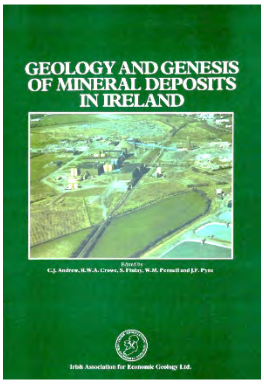

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Hydrothermal chimneys and fossil worms from the Tynagh Pb-Zn deposit, Ireland.

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Abstract

Hydrothermal black smokers on the East Pacific Rise issue from sulphide chimneys and mounds. At these vents chemosynthetic life is prolific. The earliest fossil hydrothermal chimneys yet discovered formed in a brine pool 350Ma ago at Silvermines, Ireland, in conditions presumably inimical to metazoan life. Fossils associated with mounds and chimneys in sulphide deposits in the ophiolite complexes of Cyprus and Oman prove that life forms similar to those colonizing active hydrothermal vents on the East Pacific Rise were extant 100Ma ago around ridge-crest hot springs. This paper reports the first discovery of fossil worms associated with hydrothermal chimneys from the sedimentary-exhalative base-metal orebody at Tynagh, Co. Galway.

Introduction

High heat flow, related to shallow magmatic intrusions, drives hydrothermal convection cells within the oceanic crust along medium to fast oceanic spreading ridges (Rona, 1984). Hydrothermal fluids, at temperatures up to 380°C, exhale from fractures in the newly formed oceanic crust on the East Pacific Rise at 21°N (Speiss et al., 1980). On turbulent mixing with near-freezing seawater, sulphides and sulphates are immediately precipitated as the pH increases. These minerals are either dispersed in the sea or may coalesce to form distinctive chimney structures. These chimneys may grow up to 5m in height, 30cm in diameter and are composed of shells of Zn, Cu and Fe sulphides together with anhydrite and subordinate amounts of silicates (Haymon and Kastner, 1981). Compositional differences within chimneys are functions of the variable degree of mixing between the two fluids, and of the resultant temperature gradients within the chimneys.

The limited amount of food, falling as particulate matter, which reaches the deep oceans (Banse, 1964) precludes the existence of a high biomass. At seafloor hot springs along the East Pacific Rise, however, an unusually diverse, abundant and bizarre fauna (Corliss and Ballard, 1977; Ballard and Grassle, 1979; Corliss et al., 1979; Speiss et al., 1980) of clams, crabs, tube worms, mussels, barnacles and many other species is supported by a profuse local supply of nutrient from bacterial carbon fixation. Chemoautotrophic bacteria derive the energy necessary for carbon fixation from the oxidation of reduced sulphur compounds, especially H_2S, which is dissolved in high concentrations in the hydrothermal fluid (Edmond et al., 1979). These bacteria are the base of a food chain, unique in being the only one known not to rely on photosynthesis for carbon fixation. Filter-feeding animals probably utilise such a food chain, although the giant vestimentiferan tube worms (Jones, 1980 and 1981; Felbeck, 1981), lacking a mouth, gut and anus, appear to live on dissolved amino and carboxylic acids.

The first evidence of fossil hot springs was the discovery (Larter et al., 1981) of hydrothermal chimneys at Silvermines, Ireland. Scott (1981) has since interpreted "tiger's eye" structures (Narita et al., 1977) as being smaller versions of the chimneys found at 21°N. Subsequent discoveries of chimney fragments and worm-like fossils (Oudin and Constantinou, 1984; Haymon et al., 1984) in ophiolite sulphide deposits at Troodos and Bayda suggest that ridge-crest hot springs were prolific during the Cretaceous. Chimneys, similar to those at Silvermines, and vermiform fossils, similar to those from Troodos and Bayda, have now been found at Tynagh.

Tynagh chimneys and fauna

This study is based on an example of a small pyrite mound which contains the chimneys, and which sits on top of laminated sedimentary sulphides, typical of the sparse development of sedimentary ore at the Tynagh deposit (Plate 1a). The top 5cm is composed entirely of coarse crystalline galena and barite, the bottom galena layer containing abundant sulphosalts whereas the upper layer contains none. The rest of the block comprises regular layers of microcrystalline sphalerite and barite with occasional clots of galena. Fracturing and disruption of the layered sulphides (Plate 1b), imbrication of the upper galena layer, barite crystals bent in the downslope direction and the chimneys lying at an angle of 50° to the laminated sulphides, all provide evidence of slumping while the top 5cm of sulphides were still semi-lithified.

