FLUID INCLUSION INSIGHTS INTO THE DEEP-SEA "PACMANUS" HYDROTHERMAL SYSTEM OF THE MANUS BASIN BACK-ARC RIFT, PAPUA NEW GUINEA

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Ocean Drilling Program Site 1188 is located in an area of active low-temperature fluid venting within the PACMANUS hydrothermal field, which also includes nearby high-temperature sulfide chimneys. The hydrothermal system is hosted by the dacitic rocks of Pual Ridge in the Manus Basin (Binns et al., 2002). This 20 x 1.5 x 0.5-km ridge is part of a back-arc spreading system that is genetically related to active subduction beneath New Britain, Papua New Guinea. Pual Ridge is situated near the eastern end of the spreading system, where extension is propagating into older crust of the inactive New Ireland arc. All of the cored rocks underlying the fresh surficial dacitic volcanic rocks are intensively hydrothermally altered. Primary fluid inclusions in widespread but sparse anhydrite ± pyrite veins provide unique fluid samples that give direct evidence for the chemical and physical properties of hydrothermal fluids present beneath the seafloor, within the ridge edifice.

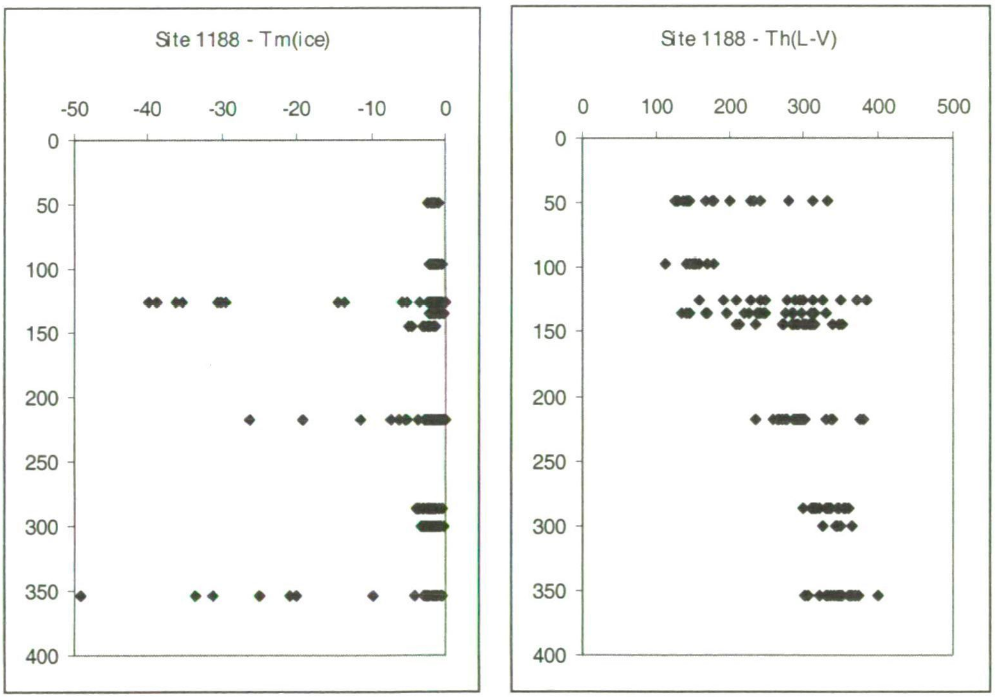
Site 1188 is located on Snowcap Knoll, an area of diffuse warm venting at a water depth of ~1645 m. Fluid inclusion data were collected on samples from ~50 m to ~350 m below the seafloor (Figure 1). Ambient temperatures are unknown, but the T measured after 8 days of thermal rebound (after drilling) at a depth of 360 m at this site was 313°C.

Primary fluid inclusions measuring up to 100 μm across are dominantly two-phase L + V inclusions, yet fluid inclusions with up to three daughter crystals are also observed. The largest daughter crystal is halite, commonly accompanied by a small transparent granular daughter crystal and an even smaller granular opaque crystal. Reconnaissance PIXE studies (C. Yeats, personal communication, 2002) suggest that the small transparent daughter mineral may be barite.

