

\*\*\*\*\* **NERC CASE PhD Studentship** \*\*\*\*\*

## **The environmental mineralogy of rapid iron sulfide oxidation in massive sulphides**

**Dr. Adrian Boyce SUERC; Dr. Ian Butler, Edinburgh; Dr. John Ashton, Boliden Tara Mines Ltd**

Many of the world's important sources of Zn, Cu, Pb, Au, Ag metals are orebodies that are characterized by massive pyritic sulphides (in some cases the iron sulphide component is not massive, but only rarely is it insignificant). These orebodies are often broadly categorized as volcanogenic (VHMS) or sedimentary (SEDEX) in origin but with considerable debate, in many cases as to the extent of involvement of relatively late, epigenetic major fluid flow (Anderson et al, 1998; Peace et al., 2003). The sulphur isotopic component of the iron sulphides in such deposits has proved to be a major investigative tool for determination of sulphur origin and at Navan has shown a strong linkage between bacteriogenic sulphate reduction and ore-forming sulphides (Fallick et al., 2001; Blakeman et al., 2002).

Some base metal deposits, including Navan, are characterized by iron sulphides that are prone to extremely rapid heating when exposed to air. Elsewhere sedimentary pyrite (for example associated with coal-bearing mudstones) is also prone to rapid oxidation. Worldwide, oxidizing iron sulphides have given rise to several problems for the mining industry:

- \* Underground heating and dust explosions, causing SO<sub>2</sub> generation, have resulted in fatalities, loss of equipment and production delays.
- \* Mineral beneficiation problems resulting in reduced recoveries and increased impurities in metal concentrates produced.
- \* Environmental problems where tailings containing acid-generating iron sulphides are stored in dams.

The current view is that chemically reactive iron sulphides reflect conducive iron sulphide mineralogy (e.g. pyrrhotite, excess sulphur) and/or a fine grain size producing a high surface area for oxidation (Rimstidt and Vaughan, 2003). While there is an enormous body of research into the precipitation of iron sulphides, framboid formation and pyritization in shallow sediments and the S isotopic systematics of these systems, there is little connection between these and the causative reasons behind rapid pyrite oxidation, particularly from the perspective of which phases are the most reactive. Consequently it may be questioned:

- \* To what extent is iron sulphide, formed in bacterial/biological systems pre-disposed to rapid oxidation when exposed to the atmosphere?
- \* To what extent does grain size and the intricate morphology (high surface area?) of framboidal sulphides influence rapid oxidation?
- \* Is rapid oxidation catalysed by either impurities in the pyrite or associated minerals?
- \* What is the role of microbiological processes in pyrite oxidation at Navan?
- \* How important are ambient environmental factors? (moisture, temperature etc).

Previous NERC Case Research work at the Navan orebody (Ford, 1999) demonstrates a clear link between reactive fine-grained iron sulphides and a depositional environment in which strongly bacteriogenically fractionated sulphide precipitated sulphides in framboidal and carbonaceous sulphide-sediments. The extensive iron sulphides at Navan, which give rise to heating and metallurgical problems, are exceptionally well preserved and form an excellent source of material to investigate relationships between iron sulphide genesis, physico-chemical properties and rapid oxidation properties.

### **Components of the proposed research are:**

- \* Review oxidation-prone iron-sulphide occurrence worldwide; particularly the extent and nature of the relationships between iron sulphides, their chemical and textural composition their isotopic signature and whether they formed in biologically active settings.
- \* Use the exceptionally well preserved iron sulphides in the Navan orebody and the immediately surrounding sediments to understand, in detail, the reasons behind the high sulphide reactivity (depositional environment, biological input, depositional rate, why the fine grain size, precise Fe:S composition, catalyst material, Fe isotopes ? etc).
- \* Better understanding of iron sulphide deposition in massive sulphide ores will allow their timing and genesis to be better understood.
- \* Better understanding of iron sulphide variants could be used in exploration to identify potential targets and favourable horizons.
- \* Application of simple laboratory scale experimental investigations to determine pyrite oxidation rates for different sulfide and/or textural assemblages and interpretation of those rate data in terms of reactive surface area, initial composition and related factors.
- \* The student will benefit from research training in both academic and industrial environments. They will be trained in field methods, optical and SEM microscopy methods, geochemical analysis, including stable isotope techniques and will gain experience of the design and implementation of experimental investigations. Training in the application of standard geochemical codes such as Geochemist's workbench and MINEQL+ will be provided.

### **Benefits:**

The Student will benefit from world-class research facilities at SUERC and the University of Edinburgh (where s/he will be based) and enjoy fully-supported, extensive fieldwork at Boliden Tara Mines Ltd, County Meath, Ireland. Tara Mines is Europe's largest Zn

producer and a world-class, giant ore deposit. The Student will thus have the opportunity to become highly employable from a number of perspectives.

The Industrial sponsor will benefit by gaining insight into the detailed reasons behind rapid oxidation and associated environmental and metallurgical problems.

The Academic hosts will benefit by opening up a potentially new research subject with strong economic and environmental relevance. In terms of SUERC the recent discovery of possible pyrite framboids on Mars may allow an interface with related interests (NASA).

### **References and Further Reading:**

Anderson, I.K., Ashton, J.H., Boyce, A.J., Fallick, A.E. and Russell, M.J. (1998) Ore depositional processes in the Navan Zn+Pb deposit, Ireland. *ECONOMIC GEOLOGY*, **93**, 535-563.

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Fallick, A.E., Ashton, J.H., Boyce, A.J., Ellam, R.M. and Russell, M.J. (2001) Bacteria were responsible for the magnitude of the world-class hydrothermal base-metal orebody at Navan, Ireland. *ECONOMIC GEOLOGY*, **96**, 883-888.

Gleisner, M., Herbert Jr, R.B. and Frogner Kockum, P.C. (2006) Pyrite oxidation by *Acidithiobacillus ferroxidans* at various concentrations of dissolved oxygen. *CHEMICAL GEOLOGY*, **225**, 16-29.

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Peace, W.M., Wallace, M.W., Holdstock, M.P. and Ashton, J.H. (2003) Ore textures within the U lens of the Navan Zn-Pb deposit, Ireland. *MINERALIUM DEPOSITA*, **38**, 568-584.

Rimstidt, J.D. and Vuaghan, D.J. (2003) Pyrite oxidation: A state-of-the-art assessment of the reaction mechanism. *GEOCHIMICA ET COSMOCHIMICA ACTA*, **67**, 873-880.

### **Contact and How to Apply:**

**To discuss the project further, please contact Dr. Adrian Boyce – [a.boyce@suerc.gla.ac.uk](mailto:a.boyce@suerc.gla.ac.uk): Tel – 01355-270-143.**

**To apply, please contact Mrs Margaret Kerr, SUERC, Rankine Avenue, Scottish Enterprise Technology Park, East Kilbride, G75 0QF, or via email – [m.kerr@suerc.gla.ac.uk](mailto:m.kerr@suerc.gla.ac.uk): Tel – 01355-270-102.**