Novel Geological Exploration Applications of Mobile Metal Ion Technology using Dynamic Reaction Cell ICP-MS

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Introduction

Mobile Metal Ion (MMI™) Technology is a commercially available weak leach that is used for a variety of resource identification and lithological mapping projects (Mann 1998). The principle of MMI™ is that mobile ions associated with an ore body migrate to the surface over a period of time. These mobile ions are extracted and measured by ICP-MS in order to detect a buried ore body through identification of anomalies over background levels. This has proven valuable for many target elements, due to the ICP-MS technique providing the necessary low detection limits (e.g. 0.1ppb for Au) to discern anomalies. MMI-M provides detailed analysis on over fifty elements.

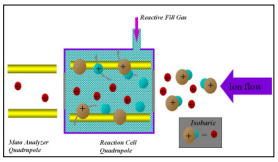
However, there are some elements, such as V, Cr and S, that cannot be measured to low level due to matrix interferences during the ICP-MS analysis. The aim of this work was to use Dynamic Reaction Cell ICP-MS to remove these interferences by chemical resolution, thereby allowing their use in exploration studies, whilst measuring all other elements in the same analysis.

Reference:
Mann, R. D. et al., 1998. Journal of Geochemical Exploration, 61, 87-102.

Mobile Metal Ion (MMI™)Technology

- Ions associated with ore bodies are released at depth, migrate to the water table and then rise by capillary action to 10–25cm below the surface at the soil horizon
- Samples are taken on a grid system over a suspected anomaly and out to background.
- Mobile Ions targeted by weak partial extraction solution and ICP-MS analysis for definition and focussed geochemical expression of buried targets
- Originally used for Gold and Base Metal exploration, but now expanded for diamond, uranium, nickel, geological mapping and other commodities using MMI-M.

Dynamic Reaction Cell (DRC) ICP-MS



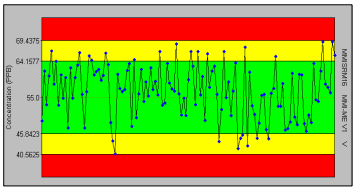
The Dynamic Reaction Cell ICP-MS consists of a pressurized cell containing a quadrupole placed between the plasma and the analyser quadrupole. Polyatomic Interferences (brown and blue) of the same mass (isobaric) as the analyte (red) enter the cell, filled with a reactive gas such as ammonia. The gas molecules react with the interference, breaking them apart. The parameters of the quadrupole inside the reaction cell are adjusted to only allow the analyte ion through to the mass analyser, and then the detector (© PerkinElmer Inc., used with permission).

Determination of Vanadium

Vanadium is an important indicator element for uranium exploration. However, its measurement by ICP-MS is hindered by the presence of a chloride interference at the same mass as the vanadium isotope:

$$^{51}V^{+} = [^{35}Cl^{16}O]^{+}$$

Ammonia gas was used in the dynamic reaction to remove this interference. The CLO interference undergoes a charge transfer reaction with NH3, resulting in it being removed from the cell, allowing the V+ ion to be measured. All other elements in the MMI™ analysis are determined after the gas has been removed from the cell. Detection limit was determined at **1ppb**.



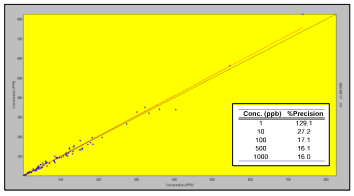
Results for the Determination of Vanadium using MMI for the standard reference material SRM14. Precision is 12%, based on 134 measurements

Determination of Chromium

Chromium is an important element in the discovery and identification of kimberlites for diamond exploration and for other ultramafic lithologies for nickel exploration. However, it suffers from interferences in ICP-MS on its major analytical isotope:

$$^{52}Cr^{+} = [^{12}C^{40}Ar]^{+}$$

As with vanadium, ammonia gas is used to pressurize the DRC. This undergoes a charge transfer reaction with the argon carbide, allowing only the Cr ion to exit the cell and be measured. All other elements are subsequently analysed in standard mode. Detection limit was measured at **1ppb**



