Organ pipes, beehive diffusers and chimneys at the Broken Spur hydrothermal sulphide deposits, 29°N MAR

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Introduction

The Broken Spur deposits at 29°10′ N on the slow-spreading MAR were discovered on March 4 1993 during cruise 76 of the RRS Charles Darwin (Murton *et al*, 1993). They were investigated in March-April (Elderfield *et al.*, 1993) and sampled on ALVIN dives 2624 and 2625 in June 1993 (Murton and van Dover, 1993). The samples from these ALVIN dives were investigated mineralogically and isotopically by our group (Duckworth *et al.*, 1994 and in prep). This communication is mainly concerned with a beehive diffuser and associated structures recovered by the ALVIN crew from an 18m black smoker edifice known as the 'Spire'.

Geology

The Broken Spur field is situated in the axial graben of the Mid-Atlantic Ridge. Three main active vent sites were discovered at between 3065 and 3086m water depth. Active vents have fluids discharging at 353–363°C and the Spire fluids are venting at 360°C. Intense, focussed hydrothermal flow discharges from organ pipes, delicate multiple chimney tips, whereas diffuse hydrothermal flow emanates from beehive diffusers, bulbous ribbed structures near the top of the Spire (Fig.1)

Methods

The samples were studied by routine optical microscopy and analysed by analytical SEM with EDS, and XRD using standard methods.

Results

The mineralogy of the Broken Spur samples includes pyrite-marcasite, isocubanite-chalcopyrite, sphalerite-wurtzite, anhydrite, iron oxydroxides, amorphous silica, with minor bornite, chalcocite-digenite, magnetite-hematite, aragonite, baryte and galena-jordanite. The major structural elements of a Broken Spur edifice are shown in Fig. 1.

Discussion

The formation of the edifice starts with the organ pipes, develops through the beehive diffusers and constructs a multiwalled, chalcopyrite chimney, which is strong enough to support the 18m high, ca 0.6m diameter, structure. The processes involved are successive and continuous as the edifice grows upwards from the seafloor. Initially, the high-temperature vent fluid precipitates chalcopyrite-isocubanite in the organ pipe chimneys. The flow entrains ambient seawater which precipitates anhydrite as the seawater warms up, due to anydrite's retrograde solubility. The anhydrite casing thickens with time constructing the beehive diffuser, which acts as a form of scaffolding for the development of the thicker and more rigid chalcopyrite chimney. As the base and exterior of the beehive becomes farther from the high temperature fluid, the enclosing seawater cools and the anhydrite dissolves and sulphides oxidise. The result is a beehive structure that moves up with the edifice as it grows.

Reactions within the anyhydrite beehive are complex. It appears that early FeS is precipitated which reacts with dissolved copper to form isocubanite. Precipitation of pyrrhotite continues and chalcopyrite begins to form by continued reaction (Cowper and Rickard, 1989). The chalcopyrite grows out along extreme sub-horizontal temperature gradients. In the chimneys themselves this growth continues intermittently possibly related to local variations in hydrothermal flow. The formation of bornite-digenite in the equigranular chalcopyrite-isocubanite might conventionally be related to surface oxidation during the growth process. However, it is identical to the sequence described by Cowper and Rickard (1989) for the diffusion-controlled reaction between *iron(II)* monosulphides and dissolved

