HYDROTHERMAL ACTIVITY AND MASSIVE SULFIDES IN THE EQUATORIAL SOUTH ATLANTIC

Petersen, Sven

GEOMAR

The southern Atlantic Ocean has, for a long time, been neglected in the search for hydrothermal systems and associated massive sulfide deposits. Only in the past few years has exploration in this area increased, mainly due to programs by British, German, and most recently Chinese scientists. The first indications for hydrothermal activity south of the equator were seen on CTD surveys in 2004 (Devey et al., 2005) near 8°20 and towed TOBI sidescan sonar surveys in 2005 where in-situ sensors (MAPR) showed temperature and light backscattering anomalies near 5°S (German et al., 2008). During follow-up cruises to both areas the autonomous underwater vehicle ABE (Woods Hole Oceanographic Institution) was deployed and followed those indications and discovered two basalt-hosted active black smokers sites at 4°48'S on the MAR in 2005 (the Turtle Pits and Red Lion hydrothermal sites; Haase et al., 2007; Koschinsky et al., 2008; German et al., 2008) and the Drachenschlund black smoker at 8°18'S that is partly associated with mantle rocks (Melchert et al., 2008). During the following years these sites and another field (the Comfortless Cove site) discovered between Turtle Pits and Red Lion were investigated in detail. Additionally, widespread low-temperature hydrothermal venting was discovered in a water depth of only 1500 m in a region with thickened oceanic crust near 9°33'S (Lilliput Hydrothermal Field; Haase et al., 2009), geologically resembling ridge portions south of Iceland that are also characterized by a lack of high-temperature venting.

Basalt-hosted massive sulfide deposits at 4°48'S all occur over a strike length of less than 2 km in a water depth of 3000 m. They are associated with young lava flows, that formed at an apparently magmatically robust spreading segment center. Two vent fields are venting phase-separated, vapor-type fluids with exit temperatures at one of the fields reaching up to 464°C, the highest temperatures ever recorded from the seafloor (Koschinsky et al., 2008). The massive sulfide deposits at 4°48'S are rather small with individual chimneys reaching a maximum of up to 13 m in height and mounds less than 50 m in diameter. Most of the sulfides are dominated by pyrite and marcasite with only subordinate chalcopyrite or sphalerite. TV-guided grab sampling indicated that the mounds at Turtle Pits contain abundant anhydrite-magnetite-hematite, an unusual mineral assemblage for most black smoker systems, which is here largely attributed to intense mixing and infiltration of seawater into the mound. Several small mounds are visible in high-resolution AUV bathymetry in the area and sampling of one of these mounds recovered intensely oxidized, massive pyrite, indicating potential for further sulfide deposits in the area. The observation of juvenile, very small black smokers in between mussel fields associated with large faults indicates that hydrothermal activity is still building up. Geochemical data of sulfides at 5°S (Table 1) reveals metal grades that are comparable to typical other basalt-hosted systems along the Mid-Atlantic Ridge (Cherkashov et al., 2008; Fouquet et al., 2010). Elevated Zn-contents in samples from Red Lion and Comfortless Cove reflect sampling of chimney

Table 1

Chemical composition of hydrothermal precipitates from active sites in the equatorial South Atlantic (T_{max}= maximum exit vent temperature; N=number of analyses).

Location	T_{max}	N	Cu	Zn	Fe	S	Au	Ag	Ni	Sn
			wt.%				ppm			
Basalt-hosted										
Turtle Pits	407°C	50	6.6	2.3	37.3	29.8	0.25	16	3	3
Red Lion	349°C	9	2.9	13.9	30.7	45.9	0.64	67	4	5
Comfortless Cove	464°C	12	2.5	12.4	34.7	45.7	0.42	40	4	25
Ultramafic-hosted										
Nibelungen	372°C	6	24.8	24.2	12.7	21.8	3.54	154	10	1074

material. Only at Turtle Pits has significant mound material been sampled to provide a more reliable grade and decreases the overall Zn-grade of the deposit while improving the Cu-grade. The Au-content is low for all hydrothermal fields.

The discovery of a mantle-hosted black smoker on the southern Mid-Atlantic Ridge near Ascension Island (Nibelungen site at 2910 m water depth; Melchert et al., 2008) gives all reason to believe that Cu-Au-rich systems such as Logatchev and Ashadze can also be found in the southern Atlantic. The Nibelungen site is characterized by a single active black smoker venting from the base of a small depression associated with a 1 km long NS striking fault. The depression and the venting from holes within the depression rather than from towering chimneys resemble vent sites seen at other mantle-hosted sulfide deposits (Logatchev and Ashadze, Petersen et al., 2009; Fouquet et al., 2010). Host rocks at Nibelungen include serpentinite in the immediate surrounding of the depression and along the fault zone (Melchert et al., 2008) as well as basalt in the far field. Secondary Cu-rich sulfides have been sampled from the active vent site while small, meter-sized Zn-rich inactive chimneys occur adjacent to the active vent site. The amount of sulfide at Nibelungen is very small and the sulfides themselves are poor in Fe, slightly enriched in Au and Ni, while Ag, and especially Sn are strongly enriched compared to the basalt-hosted sites, a feature it shares with other mantle-hosted sulfide deposits (Fouquet et al., 2010).

The discovery of several active and inactive vent sites south of 10°S by Chinese exploration efforts clearly suggests that sulfide potential here is certainly not less then at the central or northern Mid-Atlantic Ridge.

REFERENCES

Cherkashov, G., et al., 2010. Seafloor massive sulfides from the northern Equatorial Mid-Atlantic Ridge: new discoveries and perspectives. Marine Georesources and Geotechnology 28, 222-239. Devey, C.W., Lackschewitz, K.S., Baker, E., 2005. Hydrothermal and volcanic activity found on the southern Mid-Atlantic Ridge. EOS 86 (22), 209—212.

Fouquet, Y., et al., 2010. Geodiversity of hydrothermal processes along the Mid-Atlantic Ridge and ultramafic-hosted mineralization: a new type of oceanic Cu-Zn-Co-Au volcanogenic massive sulfide deposit, Diversity of Hydrothermal Systems on Slow Spreading Ocean Ridges. American Geophysical Union, pp. 321—367.

German, C.R., et al., 2008. Hydrothermal activity on the southern Mid-Atlantic Ridge: tectonically- and volcanically-controlled venting at 4—5°S. Earth and Planetary Science Letters 273, 332—344.

Haase, K.M., et al., 2007. Young volcanism and related hydrothermal activity at 5°S on the slow-spreading southern Mid-Atlantic Ridge. Geochemistry Geophysics Geosystems 8, doi:10.1029/2006GC001509.

Haase, K.M., et al., 2009. Diking, young volcanism and diffuse hydrothermal activity on the southern Mid-Atlantic Ridge: the Lilliput field at 9°33'S. Marine Geology 266, 52—64.

Koschinsky, A., et al., 2008. Hydrothermal venting at pressure-temperature conditions above the critical point of seawater, 5°S on the Mid-Atlantic Ridge. Geology 36, 615—618.

Melchert, B., et al., 2008. First evidence for high-temperature off-axis venting of deep crustal/mantle heat: The Nibelungen hydrothermal field, southern Mid-Atlantic Ridge. Earth and Planetary Science Letters 275, 61—69.

Petersen, S., et al., 2009. The geological setting of the ultramafic-hosted Logatchev hydrothermal field (14°45'N, Mid-Atlantic Ridge) and its influence on massive sulfide formation. Lithos 112, 40—56.