

# PROTON INDUCED X-RAY EMISSION (PIXE) AND PROTON INDUCED GAMMA RAY EMISSION (PIGME) ANALYSES IN GEOCHEMICAL EXPLORATION FOR GOLD AND BASE METAL DEPOSITS

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## Introduction

Geochemistry in mineral exploration is based on systematic determination of multi-elements in various sample media such as rock, regolith (weathered rock, soil, stream sediments), water, leaves and air (gas). There are many analytical methods used in exploration geochemistry; among them Inductively Coupled Plasma Emission Spectrometry (ICP-ES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Neutron Activation Analysis (NAA) and X-ray fluorescence (XRF) are commonly used analytical methods at present. Atomic Absorption Spectrometry (AAS) is also still used in some geochemical exploration programs and research. We have tested and then used simultaneous quantitative proton induced X-ray emission (PIXE) and proton induced gamma ray emission (PIGME) analyses in geochemical exploration for gold and base metal deposits since 1990. These analyses are parts of the research grant from Australian Institute of Nuclear Science and Engineering (AINSE). These analytical methods determine multi-element composition of acid insoluble residues of rock, regolith and vein quartz samples in relation to gold and base metal mineralisation (Aung Pwa et al., 1999a and 1999b). The PIXE and PIGME methods have high precision which is an important factor in geochemical exploration and can analyse with a high accuracy some useful elements such as Cl, F, V, Ga, Ge and Li in the study of hydrothermal alteration. The precision for more abundant elements is 2% or better whereas generally the accuracy of the PIXE analyses is about 5% (van Moort et al., 1995).

## Objectives

Application of PIXE/PIGME data in the following Exploration geochemistry studies:

- (1) Determination of Geochemical signatures related to or associated with mineralisation in rocks, regolith and quartz veins
- (2) Distinction between mineralised and barren rocks, regolith and quartz veins
- (3) Identification of hydrothermal alteration associated with mineralisation in rock, regolith and quartz vein

## Sample Preparation

Sample weight: Two grams of the powdered samples (<75  $\mu$ m fraction)

Acid Digestion: Sequential acid digestion; (a) aqua regia (3 HCl: 1 HNO<sub>3</sub>) at 60 °C for 12 hours in order to remove iron and manganese oxides and hydroxides, sulphides, carbonates, and most sulphates, and (b) H<sub>2</sub>SO<sub>4</sub> (15 ml) at 60 °C for 12 hours to dissolve clay minerals

Sample for analysis: Residues after acid treatments (washed with distilled water four times, and dried in an oven at 90 °C for 15 hours)

Mineral composition of residue: Mainly quartz (primary and secondary), with minor mica

Making pellet: Weighed residue powder and mechanically mixed with spectrographically pure graphite powder in a ratio of 4:1. Pressed into a small aluminium cup (12 mm in diameter) to get pellet sample.

## PIXE/PIGME Analysis

# PIXE/PIGME Analysis on a 3MV Van de Graaff accelerator at ANSTO, Lucas Heights

# Use of 2.5 MeV protons with 3 mm beam diameter target of sample pellet

# Proton induced X-ray emission (PIXE): Si, K, Fe, Ca, Ti, Mn, Cl, S, Ga, Rb, Sr, Zr, Y, Nb, Cu, Zn, Pb, Ni, As, Th, V, Mo, Cr, Ge, Ba and Br

# Proton induced Gamma ray emission (PIGME): Al, Na, Mg, F and Li

Detection Limits: Table 1 showing detection limits of some element and comparison between PIXE/PIGME, XRF and NAA