Two different types of chimney-like structures (Plates 2a and 2b) composed entirely of pyrite, have been recognized at Tynagh. Their maximium dimensions are: length 15mm, diameter 7mm, and central aperture 4mm. The central channels are generally circular in plan although a few are elliptical; the channels may be empty, filled with a later generation of framboidal pyrite or may contain the remains of worm-like fossils (Plate 2c). Type 1 structures (Plate 2b) have central apertures, on average 1.5mm in diameter with walls 0.2mm thick. These are interpreted as worm tube moulds. They resemble the tube moulds recovered from Juan de Fuca (Koski et al., 1984), Troodos (Oudin and Constantinou, 1984) and Bayda (Haymon et al., 1984). Type 2 structures (Plate 2a) have central apertures 2mm in diameter with walls of approximately the same size which have a distinctive radiating crystal structure. These are interpreted as small hydrothermal chimneys produced by the exhaling solutions, and are comparable to the type 2a chimneys described from Silvermines (Boyce et al., 1983).

Numerous vermiform fossils have been found in both type 1 and type 2 structures. The fossils have a thin outer

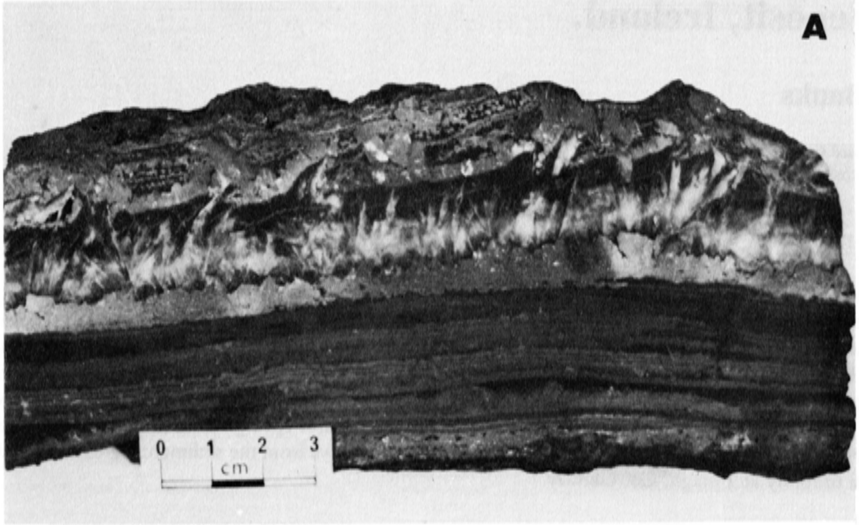


Plate 1a. Laminated sedimentary sulphides underlying the pyrite mound and chimneys. Arrow indicates the orientation of the central channel of the chimneys. Note the flowering up structure of the lower galena layer and the imbrication of the upper layer.

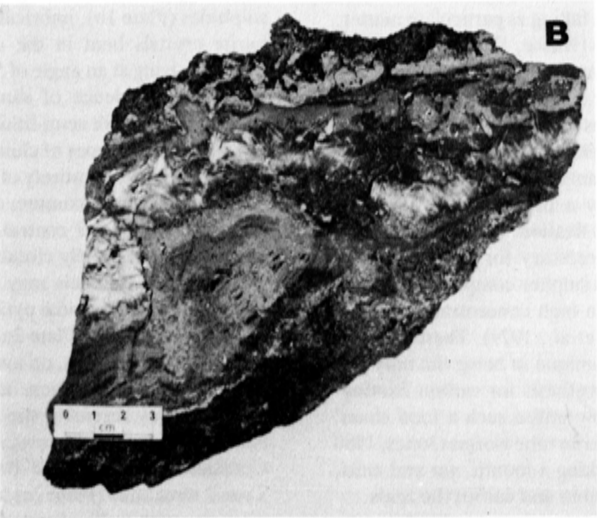
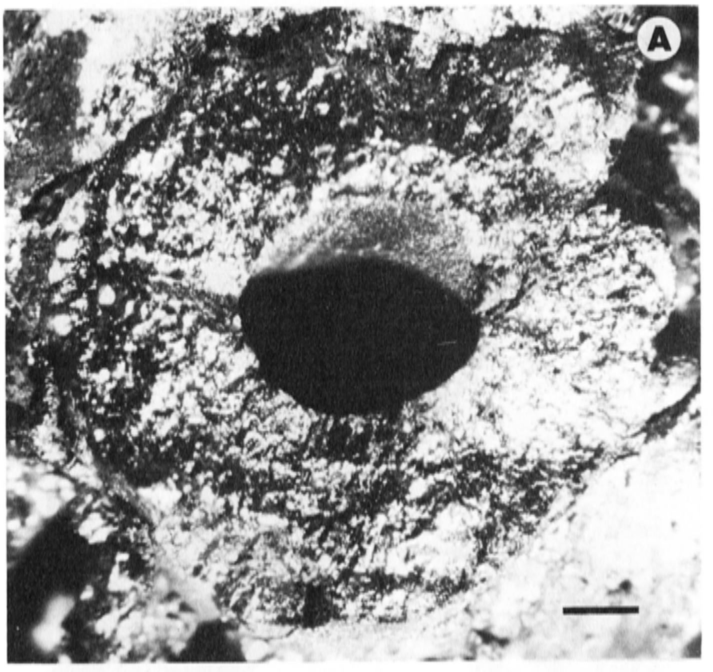


