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A reappraisal of the age, origin and structural setting of sulphide mineralisation in the UK North Pennines Orefield

Bob Holdsworth, Eddie Dempsey, David Selby, Chris Le Cornu, and Brian Young
Durham University, Dept of Earth Sciences, Durham, United Kingdom (r.e.holdsworth@durham.ac.uk)

The North Pennines Orefield (NPO) is centred on the Alston block, a structural high of fractured Carboniferous sedimentary rocks that unconformably overlie a Devonian age (ca. 399 Ma) granite pluton buried at shallow depths (<0.5 km). The orefield has long been considered to be a classic example of a Mississippi Valley Type (MVT) deposit where the source of the metals and sulphur are derived by hydrothermal leaching of the host sedimentary (carbonate-rich) rocks. The vein-hosted part of the orefield consists of linked systems of shear and tensile fractures with a variety of regionally recognised orientations (ESE-WNW Quarter Point, NE-SW, NW-SE Cross Veins). These are associated with lead (galena), iron (pyrite, pyrrhotite, marcasite), copper (chalcopyrite), zinc (sphalerite), fluorite, barite and quartz mineralization.

New Rhenium-Osmium (Re-Os) isotope geochemical analysis of the vein-hosted pyrite mineralization suggests that: (i) the metalliferous ores of the NPO formed ca. 294Ma (earliest Permian); and (ii) that they carry an initial Os ratio indicative of a mantle source similar to that indicated by the initial Os ratio of the Whin Sill dolerite suite (emplacement ages ca. 297-294 Ma).

New field observations and stress inversion analyses show that at least two regional deformation events are recognised in the Carboniferous host rocks of the NPO. A initial phase of Late Carboniferous ('Variscan') N-S compression pre-dates mineralisation and leads to formation of the NW-SE fractures, initiation of the Burtreeford Disturbance as a N-S fault and compressional reactivation of the previously extensional E-W Lunedale Fault. A later phase of dextral transtension (NNE-SSW extension, ESE-WNW compression) leads to the formation of the ESE-WNW and NE-SW veins, together with compressional reactivation of the Burtreeford Disturbance and Lunedale Fault. Field and microstructural analyses show that the transtensional deformation is synchronous with the main phases of NPO mineralisation and also with emplacement of the Whin Sill and associated intrusions.

We conclude that: (i) the main phase of NPO mineralization occurred synchronously with regional dextral transtension during the earliest Permian; (ii) that mineralization is genetically linked to a mantle source and (iii) that the genesis of the NPO is closely linked to that of the broadly penecontemporaneous Whin Sill and associated intrusions in northern England.

Our new findings are consistent with structural histories recognised in adjacent regions (e.g. Dent-Pennine Fault systems; Northumberland Basin) and point to a major regional phase of mantle-sourced mineralization, igneous intrusion and transtensional deformation in the early Permian. Previous models suggesting that the NPO is a classic example of a MVT mineral deposit or that the mineralizing fluids are related to the influx of Mesozoic brines are largely incorrect.