT plot was expanded to cover the depth of the Mn anomaly. The depth of the break in PT (967 m) coincides exactly with the maximum in Mn. This result is consistent with a virtual minimum being imposed on Mn by cold water sweeping along the ridge crest. The stair-step features in PT above this depth coincide with the advection of Mn-rich plume water.

Pore waters in the crater are also depleted in chloride. Low chloride is consistent with a low-chloride fluid end-member or phase separation [23]. We invoked phase separation in Bransfield Strait in an earlier study to explain differences in helium and turbidity plumes [13]. We expand on the topic of phase separation at Hook Ridge in a companion paper in this volume [20].

The facts that the pH in the crater core is < 5 at 50 cm, that the temperature in the core on deck was > 48°C, and that we recovered a section of chimney suggest that the sediment cover is relatively thin. This environment is similar to other backarc settings that host Kuroko-type polymetallic deposits [24].

We completed an extensive seafloor observation program of the ‘crater’ vent site using additional OFOS operations in order to document the type and spatial distribution of fauna. Images from OFOS tracks revealed some interesting zonation patterns in the biota around the crater-like depression. On the outer rim there is a high abundance of large corals and sea lilies, and on the upper ridge there are brittle stars and few anemones. The inner walls of the crater are covered with calcareous worms and cup corals, as well as some sponges and gorgonian corals. Brittle stars and anemones characterize the inner part of the crater. The anemones in this part of the crater are located primarily at the base of small rocky outcrops. TV-grab samples, which are largely mud, captured macro-faunal invertebrates. We also observed empty tubeworms that resemble polychaete tubes, and some pogonophorans. There were also clumps of sediment in the grabs apparently bound by sulfur-oxidizing bacteria.

4.2. Middle Sister

We decided to leave the Hook Ridge hydrothermal site for the last few days and explore other promising areas in Central Basin identified during our previous survey. We visited Viehoff Seamount, Little Volcano, and the Three Sisters areas [15]. As in the past, we initiated our survey with a series of ZAPS lowerings to look for indicators of hydrothermal activity in the water column.

We found no evidence of activity at Viehoff Seamount or Little Volcano, but water column plumes were detected on the north flank of Middle Sister. Based on our water column findings, we dredged a nearby topographic high (Fig. 8). This dredge contained fresh pillow basalt and a range of hydrothermal precipitates including massive barite–silica rocks, silica crusts and layered Fe-oxyhydroxides. We confirmed the presence of active venting at this site when the ZAPS package detected Mn, temperature, and turbidity anomalies during several deployments. The profiles in Fig. 9 were collected near the vent site.

We deployed OFOS several times on Middle Sister to observe biological communities (Fig. 8). This photographic reconnaissance revealed that Middle Sister contrasts with Hook Ridge in many respects. For one thing, relatively fresh pillow basalt covers wide areas of the ridge. The biological communities at Middle Sister are also strikingly different having very abundant and diverse suspension-feeding invertebrates. Large anemones and gorgonian soft corals dominate the assemblages. There are also several species at Middle Sister that were not seen at Hook Ridge, including large barrel sponges. Filter feeders tended to occur near the hydrothermal site leading us to hypothesize that their distribution may be affected by enhanced food supply provided by free-living chemoautotrophic bacteria at the vents.

5. Conclusions

This project produced direct evidence of extensive high-temperature hydrothermal activity in Bransfield Strait and located two new hydrothermal sites (Table 2). The 'crater site' near the summit of Hook Ridge is an unusual area dominated by hydrothermal flux through a thin sediment layer. Water column plumes in this area occur at two distinct depths (700 and 115 m). Sediment-hosted venting at the ridge crest is consistent with the depth and low turbidity in the 700-m plume. But it is unlikely that the summit vents support the deeper plume layer, indicating that there is at least one additional site at Hook Ridge. Turbidity anomalies in the deeper plumes at Hook Ridge are comparable in magnitude to the TAG site on the MAR but there is relatively little Mn indicating unusual vent fluid chemistries with high Fe and low Mn. Pore water chemistry is consistent with phase separation of fluids below Hook Ridge. This aspect of our work is elaborated on in a companion paper [20].

While the bottom fauna at both sites is rich and varied, we did not photograph animals at either Hook Ridge or Middle Sister that would be considered endemic vent species at MOR hydrothermal sites, but neither did we photograph active vents. Since bottom transponders were not available for our cruise it is possible that we missed hydrothermal areas which are typically small. It is also possible that vents in Bransfield Strait do not support unusual megafauna.

Assuming that our photographic reconnaissance is in fact representative, vent fauna may be absent from Bransfield vent sites for a couple of reasons. Vent assemblages may not exist because the sites are remote from the MOR system and therefore inaccessible to vent-species larvae. It may also be that because Bransfield Strait is a relatively new system, vent species have not had time to develop vent communities.

Their remote locations in Antarctic waters and the relatively short volcanic history of the Bransfield backarc system make these hydrothermal sites important pieces of the global biogeographic puzzle of vent fauna evolution. Discovery of these sites and recent hydrothermal investigations in the East Scotia Sea [25] open up the Southern Ocean to further exploration that is essential to our understanding of vent fauna biogeography.

Table 2
Vent site locations in Bransfield Strait from this work

Vent site	Latitude (°S)	Longitude (°W)	Water depth (m)
Hook Ridge	62°11.64	57°16.47	1080
Middle Sister	62°38.52	58°59.00	1040

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