Plate 1b. Vertical section 8cm from the section in 1a. The laminated sulphides have been fractured and disrupted by the movement of fluid to the surface.



Scale bar = 1mm.

Plate 2a. Small hydrothermal chimney found in the pyrite mound.

Plate 2b. Fossil worm tube mould found in the pyrite mound. The walls of the mould are much thinner relative to the central channel than the walls of the chimney in 2a.

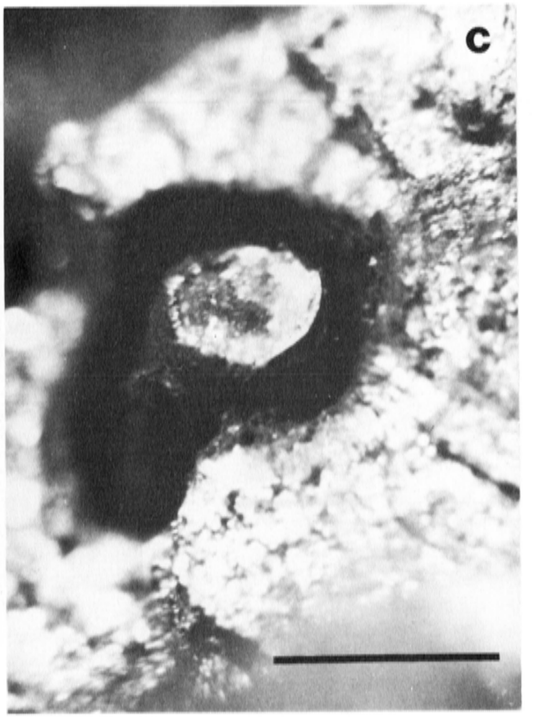
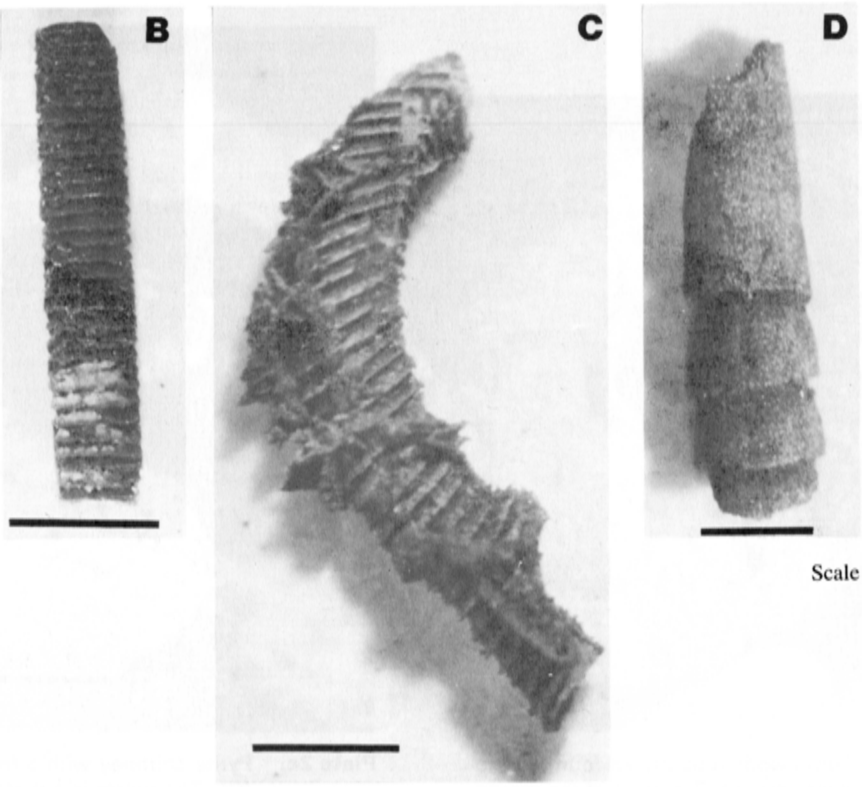


