ISOTOPIC CONSTRAINTS ON LARGE-SCALE SEDEX OR MVT MINERALISATION WITHIN THE CAMBRIAN CARBONATE COVER SEQUENCES, NORTHWEST QLD

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INTRODUCTION

The anomalously high Pb, Zn and Cu abundances recorded at the Cambrian – Proterozoic unconformity north -west of Mt Isa, Queensland are regarded by the exploration industry as either: an expression of a large-scale sedex deposit (Century-style) hosted within the underlying Proterozoic units; or smaller-scale Mississippi Valley Type (MVT) deposits from a Cambrian mineralising event. The development of a highly weathered terrain during the prolonged quiescence prior to Cambrian carbonate deposition, and the scavenging of metals by the iron oxy-hydroxides during this process, has resulted in geochemical dispersion signatures in duricrusts developed over Proterozoic terrains that reflect mineralisation within the underlying rocks. Preliminary assessment of the ferruginous sediments in the Mt Isa region in general indicate that a detailed understanding of the regolith processes and development of, in particular, a cherty breccia unit at the base of the Cambrian sequence (Georgina Basin) may yield potential exploration strategies (Anand *et al*. 1997). Before developing any exploration strategy, however, the detailed characterisation of this chert breccia unit is necessary and, in particular, the assessment of the possible sources of any mineralising fluids that may have contributed to the metal concentrations observed during routine soil and rock chip sampling. The preliminary results presented below represent the first step in assessing the depositional framework for the Georgina Basin.

A summary stratigraphic framework for the eastern Georgina Basin is presented below (Table 1). The carbonate sequences were deposited within a shallow marine environment during the Early to Middle Cambrian (Southgate & Shergold 1991). Extensive and ongoing industry-sponsored exploration has focused on two areas within the Georgina Basin: along the north-eastern margin where shallow carbonate deposition overlies targeted Century-age Proterozoic sandstones – sedimentary exhalative mineralisation (Denaro & Culpeper 1999); or in the vicinity of the Morstone Lead Belt ca. 50 km into the basin proper – MVT mineralisation (Culpeper & Denaro 1999). In general, the Cambrian Thorntonia Limestone is viewed as being most prospective. Drill cores from these two areas have been studied to determine the regional signature of mineralising events. This study therefore represents a basin-wide approach to ore-deposition rather than working out from an economic deposit and extrapolating regionally.

Table 1: Simplified Georgina Basin (eastern margin) stratigraphy and depositional environment, oldest units first, all units are Early to Middle Cambrian in age (after Southgate & Shergold 1991).

Stratigraphic Unit	Description	Environment
Mt Hendry Formation	Conglomerate, sandstone	Coastal plain clastics and carbonates
Thorntonia Limestone	Limestone, chert, dolomite / sandstone, conglomerate	Platform carbonates
Beetle Creek Formation	Siliceous shale, chert, sandstone, phosphorite	Peritidal phosphorites and phosphatic limestones
Inca Formation	Laminated siliceous shale, chert, sandstone, bituminous shale	Shelf phosphorites and phosphatic limestones
Currant Bush Limestone	Limestone	Ramp carbonates
Age Creek Dolomite	Packstone, grainstone, dolostone	Platform edge grainstones
Camooweal Dolomite	Grainstone, dolomite	Platform carbonates

SULPHUR ISOTOPIC RATIO FOR SYN-DIAGENETIC PYRITE

A detailed investigation of the isotopic variation of sulphur throughout the Cambrian stratigraphy was undertaken to quantify the role of syn-diagenetic sulphide formation at a regional scale. Samples from two drill cores representing the two exploration targets, i.e. adjacent to the basin margin, and ca. 50 km into the basin proper were analysed. The Age Creek Dolomite – Currant Bush Limestone boundary was easily identified in each core facilitating comparison of results between cores. Polished, resin-mounted samples of pyrite that occurred either enclosed within chert or along bedding planes were analysed using secondary ion mass spectrometry (SIMS). Multiple spots (250 μm diameter) were obtained for each sample and averaged with frequent calibration with a control sample, allowing the presentation of the sulphur isotope ratio of the

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sample to be expressed relative to Canyon Diablo Troilite (CDT) in per mil, i.e. ($^{34}S/^{32}S$ sample – $^{34}S/^{32}S$ standard) / $^{34}S/^{32}S$ standard x 10^3. The results obtained for core NF004 (Morstone Lead Belt) indicate a cyclic shift towards isotopically-heavier pyrite within each stratigraphic unit (Figure 1). Since pyrite preferentially incorporates ^{32}S into its structure, this up-core shift towards the isotopically-heavier ^{34}S suggests biogenic fractionation of pyrite within a closed sedimentary basin (i.e. no input of sulphur from terrestrial or hydrothermal sources during deposition and subsequent diagenesis). The large variation in $\delta^{34}S$ is atypical of both VHMS mineralisation and a magmatic source (which would constrain the sulphur ratio values to a narrow range near 0‰.) The repeated cycling from extremely bacterially-fractionated sulphur to approaching equilibrium with sea-water sulphate during Cambrian times is interpreted to represent four transgressive events where available space for deposition has limited the sedimentary package (Cotter 2001). This isotope ratio variation therefore supports the stratigraphy previously identified from regional drilling. Fundamentally, there is an absence of isotopic overprinting that would be expected if hydrothermal mineralising fluids had entered the basin.