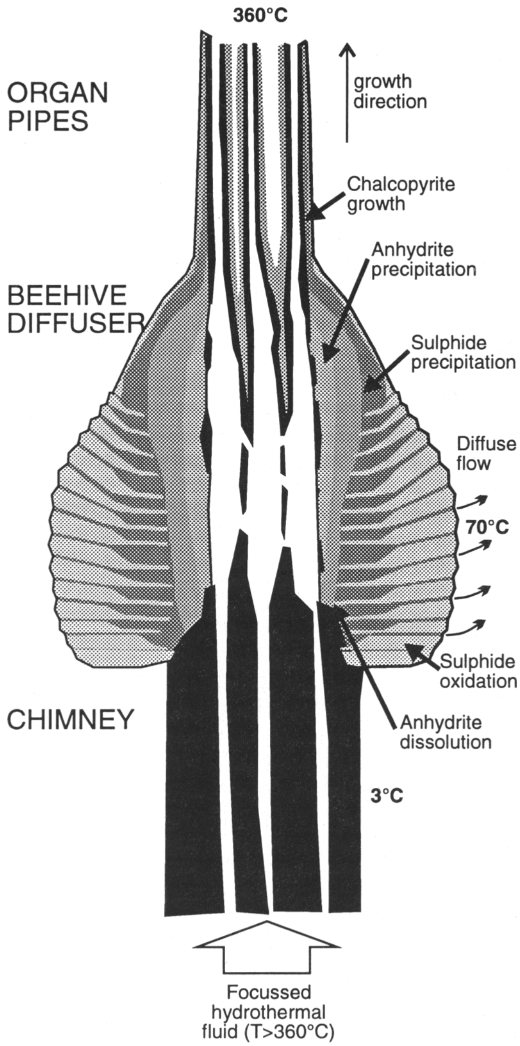

FIG. 1. Elements of a Broken Spur Edifice. The *chimney* consists of repeated layers of horizontally elongated chalcopyrite-isocubanite with thin bands of equigranular chalcopyrite-isocubanite. Each of the intergranular layers shows the development of bornite and digenite-chalcocite. The *beehive diffuser* is a ribbed, beehive-shaped mass of layered anhydrite pyrite-marcasite-FeOx surrounding chalcopyrite-anhydrite coated internal conduits from which vent fluids diffuse. Within the anhydrite, clusters of acicular pyrrhotite occur consisting of < 75μm laths. The paragenesis in the beehive samples is: (early) anhydrite → isocubanite-ZnS → pyrrhotite - chalcopyrite → pyrite-magnetite-serpentinite - talc(late)-FeOx. The delicate *organ pipe* structures that top the beehive diffusers consist of thin layer of chalcopyrite-isocubanite surrounded by anhydrite and channel focussed flow of the vent fluids.

aqueous copper which initially develops chalcopyrite through a cubanite-precursor; Cowper and Rickard (1989) noted that continued reaction resulted in bornite and ultimately digenite.

The Broken Spur edifices contrast with the standard EPR-type bare ridge chimneys. Similar stuctures have been described from Snakepit hydrothermal field (Fouquet *et al.*, 1994) at 23°N on MAR and the northern Cleft segment of the Juan de Fuca ridge (Koski *et al.*, 1994.) However, the Snakepit beehives are ZnS dominated and contain no anhydrite. Koski *et al.* (1994) believe that the ZnS ultimately replaces the anyhydrite forming the mound edifice.

Conclusions

The organ pipes are analogous to conventional, bare ridge, EPR-type chimneys. These delicate structures are able to form at Broken Spur together with the beehive diffusers because of less intense, turbulent flow at the chimney vent. The chimney part of the Broken Spur edifice effectively represents the subsurface parts of EPR bare ridge chimney. Because of enhanced tectonic stability of the slow spreading ridge at Broken Spur, the edifices are able to grow to considerable heights above the seafloor.

Acknowledgements

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References

Cowper , M. and Rickard, D. (1989) *Chem. Geol.*, **78**, 325–41.

Duckworth R.C., Knott, R., Fallick, A.E., Rickard, D., Murton, B.J., van Dover, C. (1994 and in prep.) *Geol. Soc. London.*

Elderfield H., German,C.R. and Palmer M.R. (1993) *BRIDGE News* **5**, 7–10.

Fouquet, Y., Wafik, A., Cambon, P., Mevel, C., Meyer,G., and Gente, P. (1993) *Econ. Geol.* **88**, 2018–36.

Koski, R.A., Jonasson, I.R., Kadko, D.C., Smith, V.K. and Wong, F.L. (1994) *J. G. R.* **99**, 4813–32.

Murton, B.J. and Shipboard Party. (1993) *BRIDGE News*. **4**, 3–6.

Murton, B.J. and van Dover, C. (1993) *BRIDGE News* **5**, 11–4.