Plate 2c. Pyrite chimney with a fossil worm in situ. The worm is not attached to the sides of chimney.

Scale bar = 1mm.

Plate 3a. Fossil worm enclosed in a pyrite chimney. External structure of the worm is delineated by a fine coating of pyrite (white). The internal structure of the worm has been completely replaced by barite (grey).



Scale bar = 1mm.

Plate 3b. Fossil worm showing close spaced annuli, 0.1mm apart.
Plate 3c. Curved example of 3b.
Plate 3d. Fossil worm with more pronounced annuli, 0.3mm apart.

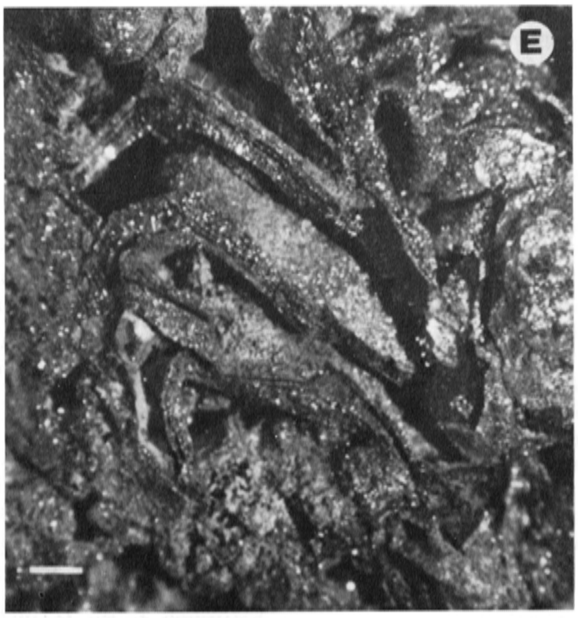


Plate 3e. Part of a larger segmented animal (possibly a cephalopod) found within massive pyrite.

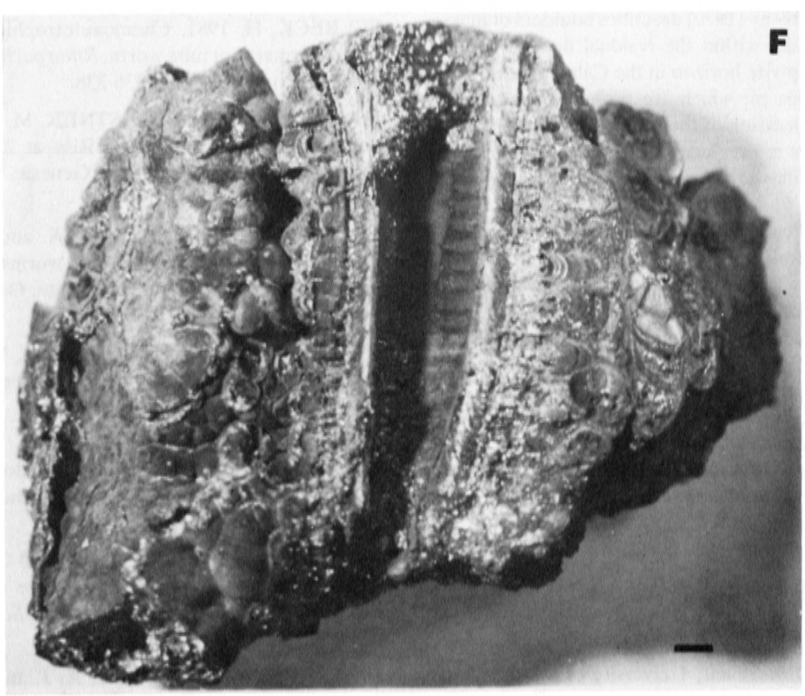


Plate 3f. Longitudinal section through a worm tube mould found in the same massive pyrite as Plate 3e. The impression left by the segments of the worm can be clearly seen on the inner walls.