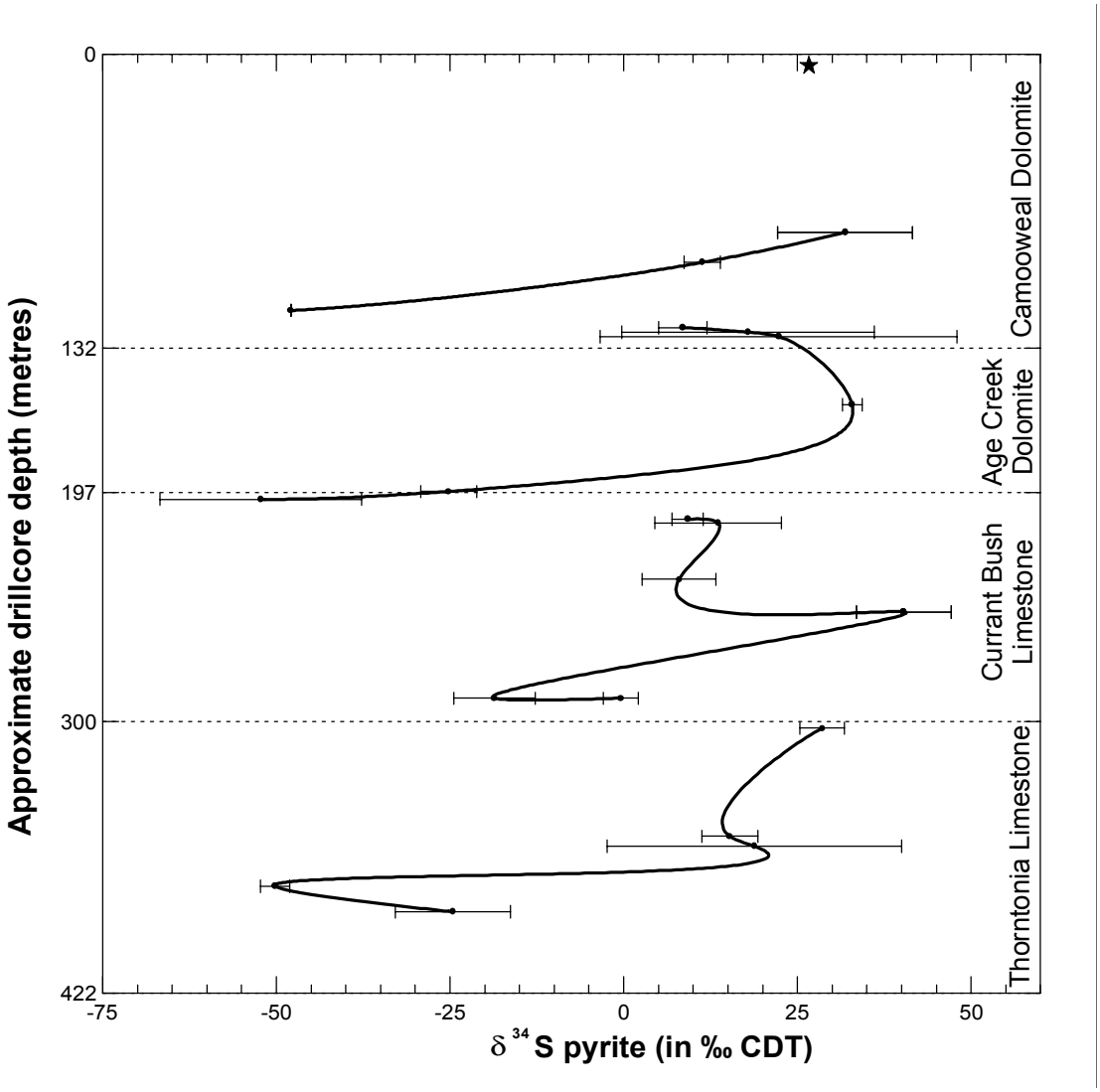

Figure 1. Sulphur isotopic ratio of syn-diagenetic pyrite relative to CDT from drill core NF004, Morstone Lead Belt, Georgina Basin illustrating a repeated cycle of upcore fractionation towards isotopically-heavier pyrite. Starred symbol represents surface galena from Totts Creek.