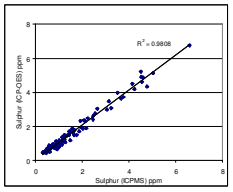
Duplicate precision for chromium using the DRC method. Precision is 16% at >500ppb and 30% at tent times the detection limit (10ppb). Results based on 118 pairs of results

Determination of Sulphur

Sulphur is a key element for nickel or oil and gas exploration, but is notoriously difficult to measure by ICP-MS, mainly because of oxygen based interferences:

$$^{34}S^{+} = {}^{17}O_2{}^{+} \text{ \& } (^{16}O^{1}H)_2{}^{+}$$

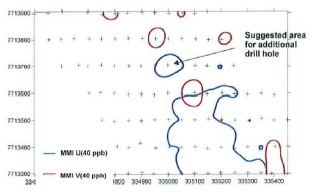
In this case, a method was developed that utilized the ability of the reaction cell to move an analyte away from interferences. Oxygen gas is used in excess to react with the sulphur ions to produce SO+ ions that are measured at a higher mass away from interferences. Again, the parameters of the quadrupole in the cell are optimized to remove other potential interferences and all other elements can be measured in the same analysis. Detection limit is **0.1ppm**



Comparison of 104 samples analysed by ICP-OES and DRC-ICP-MS in order to test the accuracy of the method. The graph indicates very good correlation between the techniques.

Vanadium Determination as part of the Uranium Exploration at Turpentine, Australia

Turpentine is part of the Mt. Isa prospects of Deep Yellow Ltd., situated to the north-east of Mt. Isa in northern Queensland. Turpentine is an area north of the Deep Yellow uranium mine in Australia. MMI-M surveys were carried out in 2009 and the vanadium and uranium responses are shown below.



The uranium anomaly over the outcropping area in the South East is evident, as is a second anomaly for potential drilling. Vanadium was the only element that appeared to have an association with the uranium signatures. The vanadium MMI image shows a corridor trending NNW, parallel to, but not coincident with the uranium. Uranyl vanadates are very insoluble and hence high values of both U and V in solution are not possible. The V tends to be zoned or fringing the uranium as shown above in a plot of contours of 40ppb and greater U and V.
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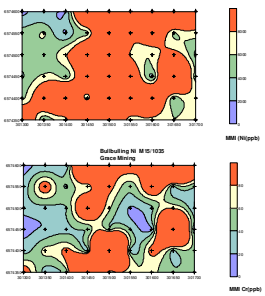
Conclusion

Vanadium has been measured at low level (1ppb D.L.) using DRC-ICP-MS as part of the MMI-M suite and has been shown to be useful in interpretation of potential uranium anomalies

Chromium Measurement at Bullabulling, Australia – A known Nickel Deposit

To test the measurement of chromium, using the DRC-ICP-MS method, MMI-M samples were analysed from a known nickel deposit at Bullabulling in Australia. Plots for nickel and chromium are shown below.



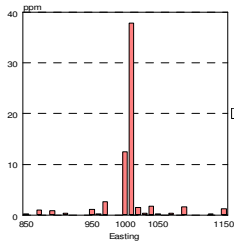
It can be seen that the Cr "maps" the channel flow in a similar manner to Ni - even down to the "hole" in the middle of the doughnut.

Conclusion

This study indicates that Cr can be used as part of the MMI-M package for Ni exploration, and is also now being used for oil and gas exploration due to the low detection limit (1ppb). This will also aid in the exploration for kimberlite-containing minerals in diamond exploration

Determination of Sulphur at Nepean, WA

The Nepean mine is located 25km south of Coolgardie in the Eastern Goldfields of Western Australia. MMI-M samples were taken across a known nickel sulphide deposit and analysed for sulphur using the DRC method. Results are shown below.



A plot of sulphur values taken from a line across a known sulphide source in the Nepean area, Australia. The major anomaly at 1000E coincides with the nickel sulphide deposit. There are further details about this anomaly available at.

See www.geochem.sgs.com/mmi, case study 35.

Conclusion

This work shows one potential use of sulphur as part of an MMI exploration package and the effectiveness of sulphur analysis using DRC-ICP-MS. Sulphur is also now being used as part of the MMI™ analysis for oil and gas exploration.