Table 1. Detection limits (in ppm) of some elements and comparison

Element	NAA*	PIXE/PIGME <sup>b</sup>	XRF <sup>c</sup>
Ag	5	80	2
Au	0.0001	7	3
Al	-	400	100
As	1	2	2
Ba	100	50	30
Ca	10000	45	100
Cl	-	75	20
Co	1	3	20
Cr	5	13	10
Cu	-	2	4
Fe	200	5	10000
Ga	-	2	5
Ge	-	2	3
K	2000	35	100
La	1	600	10
Mg	-	1500	100
Mn	-	8	100
Na	100	40	250
Nb	-	5	4
Ni	50	4	5
P	-	40	50
Pb	-	4	5
Rb	30	3	5
S	-	140	50
Sc	0.1	40	2
Si	-	1100	10000
Sn	100	100	5
Sr	500	3	10
Th	0.5	10	10
Ti	-	17	100
V	2	13	5
Y	1	4	10
Zn	50	2	5
Zr	500	5	10

\* -- Bequerel Laboratories, Lucas Heights, NSW, Australia

# -- van Moort (1999) and present study, Physics Division, ANSTO, Lucas Heights, NSW, Australia

+ -- CSIRO, Wembley, WA, Australia

## References

- Aung Pwa, Bailey, G.M., van Moort, J.C., McQueen, K.G., 1999a. An integrated geochemical and paramagnetic exploration at the McKinnons gold deposit, Cobar, NSW. In: G.M. Taylor and C.F. Pain (Editors), New Approaches to an Old Continent. Proceedings of Regolith '98, pp. 181 - 190.
- Aung Pwa, McQueen, K.G., Scott, K.M., van Moort, J.C., 1999b. Regolith geochemical exploration using acid insoluble residues as a sample medium for gold and base metal deposits in Cobar region, NSW, Australia. J. Geochem. Explor., 67: 15-31
- Shen, X.C., Dunlop, A.C., Cohen, D.R., 1999. Geochemical dispersion in residual and transported regolith near the CSA mine, Cobar, New South Wales. In: G.M. Taylor and C.F. Pain (Editors), New Approaches to an Old Continent. Proceedings of Regolith '98, pp. 263-270.
- van Moort, J.C., 1999. Quartz and the acid insoluble residue of rock and regolith as a sample medium in mineral exploration. In GEOANALYSIS, a short course presented at 19th International Geochemical Exploration Symposium, Vancouver, Canada.
- van Moort, J.C., Hotchkis, M. A.C., Aung Pwa, 1995. EPR and lithochemistry of jasperoids in Carlin, Nevada: Distinction between auriferous and barren rocks. J. Geochem. Explor., 55:283-299.

## Study Areas (Figure 1)

# Gold/base metal deposits and prospect (Cobar, New South Wales)

- (1) McKinnons gold deposit
- (2) Peak gold deposit
- (3) Wagga Tank base metal deposit
- (4) Lower Tank prospect, CSA east

Geology: Clastic sediments and volcanics of the Early Devonian Cobar Basin and its equivalents (eg. Mt Hope Trough). Mineralisation along fracture zones associated with silicification, sericitisation and clay alteration

## Results

Gold/base metal deposits (Cobar, New South Wales)

# McKinnons gold deposit

# Peak gold deposit

# Wagga Tank base metal deposit

Ore indicator elements: Enrichment in Cu, Zn, Pb, As and Ni

(Figure 2) together with elevated Au, Ag and Sb  
 Alteration indicator elements: Depletion in K, Al, Ca, Na, Ti, Rb, Sr, Ga and V (as a result of feldspar and mica destruction followed by silicification) (Figures 3, 4 and 5).

Presence of these indicators: in both fresh rock and regolith associated with gold and base metal mineralisation;

Lack of alteration in barren areas (Figures 3 and 8)

