

Detailed sulphur isotope studies of Lower Palaeozoic-hosted pyrite below the giant Navan Zn + Pb mine, Ireland: evidence of mass transport of crustal S to a sediment-hosted deposit

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Introduction

Anderson's (1990) detailed petrographic and sulphur isotopic study showed that, although most of the sulphide ore at Navan was precipitated via the combination of hydrothermal metals and local bacteriogenic sulphide, a small but significant component of the ore was deposited using a hydrothermal sulphide source: that is, sulphide entrained in the hydrothermal solutions along with the metals. The two sulphide components have distinctly different $\delta^{34}\text{S}$: the 'bacteriogenic' ores having $\delta^{34}\text{S}$ around -15‰ , and the 'hydrothermal sulphides' having a calculated maximum $\delta^{34}\text{S}_{\text{H}_2\text{S}} + 15\text{‰}$ (Anderson, 1990). This dual source sulphide is also seen in the two other major base-metal ore producers in Ireland (Silvermines and Tynagh; Anderson *et al.*, 1989).

The ^{34}S -enriched nature of the hydrothermal component demands that the source of S be similarly enriched. The currently dominant genetic model envisages the metals and some sulphur being derived from the thick sequence of Silurian and Ordovician turbiditic mudstones, siltstones, sandstones and volcanics which underlie the deposit (on the southern flank of the Longford-Down Inlier). The solutions are transported to the depositional site by large scale (≥ 30 km diameter) convecting hydrothermal systems (Russell, 1978; Mills *et al.*, 1987). The hydrothermal sulphur is suggested to be leached from diagenetic pyrite in the Lower Palaeozoic rocks. However, theoretical considerations of the isotopic content of these lithologies suggests that this source should have a low mean $\delta^{34}\text{S}$ (nearer -10‰ , rather than the $+15\text{‰}$ seen in the hydrothermal component).

Nonetheless, conventional, systematic sulphur

isotope study demonstrates that pyrite-S, remobilised from the Lower Palaeozoic sediments below the Navan Zn + Pb deposit, could have been the source of hydrothermal sulphide in the overlying ores (Boyce *et al.*, 1993). Furthermore, petrographic studies have shown that the 'Lower Palaeozoic' pyrite has a complex origin, involving at least four phases of growth. Therefore, although the main conclusion of the study is relatively simple, the great variation in $\delta^{34}\text{S}$ within the Lower Palaeozoic pyrite (-62.5 to $+61.79\text{‰}$, Fig. 1), together with the details revealed by laser microsampling, allow us to assess the relative contribution of each pyrite phase to the hydrothermal sulphide reservoir.

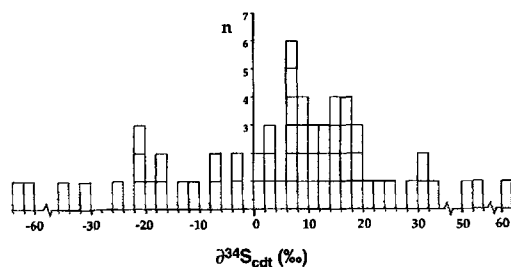


FIG. 1. Histogram of Lower Palaeozoic-hosted pyrite conventional $\delta^{34}\text{S}$ (note jumps in x-axis).

Geology

The Navan Zn + Pb deposit occurs in the central Irish Carboniferous basin, on the southern flank of the Longford Down inlier. It is a world-class base-metal orebody (~ 69.9 Mt at 10.1% Zn and

2.6% Pb), with the ores occurring in complex stratiform to stratabound tabular lenses. It is hosted in Lower Carboniferous shallow-water carbonate lithologies, during the diagenesis of which the base-metal sulphides were precipitated (Ashton *et al.*, 1992).

The Lower Palaeozoic lithologies studied come from drillcore close to the Navan deposit, and are dominated by Ordovician and Silurian turbiditic mudstones, siltstones and sandstones, with subordinate volcanic lithologies. A weak slaty cleavage is commonly present and shearing and veining are locally intense.

Pyrite is almost exclusively the only sulphide found in all cores. The main core studied (N1014) is strikingly rich in pyrite (several % over > 1 m). Petrography reveals a complex range of textures, which range from early framboids ($\leq 10\mu\text{m}$) to later massive nodular concentrations ($\leq 5\text{ cm}$, Fig. 2). We have observed a general coarsening of pyrite through the paragenetic sequence. The relationship of these occurrences to the host-rock suggests that they were formed during diagenesis. Subsequently, during a phase of brittle deformation, the earlier lenses and nodules are fractured, and fine replacive pyrite networks overprinted.

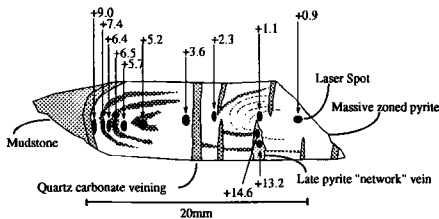


FIG. 2. Patterns of $\delta^{34}\text{S}$ in concentrically zoned pyrite nodule: Hole N1014, Navan.

Results

Standard techniques were employed for conventional $\delta^{34}\text{S}$ analyses (Anderson, 1989): procedures for laser microsampled $\delta^{34}\text{S}$ followed those given in Fallick *et al.* (1992).

The range of $\delta^{34}\text{S}$ for all conventional analyses is between -62.5 and $+61.7$, with a mean of $+5.3 \pm 22.5\%$ (1σ ; $n = 61$), a mode around 6 to 8‰ and > 70‰ of the data > 0‰ (see Figure 2). The maximum scale of variation with in a microsampled section is 36.8‰, in contrast to the 124.2‰ variation seen in the conventional results.

Figure 2 illustrates the trend that is noted throughout the drillcore: in any given sample, later textures give higher $\delta^{34}\text{S}$. However, we note that between samples, similar textures can give substantially different $\delta^{34}\text{S}$. Therefore, it is not possible to judge on the basis of texture alone which generation of pyrite gives the greatest contribution of S to the hydrothermal fluid.

Conclusions

Laser microsampling in conjunction with petrographic analysis of pyrite from the Lower Palaeozoic rocks below the Navan mine reveal a complex history of early and late diagenetic growth, and subsequent pyrite deposition during brittle fracturing. Despite this complexity at the microscale, conventional S isotope analyses indicate that hydrothermal sulphide in the overlying deposit could have been sourced through remobilisation of the Lower Palaeozoic-hosted pyrite.

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