Mapping regional alteration patterns using hyperspectral drillcore scanner

Alan J Mauger
CRCLEME c/- Geological Survey, Primary Industry and Resources South Australia
PO Box 1671, Adelaide, SA, 5001
mauger.alan@saugov.sa.gov.au

SUMMARY

Hyperspectral drill core scanning undertaken using the CSIRO HyLogger™ between 2002 and 2005 focused on accumulating spectral data from a series of signature holes from across the State of South Australia. One component of the software used to process the data provides a summary for each hole indicating the amount of each detected mineral as a percentage of the scanned hole. By converting this percentage into the number of metres of detected mineral present in the drill hole this information can be presented in a GIS.

Four mineral suites are coming to the fore in alteration mineral mapping using HyLogger™: white micas, chlorites, carbonates and iron oxides. Each of these suites can relate to Eh-pH conditions in a mineralising system. For white mica, the transition from muscovite through phengite, as measured by the progressive change in wavelength position of the ~2200 nm absorption feature to longer wavelengths, corresponds with increasing replacement of aluminium in the crystal structure by iron or magnesium. Empirical studies show a correlation between concentration of economic metals and the presence of phengite that may also reflect local fluid pressure conditions. The ratio of Fe/Mg in chlorite has also been shown to vary in proximity to mineralisation. Calcium, iron and magnesium carbonates are a third component. Spectral studies have distinguished between hematite, Fe^{2+} goethite and Fe^{3+} goethite. HyLogger detects in wavelengths appropriate to these suites and software interprets relative abundances. Plotting the number of downhole metres of core containing these assemblages in their relative geographic locations permits interpretation of regional patterns of alteration. With some 600 holes (including 300 on open file) and 61,000 metres of core scanned across South Australia, regional patterns are starting to appear.

Key words: Hyperspectral, spectral geology, alteration mapping, South Australia, core logging.

INTRODUCTION

The completion, in 2002, of AMIRA Project P685 "Automated Mineralogical Logging of Drill Core, Chips, and Powders" culminated in CSIRO's successful commissioning of the prototype spectral core scanner HyLogger™. Various deployments of the scanner followed, of which PIRSA hosted two (2003-2004 and 2004-2005), that demonstrated its capacity for operational, routine acquisition of spectral data from diamond drill core. Over 300 open file drill holes from South Australia were systematically scanned as representative of the principal examples of mineralised environments encountered in the State. Spectral results focussing on clays, micas, chlorites, carbonates and iron oxides enable the semi-quantitative examination of alteration systems hitherto only described qualitatively with a significant underestimation of their extent and continuity. The opportunity to map regional alteration patterns is now limited only by the geographic distribution of diamond drilling. In order to demonstrate the application the Olympic Domain in South Australia was selected as the region of interest (Figure 1).

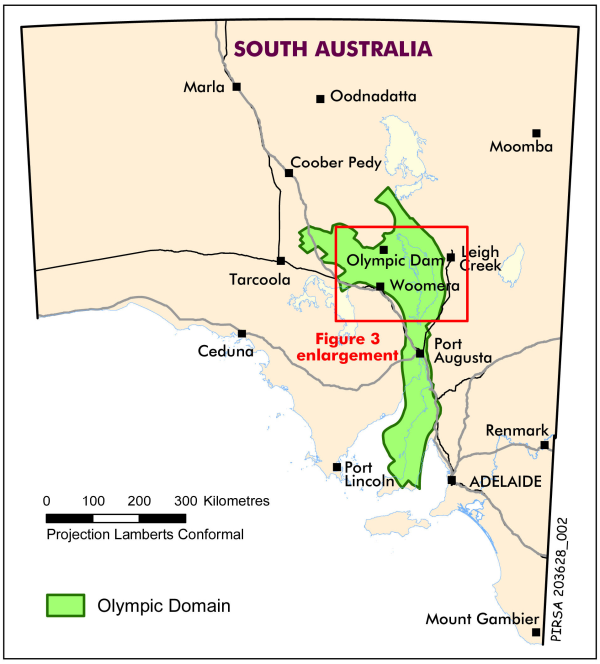

Figure 1: Location of study area showing Olympic Domain

METHOD

The core scanning HyLogger™ incorporates a hyperspectral radiometer measuring reflected electromagnetic radiation across the wavelengths 450nm to 2500nm. Combined with a high resolution linescan camera and a laser height profiler the instrument suite is mounted over a robotic table capable of accommodating the majority of diamond core trays currently in use (Huntington *et al.*, 2004) (Figure 2).