In contrast to the pyrite, galena (present as void and joint-fillings and enclosed within siliceous crusts) is in equilibrium with sea-water sulphate during Cambrian times (i.e. $\delta^{34}S$ 25-35 ‰; Hoefs 1997). Elevated Pb abundances occur at each of the breaks in the Cambrian sedimentary sequence suggesting that evaporative hyper-saline near-shore environments have contributed to the preservation of small-scale Pb deposits within the Cambrian stratigraphy. Typically, the galena-bearing siliceous facies is overlain by siliclastic sediments, frequently dolomitised, and has a similar depositional association to the siliceous crust-type (SCT) mineralisation described by Brigo *et al*. (2001). This would indicate that Pb has a Cambrian origin rather than reflecting a underlying Proterozoic source.

LEAD ISOTOPES

Results for two galena samples, obtained from the Morstone Lead Belt, assessed relative to published data, indicate that the $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ isotopic ratios preclude any underlying Proterozoic source. The Totts Creek data shows close correlation with the trend shown by other data held by CSIRO on the Georgina Basin and closely approximates the age pair of 1860 Ma – 320 Ma which would correspond to the extraction of lead from Barramundian sediments during the Alice Springs Orogeny (Denton *pers. comm.* 2001). In contrast, ferruginous duricrusts along the eastern margin of the Georgina Basin possess lead isotope signatures that either reflect underlying Proterozoic mineralisation, e.g. near Century (Whitbread 1995) or lead sourced from sediments of similar age to Mt Isa in Cambrian time, e.g. Freytags Gossan near Lady Loretta (Denton *pers. comm.* 2001).

Table 2: Lead isotopic data obtained from the Morstone Lead Belt, Georgina Basin illustrating a Cambrian mineralising event.

Sample Location	Sample description	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Totts Creek galena Morstone	Galena filling voids, silicified	19.497	15.792	39.496
Totts Creek 1 Morstone	Weathered galena in void	19.535	15.798	39.536

SUMMARY

The belief that the Cambrian sedimentary sequence in northwest Queensland either hosts significant mineralisation or overlies large-scale mineralisation can be questioned based on isotopic analyses. The available Pb isotopic evidence indicates that, at least for the north eastern portion of the Georgina Basin (nearest to the Century, HYC and Mt Isa deposits), there is no expression of any Proterozoic deposits within the Cambrian sequence. Furthermore, the substantial and cyclic sulphur isotopic ratio variations can be accounted for by burial diagenesis alone. Minor siliceous crust-type occurrences of galena are indicative of the evaporative hyper-saline near-shore environments and are typically preserved as small-scale void-filling mineralisation near stratigraphic boundaries. This study has illustrated that at the basin-wide scale, isotopic variations can be critical in determining the location of mineral deposits.

REFERENCES

ANAND R.R., FRASER S.J., JONES M.R., SHU L., MUNDAY T.J., PHANG C., ROBERTSON I.D.M., SCOTT K.M., VASCONCELOS P., WILDMAN J.E. & WILFORD J. 1997. *Geochemical exploration in regolith-dominated terrain, north Queensland, CRC LEME – AMIRA P417 Final Report*. CRC LEME **Restricted Report 63R / E&M Report 447R**, 130 pp.

BRIGO L., CAMANA G., RODEGHIERO F. & POTENZA R. 2001. Carbonate-hosted siliceous crust type mineralisation of Carnic Alps (Italy-Austrai). *Ore Geology Reviews* **17**, 199-214.

COTTER S.J. 2001. Sulphur isotopes and burial diagenesis. *AINSE Occasional Papers*. http:www.ansto.gov.au/ainse/occasional_3.htm.

CULPEPER L.G. & DENARO T.J. 1999. Mineral exploration in the Camooweal 1:250,000 Sheet area, north-west Queensland. *Queensland Geological Record* **1999/3**, Department of Mines and Energy, Brisbane.

DENARO T.J. & CULPEPER L.G. 1999. Mineral exploration in the Lawn Hill 1:250,000 Sheet area, north-west Queensland. *Queensland Geological Record* **1999/2**, Department of Mines and Energy, Brisbane.

HOEFS J. 1997. *Stable isotope geochemistry, Minerals, Rocks and Inorganic Materials*. Springer, Nerlin, 201 pp.

SOUTHGATE P.N. & SHERGOLD J.H. 1991. Application of sequence stratigraphic concepts to Middle Cambrian phosphogenesis, Georgina Basin, Australia. *BMR Journal of Geology & Geophysics* **12**, 119-144.

WHITBREAD M. 1995. *The effects of weathering on the geochemical migration of Zn and Pb derived from the Century deposit.* B.Sc. Honours Thesis, University of Queensland, unpublished.

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