LATERITE GEOCHEMICAL DATABASE FOR THE CENTRAL YILGARN CRATON, WESTERN AUSTRALIA

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Abstract

This report documents a laterite geochemical database with multi-element analyses of 4441 samples from the central Yilgarn Craton, Western Australia. The database was compiled as part of a collaborative research project called 'Astro Yilgarn Regolith' that was conducted between 1997-2000 and sponsored by Astro Mining NL. The purpose of the project was to develop and test new techniques for diamond exploration in the Yilgarn Craton with particular emphasis on the use of laterite geochemistry. This data set comprises samples taken as part of an exploration program to detect kimberlite pipes in the Yilgarn Craton.

1. Introduction

The laterite[1] geochemical database was compiled as part of a collaborative research project between CRC LEME and Astro Mining NL between 1997 and 2000. The research was aimed at developing new geochemical exploration methods for diamond exploration in the Yilgarn Craton. Emphasis of the project was on the use of laterite geochemistry for diamond exploration in low relief terrain, deep weathering and extensive areas of laterite cover and
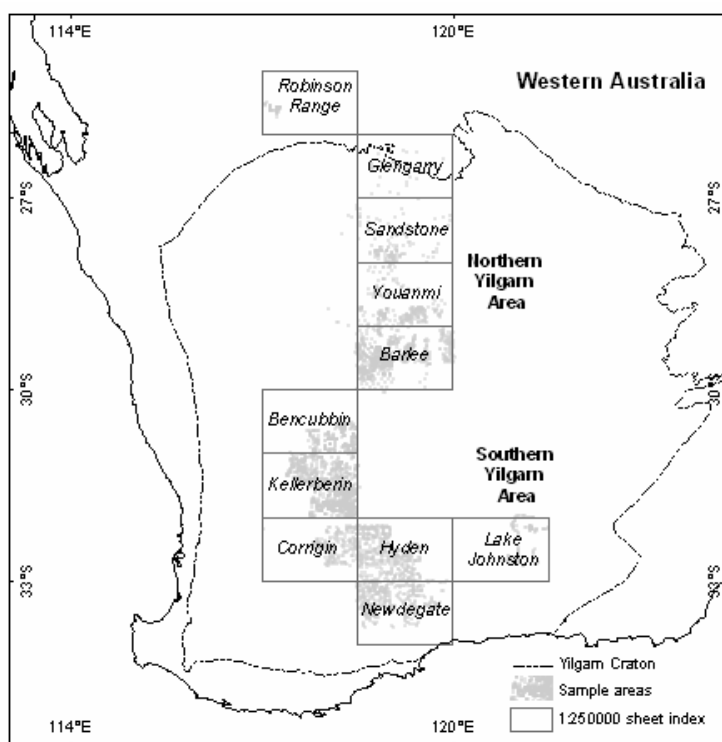
Figure 1. Extent of the laterite geochemistry sampling programme.

sandplain. In these areas, the elsewhere widely used indicator mineral survey techniques may be ineffective because i) the required abundance of drainage networks are generally absent, ii) deep weathering has destroyed most indicator minerals, and iii) laterite and sandplain blanket the terrain. Together these would limit the dispersion of recognizable kimberlite indicator minerals.

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[1] In this report, 'laterite' is used descriptively in an informal and broad sense to refer to lateritic residuum (ferruginous duricrust, nodules and pisoliths), and lag formed from lateritic residuum, in the context of laterite geochemistry or laterite sampling.

Figure 1 shows the extent of the sampling programme. The database contains 9078 analyses for 4441 laterite samples mainly from the central Yilgarn Craton, Western Australia.

2. Sampling

Sampling commenced on the Bencubbin 1:250 000 sheet in the southern Yilgarn Craton (Figure 1) near Merredin. In areas with good road access, sampling at 1 to 3 km spacing was completed along road reserves, in gravel pits and on paddocks, but avoiding disturbed or imported material. In less accessible areas of the northern Yilgarn (Glengarry, Sandstone, Youanmi and Barlee 1:250 000 sheets), approximately 500 samples were taken by helicopter at 8 to 10 km spacing on a triangular grid to establish a regional laterite geochemical framework (actual average coverage: one sample per 85 km^2). Subsequent infill sampling over selected parts in the northern Yilgarn closed the sample spacing to about 3 km, or one sample per 7 km^2, to increase the probability of detecting preserved pipes.

