THE PALEOPROTEROZOIC MCARTHUR RIVER (HYC) ZN/PB DEPOSIT AND CONTROVERSIAL HYPOTHESES OF ITS ORIGIN

G. Vinnichenko[1], J.M. Hope[1], A. Jarrett[2], J.J. Brocks[1]

[1]The Australian National University, Australia; [2]Geoscience Australia, Australia

The goal of this study is to distinguish between alternative genesis models of the well-preserved, stratiform, sediment-hosted HYC base-metal deposit in the McArthur Basin, Northern Australia. Reliable information about the temperature of ore-forming fluids during ore precipitation is crucial to distinguish between alternative HYC genesis models, as moderate temperatures (100-150˚C) would point to syngenetic models while higher temperatures (150-250˚C) are more consistent with epigenetic models. We here try to answer this decade-old question by using lipid biomarkers in combination with Rock-Eval pyrolysis and stable isotope ratios of hydrogen (δD).

Results from GC-MS analyses on the lipid hydrocarbons extracted from 11 mine samples, illustrate that the maturity level of all samples is too high for preservation of polycyclic biomarkers as hopanes or steranes. Vitrinite reflectance equivalent (Rc) values based on the methyl-phenanthrene index (MPI-1) fall into the range 1.2-1.3% for the entire sediment package from the hanging wall, through the ore body and into the footwall (Figure 1). These values contradict previous Tmax and bitumen reflectance values of Logan et al. (2001) that suggested elevated maturities in the ore layers (Figure 1). There are two potential explanations for this discrepancy: (1) published Rock-Eval maturity data are artificially elevated, e.g. by the excessive sulphide content; (2) ore formation indeed was accompanied by a thermal anomaly and all indigenous hydrocarbons were destroyed – the detected hydrocarbons may then have migrated from the surrounding Barney Creek Formation (BCF) into the orebody. To distinguish these hypotheses, we obtained Rock Eval data on isolated kerogen. Newly acquired Tmax data indicate that organic matter (OM) is indeed severely altered, either by high temperature or oxidation, and the observed biomarkers in the ore body most probably represent migrated oil.

In support of the epigenetic model, a study by Chen et al. (2003) found distributions of polycyclic aromatic hydrocarbons (PAHs) in the HYC ore zone similar to those seen in hydrothermal petroleum from the Guaymas Basin, Mexico, proposing high formation temperatures (250-400˚C). A follow-up study by Williford et al. (2011) suggests that a significant component of PAHs likely originated in black shales of the underlying Wollogorang Fm at a depth of 6 km at temperatures of 250˚C and migrated into the HYC deposit. If this was the case, MPI indices should reflect high maturity values consistent with such temperatures. However, this is contradicted by the lower maturity of the hydrocarbons found in this study. In addition, we detected similar distributions of PAHs in the ore zone and in the hanging wall up to 180 meters above the ore, suggesting that PAHs may have been formed at low temperatures.

Williford et al. (2011) demonstrated that HYC *n*-alkanes are enriched in deuterium (D) relative to *n*-alkanes in unmineralized BCF sediments distal from the mine. The authors interpreted this as a result of equilibrium hydrogen exchange during ore genesis with a highly D-enriched fluid, presumably coming from evaporites of the underlying Tawallah Group. Our measurements confirm that *n*-alkanes from the ore sequence are enriched in δD, but we observed the same isotopic composition in the hanging wall above the ore. This observation supports the idea that hydrocarbons in the ore zone are migrated from surrounding unmineralized sediments and the hydrogen isotopic composition is therefore not connected to the presence of hydrothermal fluids.

To summarize, our data are most consistent with OM alteration in the ore body either by pyrolytic temperatures and/or thermochemical sulphate reduction. The observed biomarkers in the ore likely represent migrated bitumen from the surrounding sediments and do not reveal the temperature of ore deposition. PAHs found in the HYC are also detected in similar distributions in the overlying hanging wall and are thus presumably not the products of hydrothermal activity but of unknown low-temperature processes – but they may have become enriched in the ore by destruction of other hydrocarbons. As the bitumen in the HYC is likely migrated, the hydrogen isotopic composition of *n*-alkanes in the ore deposit does not reflect the metal-bearing fluids rising from the Tawallah Group.

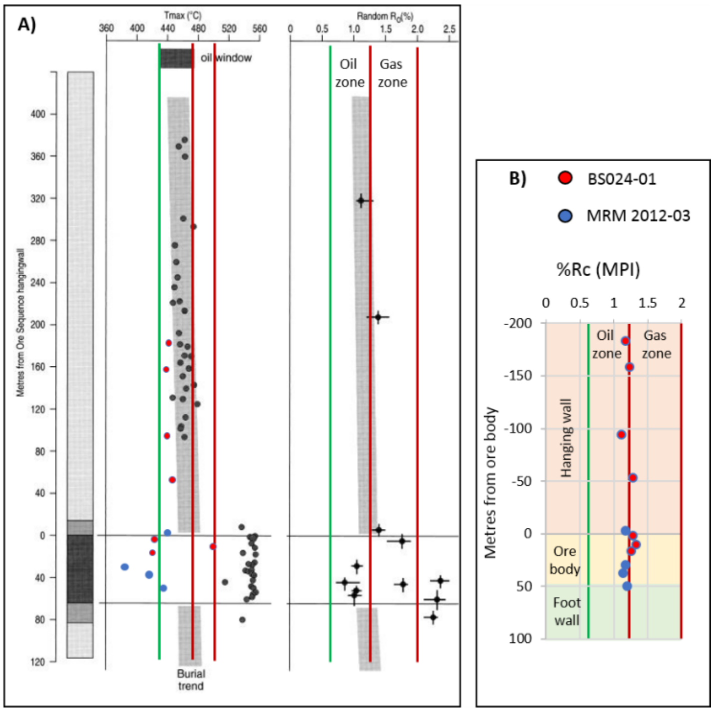

Figure 1 *A) Rock-Eval and random Ro data from drill hole and mine samples around the HYC deposits, plotted relative to the ore body (modified after Logan et al., 2001); and Tmax data on isolated kerogen from this study (red and blue circles). B) Calculated vitrinite reflectance (Rc%, from the MPI) from two HYC drill cores.*

References

Chen, J., M. R. Walter, G. A. Logan, M. C. Hinman and R. E. Summons (2003). "The Paleoproterozoic McArthur River (HYC) Pb/Zn/Ag deposit of northern Australia: organic geochemistry and ore genesis." Earth Planet. Sci. Lett. 210(3-4): 467-479.

Logan, G. A., M. C. Hinman, M. R. Walter and R. E. Summons (2001). "Biogeochemistry of the 1640 Ma McArthur River (HYC) lead-zinc ore and host sediments, Northern Territory, Australia." Geochimica et Cosmochimica Acta 65(14): 2317-2336.

Williford, K. H., K. Grice, G. A. Logan, J. Chen and D. Huston (2011). "The molecular and isotopic effects of hydrothermal alteration of organic matter in the Paleoproterozoic McArthur River Pb/Zn/Ag ore deposit." Earth Planet. Sci. Lett. 301(1-2): 382-392.