coating of fine-grained pyrite enclosing barite, which has completely replaced the internal structure of the organism (Plate 3a). Two different types of worm have been found, one has close-spaced annuli 0.1mm apart (Plates 3b and 3c), whereas the other has more pronounced annuli 0.3mm apart (Plate 3d). Maximum dimensions of the recovered fossils are length 10mm and diameter 0.8mm. Specimens are generally straight, but some curved examples have been found (Plate 3c). Two additional species were found in massive pyrite which probably formed contemporaneously with the pyrite chimneys. The first is the remains of a larger segmented animal, possibly a cephalopod (Plate 3e), while the other is a worm burrow or more likely a worm tube mould. The latter is similar to the type 1 structures but is significantly larger, with a diameter of 7mm and walls approximately 0.5mm thick. Smaller worm tube moulds are also found, and show the impression left by the worm on the inner wall (Plate 3f). Particular hydrothermal vents were apparently colonized by worms during periods of exhalative quiescence; subsequent closure of the vents entombed the worms and resulted in their well-preserved state.

Discussion

At Tynagh, Lower Carboniferous rifting and a high geothermal gradient initiated hydrothermal convection cells within the underlying Lower Palaeozoic sediments (Russell et al., 1981). The resulting acid, metal-bearing solutions migrated up the Tynagh Fault (Boast et al., 1981) and precipitated sulphide minerals mainly as replacements and fracture fillings in Waulsortian carbonate mudbanks (Derry et al., 1965).

It is envisaged that the pyrite mounds and chimneys formed on a fault scarp when hot, buoyant, iron-bearing solutions leaked slowly through small fissures onto the seafloor. The major proportion of the fluid escaped through larger fissures or via the fault plane and formed a massive pyrite horizon. Morrissey (1970) describes boulders of massive primary sulphides within the residual deposit and a massive 1.5m thick pyrite horizon in the Calp at the northern edge of the open pit which are probably analagous. However the exact location of the examples described and of further examples is precluded by the flooding of the Tynagh open pit with the the cessation of mining operations.

The fossil worms found at Tynagh are the oldest and best preserved examples of the fauna which existed at ancient seafloor hot springs. It is not possible, at present, to determine if these worms are ancestral forms of the modern hot spring worms or if readaption has taken place. It is significant that a fauna previously only recorded from oceanic ridge-crest hot springs has now been found associated with hydrothermal chimneys in a relatively shallow intracontinental basin. The realization that life did exist where hot metal-bearing solutions exhaled at the seafloor may lead to further discoveries of fossils in sedimentary-exhalative orebodies.

Acknowledgements

The author thanks the staff and postgraduates of the Applied Geology Department, University of Strathclyde, especially John Gilleece, Mike Russell, George Bowes and Adrian Boyce. John Clifford, Ennex International PLC, is acknowledged for his help and permission to work on the Tynagh deposit. Strathclyde University is thanked for financial support by the award of a John Anderson Postgraduate Studentship.

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Discussion

DAVID BURDON (Minerex Ltd.) asked:

How long would it take for the fossil worm community to live and build up the deposits described in this paper? If the fossils lived for a long period, this would mean that temperatures around their habitat remained constant for the same long time. Sharp rises or falls in temperature would surely cause their extinction, since they do not seem to have been very mobile. Such constant temperature in their locality would indicate that the hot springs were stable in temperature, pressure, funnels of exit from the rock and related phenomena. If the springs were constantly changing, the stable zone in which the worms lived could not have existed. The form of such organic deposits gives information on the regime of the springs.

REPLY:

The chimneys described in this paper were not constructed by the worm community, but are products of the exhaling hydrothermal fluid. The time required for construction would only be a matter of hours, or one or two days. Worm tube moulds, which are also present, would similarly only require a short time for construction. It is not possible to assess the length of time the worms lived around the vents, so the only thing we can say about the regime of the springs is that initially the temperature was fairly hot, that it cooled to about 25°C (when they were colonized), and at some later time became reactivated.