Figure 2: HyLogger™ at PIRSA's Glenside Core Library.

Output consists of contiguous spectra representing 1cm x 1cm sample intervals for the full length of the core, dynamically co-registered with the 0.1 mm resolution colour image. The software which enables such functionality is called "The Spectral Geologist - Core"™ or TSG-Core (Mason *et al.*, 2007). TSG-Core has the capability of estimating the relative proportions of Visible-Short Wave Infrared (Vis-SWIR) responsive minerals of which it refers to over 50 in its internal library. As a summary TSG-Core produces an output listing the relative proportions of each mineral it detects in a hole. By factoring against depth, the number of metres of each mineral detected in a hole can be calculated. This parameter then becomes the basis for plotting geographically the regional distribution of alteration mineral assemblages.

In this study of iron-oxide-copper-gold systems (IOCG) the three main groups of minerals under consideration are: white mica, chlorite and carbonate. Within each group the species of interest are phengite, Fe-chlorite and siderite - Fe-rich members of each group respectively.

Using a Natural Neighbour algorithm readily available in ArcGIS V9.0 the spatial variability of each mineral was plotted. To enumerate the regional trend in alteration the sum of phengite, Fe-chlorite and siderite was examined (Figure 3).

Alteration Mineral Assemblages

Mineral assemblages of interest that can be measured with this spectral range include kaolin, white mica, chlorite, carbonate, iron oxide and amphibole. This study considers white mica, chlorite and carbonate distribution in the Olympic Domain. Skirrow *et al.* (2002) identified an HSCC: hematite-sericite-chlorite-carbonate ± Fe-Cu sulphides ± U, REE mineral assemblage as one of three key hydrothermal alteration and ore mineral assemblages of this metallogenic province.

White mica, or sericite, encompasses illite, muscovite and phengite. Phengite is a white mica mineral series characteristic of high-pressure, regional metamorphic rocks. It is also a common alteration mineral found in hydrothermally-altered igneous rocks associated with mineral deposits (Mason *et al.*, 2007). Phengites cover a compositional range varying between muscovite and celadonite. Aluminium in octahedral sites in the crystal lattice is progressively replaced by Mg and/or Fe^{2+}. This chemical change is reflected in the changing wavelength of the ~2200 nm absorption feature to longer wavelengths with increased substitution of Al by Mg and Fe^{2+}. Previous studies (Yang, et al 2001, Prendergast, 2007) have demonstrated a relationship between the changing chemistry of muscovite-phengite with decreasing Al content in proximity to Au mineralisation.

Variations in the chemistry of chlorite may also provide a vector to ore. The Mg number of chlorite (normalised ratio of Fe to Mg content), derived from the wavelength of the major absorption features has been shown to vary in proximity to ore mineralisation (Mason *et al.*, 2007). In the case of IOCG it is anticipated that the more Fe rich species would have greater affinity for mineralisation.

Carbonate is a major component of the IOCG style of mineralisation found in the Olympic Domain. Given the prevalence of Fe in the system, variation in the presence of siderite, dolomite and ankerite are potentially useful in understanding variation in the Eh-pH conditions within the alteration system.

After normalising the ranges of the three target minerals, the metres of phengite, Fe-chlorite and siderite were summed to provide a combined alteration trend defined using a single variable, 'equivalent metres of alteration'.

