

# **Metals, hydrocarbons and multicellular life: unconventional hydrocarbon-related precious metal ores formed during the early Cambrian evolutionary explosion**

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The major aim of the project was to understand the mechanisms by which transition metals become concentrated into organic-rich sediments, with a specific emphasis on one highly unusual but very extensive of nickel and platinum rich black shales in the Yangtze Platform in southern China. The project expanded to take in a similar occurrence in Canada, and also a comparative study with metal poor but otherwise similar sediments in northern Australia. The latter part of the study provided some intriguing new insights into the connection between oxygen and sulfur fluctuations in the biosphere and sudden extinction events taking place early in the history of metazoan life.

Dr Pages has investigated black shales of Cambrian age in South China. These shales host a thin accumulation (5 – 20 cm) of highly abundant Ni, Mo, Au, Ag, Se, Cr, V, Zn, U, PGEs and REE that can be traced along the same stratigraphic horizon for up to 2000 km. This is one of the most enigmatic examples of ore-grade polymetallic concentrations in organic-rich sediments and its origin remains highly controversial. Synchrotron XFM analyses on the mineralised layer revealed incredibly complex structures resulting from rapid and intense variations of redox conditions that can only be explained by the activity of microorganisms. The study shows for the first time an unusual association of precious platinum group elements with phosphorite nodules, and furthermore that these may have derived from precipitation of apatite within giant sulfur bacteria, previously unreported in Cambrian sections worldwide. This work has been presented at the SEG, XRF, Goldschmidt, AOGC and Geofluid Conferences, the Ni-Cu-PGE symposium and the Australasian Astrobiology meeting. It is currently being written up for a series of high-impact publications.

Dr Pages also investigated sediments of similar age from the Georgina Basin in central Australia, for comparison purpose. Biomarker (fossil organic molecules) and isotopic studies revealed that euxinic shales are present in the Cambrian sections and contain enhanced concentrations of metals sensitive to changing oxidation state. These intervals correlate with significant extinction events, relating to interruptions in the rise of atmospheric oxygen in the Cambrian period that is generally associated with the evolution of metazoans. This study, recently accepted for publication in two prestigious international journals, *Palaeo3* and *Earth and Planetary Science Letters*, also showed the potential use of stable isotope anomalies for refining global stratigraphic correlations across Australian basins and across continents.

Jurassic black shales hosting numerous carbonate concretions, renowned for their remarkable preservation of organic matter, were also examined for further comparison. The study of metal distribution, isotopic and biomarker composition revealed strong interactions between metals and organic matter within concretions formed in black shales and was published in *Chemical Geology* with Dr Pages as co-author.

In summary, the project has made significant scientific advances in the understanding of metal accumulation in organic-rich sediments and has established a highly promising new career for Dr Pages at CSIRO.