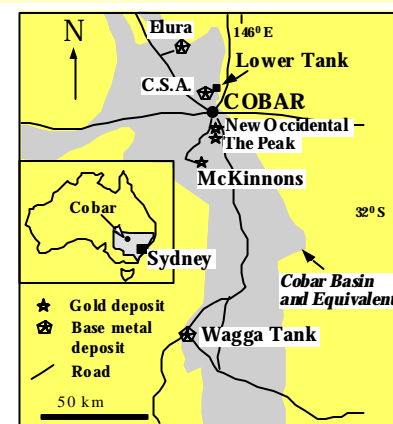


Figure 1

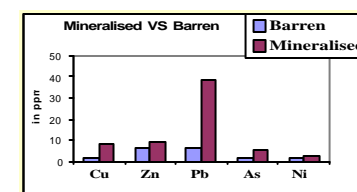


Figure 2

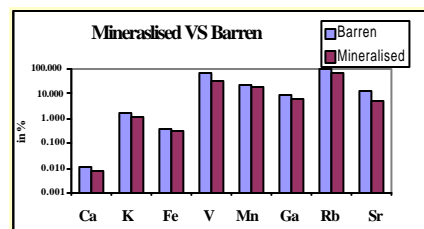


Figure 3

Figure 2 and 3 show enrichment in Cu, Zn, Pb, As and Ni as an ore indicator and depletion in Ca, K, Fe, V, Mn, Ga, Rb and Sr as an alteration indicator in regolith associated with gold and base metal deposits in Cobar, N.S.W.

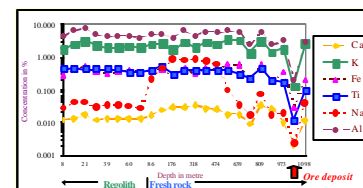


Figure 4

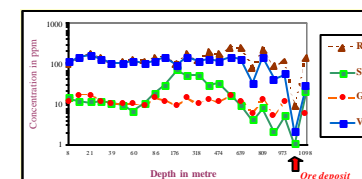


Figure 5

Figures 4 and 5 show the variation of some elements along Drill hole PK 29, Peak gold deposit, Cobar, NSW. Depletion in Ca, K, Fe, Ti, Na, Al, Rb, Sr, Ga and V in the rocks and regolith as an alteration indicator associated with ore deposit.

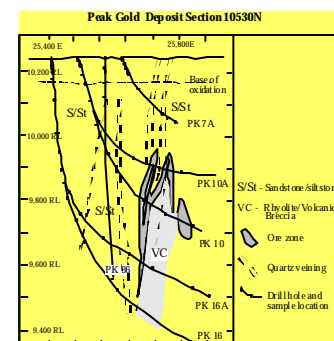


Figure 6

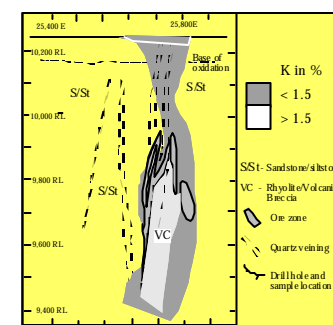


Figure 7

Figures 6 and 7 show rock units, ore zones and distribution of K in drill hole samples along 10530N section, Peak gold deposit, Cobar, NSW. Depletion halo of K associated with ore zones along vertical fracture zones.

# Lower Tank prospect (CSA mine East): Presence of Au, Cu, Zn, Pb, As and Sb anomalies in drainage sediments defined by earlier auger and RAB drilling; Lack of geochemical alteration (no depletion in K, Fe, Ca, Na, Rb, Sr, Mn, Ga and V, Figure 8)  
 Result: No mineralisation associated with the anomalies (Shen et al., 1999).

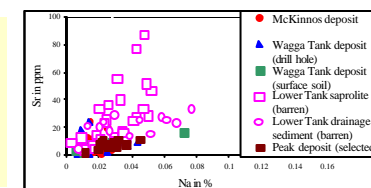


Figure 8

## Conclusions

# PIXE and PIGME are useful analyses in geochemical exploration for gold and base metal deposits.

# Ore indicator elements such as Au, Cu, Zn, Pb, As, Ag, Ni and Sb are elevated in the rock and regolith near and around the ore deposits while the alteration indicator elements, K, Al, Ca, Na, Ti, Rb, Sr, Ga and V are depleted as a result of feldspar and mica destruction followed by silicification.

# Barren rocks are not associated with above ore and alteration indicators. Barren regolith does not show alteration indicator (a depletion in K, Al, Ca, Na, Ti, Rb, Sr, Ga and V).

## Acknowledgements

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