Structural geology of the Lisheen carbonate-hosted Zn-Pb deposit, Ireland - constraints on ore genesis

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The role of extensional structures in influencing sedimentation and controlling mineralisation at the Lisheen Zn-Pb deposit was first examined from exploration data (Shearley *et al*., 1996). In the last seven years, an expanded database of *ca.* 1200 surface diamond drill-holes, permitting more accurate definition of major faults, has been supplemented by extensive underground workings, since 1999. These data permit more accurate definition of the geometry of geological structures from outcrop- to deposit-scale, and provide improved constraints on their relationship with mineralisation.

Extension-related structures

The most important tectonic feature within the area of the mine is an *en-échelon* array of three E-W to WNW-ESE trending, north dipping, normal faults with maximum displacements of *ca.* 220 m. These are, from the SW: the Killoran, the Derryville and the Bog Faults. Sympathetic displacement changes on these faults suggest that they all belong to a kinematically coherent ENE-WSW trending fault array, which we term here the Rathdowney Fault System. The overlapping areas between any two of these faults constitute left-stepping relay zones, generally with intact relay ramps except for a few NE-SW trending, NW dipping transverse faults. Approximately E-W trending, north dipping normal faults belonging to the Barnalisheen Fault System at the north-western edge of the deposit have a cumulative displacement of *ca.* 80 m. Significant fault segmentation occurs along the Killoran and the Derryville Faults, as evidenced by the presence of fault lenses and relay zones. In 3-D, these relays define narrow and vertically persistent zones of highly fractured rocks.

The activity of the major faults is recorded by rapid sedimentation changes in their immediate hanging-wall: (i) development of slightly argillaceous crinoidal facies, halfway through the deposition of the Waulsortian Limestone Complex in the late Courceyan, followed in the late Courceyan to early Chadian by the deposition of cherty argillaceous limestones, assigned to the Crosspatrick Fm. (Shearley *et al*., 1996); (ii) local development of polymictic breccias, from the lower half of the Waulsortian Limestone Complex through to the lower Crosspatrick Fm. These breccias are broadly similar to those described in the Silvermines deposit, where they have been interpreted as debris-flow breccias (Lee & Wilkinson, 2002).

Contraction-related structures

Thrusts are common in the southeastern edge of the deposit, where they buttress against the major bounding faults, causing localised repetition of the orebodies. Typical inversion structures such as footwall shortcuts and backthrusts indicate that the location and orientation of thrusts is largely influenced by the pre-existing normal faults. Their geometry is consistent with NNW-SSE directed shortening.

Strike-slip faults define long (up to several hundreds of m) and wide (up to about 20 m) fault clusters. They are either oriented NW-SE to NNW-SSW or NNE-SSW to NE-SW. Their movement is also consistent with N-S to NNW-SSE directed contraction.

Folds are widespread throughout the deposit. They are often associated either with thrusts, as parasitic folds or fault propagation folds, or with strike-slip faults, possibly as transpressive, positive flower-structures. Elsewhere in the deposit, the dispersion of fold axes and characteristic “whale-back” geometries suggest that many of the folds are interference structures resulting from the buckling of earlier normal faults.

Thrusts, folds and strike-slip faults at Lisheen are consistent with NNW-SSW to N-S directed contraction and are principally attributed to Variscan deformation (due to the lack of appropriate stratigraphic record, a Tertiary age cannot, however, be ruled out). Both strike-slip and thrust planes are observed to cut and offset the sulphide lenses, indicating that the Waulsortian-hosted mineralisation is pre-contraction.

Structural controls on mineralisation

The bulk of the mineralisation occurs in up to three superposed stratabound sulphide lenses in the lower 40 m of the Waulsortian Limestone Complex. Where bedding is visible, the lenses are often seen to cut it sharply, suggesting that mineralisation formed predominantly by replacement of an already compacted host rock. Sub-Waulsortian mineralisation is (i) disseminated, stockwork-style and very locally massive at the top of the ABL, where it connects with basal Waulsortian lenses; (ii) massive, lens-like in the upper part of an intra-ABL oolitic member (Lisduff Oolite); (iii) discordant and vein-hosted throughout the ABL sequence.

Significant thickening of the basal sulphide lens is often observed in the hanging wall of minor (down to a few cm of displacement) to medium-scale (up to 30 m of displacement) normal faults throughout the deposit; particularly thick ore bodies (up to 30 m) occur within or close to highly fractured relay zones within the Killoran and Derryville Faults. Detailed mapping shows that (i) fracture density is very high in the immediate hanging-wall of faults and (ii) thin shale smears often develop along fault and fracture contacts. These shale smears appear to have acted as permeability barriers by compartmentalising mineralisation - and creating effective “hanging-wall traps”. No unequivocal evidence of mineralisation offset by normal faulting has been observed, suggesting that the bulk of the Waulsortian-hosted mineralisation is post-normal faulting.

Minor, apparently fault-related, mineralisation has been intersected at various elevations in the ABL along the Rathdowney Fault System, but particularly within relay zones along the Killoran and Derryville Faults. These zones of highly fractured rocks are believed to have provided the main upward conduits for the metal-carrying fluids.

References

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