RESULTS

Phengite displays a wider geographic distribution than previously recognised. This reflects in part the difficulty in previous studies of identifying this species of mica in hand specimen. In addition the subtleties of chemical variation can be expensive to validate by traditional means. While presence/absence might be documented, semi-quantitative statistical variation is very difficult to estimate by any method other than spectral analysis.

Siderite and Fe-chlorite are also prevalent in this domain. In an IOCG high iron environment the Fe-end members of carbonate and chlorite tend to be distributed proximally to mineralisation. By combining the three minerals in a single plot, regional trends can be mapped.

Using alteration data from three areas: Olympic Dam, Emmie Bluff and Pernatty Lagoon, preliminary alteration trends can be plotted (Fig. 3). The Olympic Dam alteration system is defined here by only one hole representing the highly significant mine. The alteration pattern near Pernatty Lagoon indicates a high intensity of Fe-metasomatism with a steep gradient on the southern eastern margin of the anomaly. Anomalous levels of Zn, Pb and U have been intersected between 600 and 1220 metres confirming the presence of mineralisation in the district.

This type of presentation of data changes the scale of observation normally associated with HyLogger^{TM} data. In contrast to individual drill hole studies this process provides a summary that can be used to visualise regional trends. Selecting holes with similar geological targets has revealed previously unrecognised trends.

DISCUSSION and CONCLUSIONS

The approach outline above is going to be affected by the depth of drilling, the proportion of the hole scanned, the geographic distribution of drill holes scanned and the general variability of geological environment.

What has been described represents a simple and effective method of visualising semi-quantitative regional alteration trends based on voluminous, detailed data derived from hyperspectral scanning of drill core. For a number of reasons this has not been physically possible to achieve before now. The technology for semi-quantitative mineralogical measurement of drill core has only been demonstrated in the last five years and the scanning of sufficient holes to commence this analysis was only undertaken in 2005. With time, as more holes are logged spectrally, the data distribution will improve and the understanding of the regional alteration pattern will also evolve.

ACKNOWLEDGMENTS

Without AMIRA Project P685 it is unlikely that this technology would have achieved the same progress as has been realised to date. CSIRO continue to be the major catalyst for the technology and prime mover for its development. HyLogger™ and TSG Core™ are trade marks of CSIRO. Georgina Gordon is acknowledged for her tireless efforts in both the acquisition and subsequent processing of the raw data. John Keeling's editorial comments were greatly appreciated

REFERENCES

Huntington, J., Mauger, A., Skirrow, R., Bastrakov, E., Connor, P., Keeling, J., Coward, D., Berman, M., Phillips, R., Whitbourn, L. and Heithersay, P., 2004. Automated mineralogical logging of core from the Emmie Bluff, iron oxide copper-gold prospect, South Australia. PACRIM 2004 Congress, Adelaide, SA, 19-22 September 2004, p 223-230, AusIMM Pub Series No 5/2004.

Mason, P., Berman, M., Lagerstrom, R., Bischof, L., and Huntington, J., 2007. The Spectral Geologist – Common Minerals. Ver 6.00.048, May 2007. CSIRO Divisions of Exploration and Mining and Mathematical and Information Sciences.

Prendergast, K., 2007. Application of lithogeochemistry to gold exploration in the St Ives goldfield, Western Australia. Geochemistry: Exploration, Environment, Analysis; v. 7; no. 2; p. 99-108; Geological Society of London.

Skirrow, R.G., Bastrakov, E., Davidson, G., Raymond, O.L., and Heithersay, P., 2002. The geological framework, distribution and controls of Fe-oxide Cu-Au mineralisation in the Gawler Craton, South Australia: Part II: Alteration and Mineralisation; *in Porter, T.M. (Ed), Hydrothermal Iron Oxide Copper-Gold & Related deposits: A Gliobal Perspective,* Volume 2; PGC Publishing, Adelaide, pp 33-47.