Ice melting temperatures for L+V inclusions vary from –0.1° to –33.6°C, but with a strong mode at about -2°C, corresponding to a seawater-like salinity. However, the range in Tm(ice) indicates that a significant number of inclusions contain quite fresh water, and others contain quite saline water. Preliminary ESEM microprobe analyses (M. Timofeeff, personal communication, 2003) suggest the presence of both K and Fe in the inclusion fluids, in addition to NaCl. Ice melting temperatures from the multiphase inclusions, measured in the presence of hydrohalite, range from –29.5° to –49.1°C, confirming their hypersaline and multicomponent (not binary NaCl-H_2O) composition. Ice melting data, and measured halite dissolution temperatures ranging from 125° to 257°C, indicate that the majority of salinities are around ~30±3 wt.% salts.

The ranges of ice melting temperatures and L-V homogenization temperatures in each sample as a function of sample depth below the seafloor are shown in Figure 1.

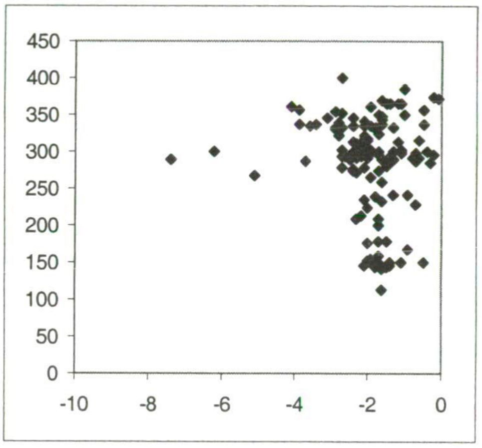
Figure 1. Tm(ice) in °C (left) and Th (L-V) in °C (right) versus subseafloor depth in meters (vertical axis).



The homogenization data indicate a general tightening of the range of Th measured for each sample as a function of depth (Figure 1, right). This is interpreted to show that the deeper vein samples formed in the presence of high-temperature fluids with a narrow temperature range, while the shallower samples have experienced both high temperatures and low temperatures. The sample at 354 m depth (where ambient T is at least 313°C) has a Th range of 303-401°C, and has not apparently encountered lower-temperature hydrothermal fluids. In contrast, the sample at 97 m has a Th range of 112-178°C, indicating that it was formed in the presence of significantly lower-T fluids than the deepest sample. Yet other shallow samples (those at 48 m and 126 m, for example) have much broader Th ranges (127-332°C and 191-372°C, respectively), indicating a broad range in hydrothermal temperatures. Hot upwelling fluid, up to 400°C, entrained and mixed with lower-temperature seawater "groundwater" at shallow levels, resulting in the precipitation of anhydrite in the fractures.

Ice melting temperatures vary significantly from about –2.0°C, indicating salinities that very significantly from seawater (Figure 1, left; Figure 2). Samples at every depth contain quite fresh solutions (the least-saline inclusions for each sample in Figure 1, with increasing depth, have Tm(ice) values of –0.9, -0.5, -1.0, -0.2, -1.2, -0.1, -0.5, -0.2, and –0.5°C). Vein samples at depths of 218, 300, and 354 m contain some fluid inclusions that homogenize to vapor. The presence of low-salinity inclusions, some of which homogenize to vapor, and probably co-genetic high-salinity inclusions, demonstrate the role of phase separation in the subseafloor.

Figure 2. Th (vertical axis) versus Tm(ice) (horizontal axis) for all Site 1188 samples, values in °C.



Higher-salinity fluid inclusions invariably have higher homogenization temperatures, generally above about 300°C (Figure 2). This places a lower limit on the temperature of phase separation, though significant cooling may have occurred to the saline inclusions as a result of mixing and/or conductive cooling. High-salinity fluids were present at several depths, reaching as high as 126 m below seafloor. This is not unexpected, in light of the high-salinity inclusions observed by Lécuyer et al. (1999) in sulfide-bearing chimneys in the back-arc Lau Basin, which seem to indicate that high-density brines sometimes reach the seafloor. The PACMANUS samples demonstrate that dense saline brines are found at multiple subseafloor depths, and together with the Lau Basin example indicate that brine venting to the seafloor is a natural process that has yet to be observed in real time.

References

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