Yang, K., Huntington, J.F., Cudahy, T.J., Mason, P., Scott, K.M., 2001. Spectrally mapping the compositional variation of white micas in hydrothermal systems and the application in mineral exploration. Geoscience and Remote Sensing Symposium, 2001. IGARSS '01. IEEE 2001 International, Sydney, NSW, Australia

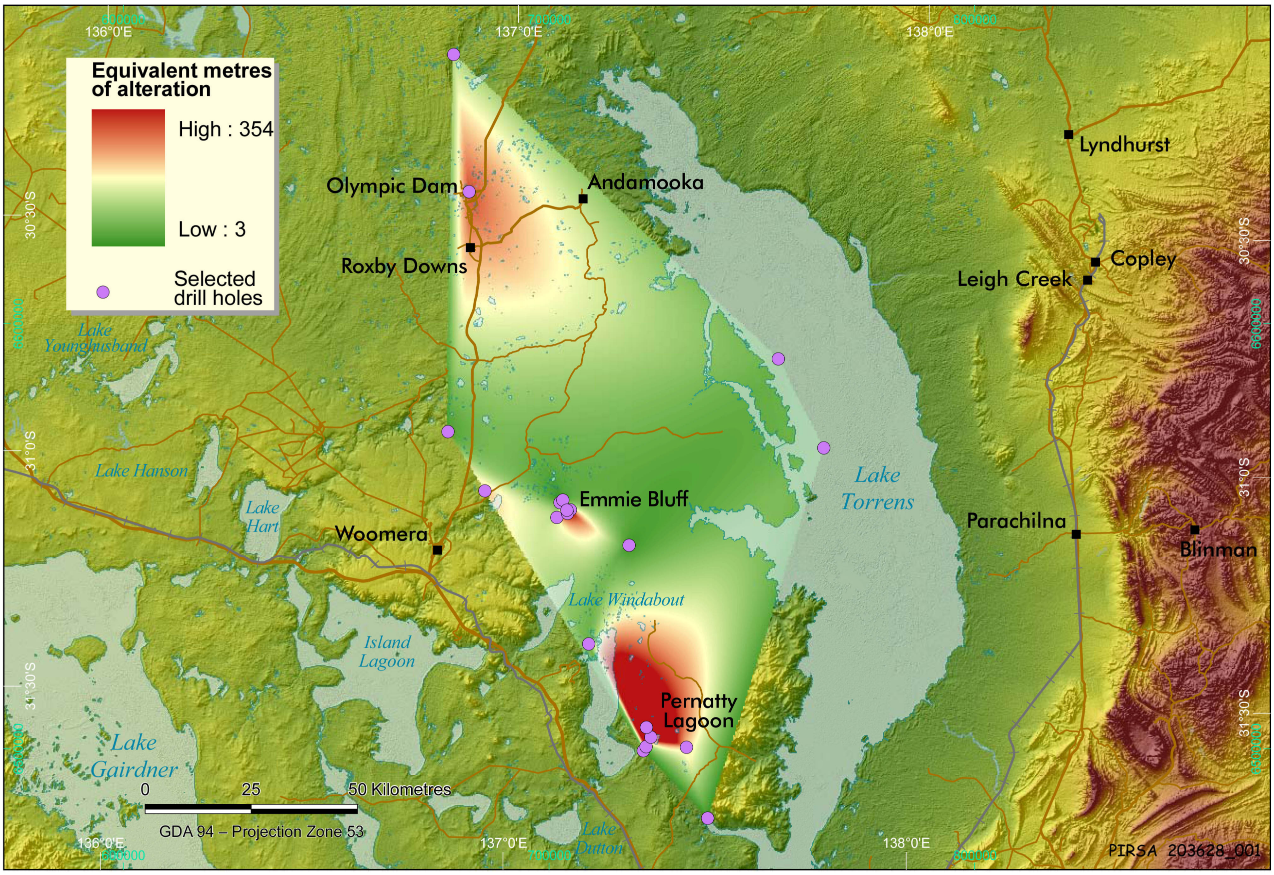

Figure 3: Regional alteration trends revealed using HyLogger™ data.