In the southern Yilgarn, sampling was extended onto the Kellerberrin, Newdegate, Corrigin and Hyden 1:250 000 sheets (Figure 1). Sample spacing in the agricultural region was determined by the road network and land access and, along roads, was 1 to 2 km. Due to the rectangular road network, some large areas (25 to 100 km^2) remained unsampled. The average coverage was one sample per 14 km^2.

Sampling followed a consistent protocol. In areas of outcropping lateritic residuum, on breakaways and backslopes, about 1 to 1.5 kg of laterite was collected by hand at each sample point. Depending on the abundance of suitable material, sampling was over 1 m to 100 m across, mostly about 10 m.

In erosional parts of the landscape, particularly in the northern and northeastern Yilgarn Craton, ferruginous materials have largely been removed, leaving an erosional surface of variably indurated clays. However, in many cases, pockets of laterite (ferruginous gravel) occur in small depressions, potholes or cracks within the undulating surface, providing adequate sample material for a regional survey.

In areas of preserved sandplain, where the thickness of sand may exceed 1.5 m, laterite samples were obtained by searching for natural accumulations of lateritic nodules and pisoliths at the surface. Where this was unavailable, ferruginous gravel beneath the sand was obtained by excavation.

A description of sampling procedures and the rationale of laterite geochemistry is given by Cornelius *et al.*, 2001. A discussion of the results and statistical techniques used for the data interpretation of this geochemical dataset is given in Cornelius *et al.*, in press.

3. Sample description

The classification of the materials uses the scheme of Anand *et al.* (2002). The majority of the laterite samples (4280) comprise lateritic residuum (LT), mostly nodules (LT104) or pisoliths (LT102), or both (LT103). Lateritic duricrust (LT200) was sampled only where loose gravel was unavailable. Experience in previous base metal exploration has shown that lateritic gravel tends to form broader dispersion patterns than the commonly underlying lateritic duricrust (Smith *et al.*, 1992 and Anand *et al.*, 1993). In some areas, the relationship between the ferruginous surface gravel and the underlying residual weathering profile was unclear and this material was therefore classified as lag (LG) to indicate the possibility of more significant lateral transport. All lag samples (161) are ferruginous and comprise nodules (LG104), pisoliths (LG102), nodules and pisoliths (LG103) and ooliths (LG101). Lithic lag material was not collected as part of this survey.

4. Sample preparation

The preparation of laterite samples from the orientation sites and the Yilgarn surveys was as follows:

1) Approximately 100-200 g of each sample was reserved in its natural state for reference.
2) From the remaining material about 1-2 kg of sample, ferruginous nodules and pisoliths were washed with tap water to remove loose sand, clay and other particles, over a 2 mm plastic sieve.
3) Quartz, lithic components, saprolitic material, organic matter and other unwanted materials were removed by hand.
4) The remaining ferruginous nodules and pisoliths were pulverised as follows:
   − Genalysis Laboratory: 500-1000 g of sample were pulverized in a large ring mill (low Cr steel). An aliquot of 150 g was split from the pulverised sample and finely ground to <75 μm in a ball mill. Between samples, the mill was cleaned with a quartz "wash" and compressed air.
   − CSIRO: 500-1000 g of sample were crushed to <5 mm, and an aliquot of about 150 g was ground to <75 μm in a low-Cr K1045 steel mill (Robertson *et al.,* 1996). The mill was "washed" with quartz after each sample, cleaned with compressed air and wiped with ethanol.

5. Chemical analyses

About 85% of samples were analyzed using X-ray fluorescence (XRF) at CSIRO Exploration and Mining, Floreat, Western Australia, and approximately 75% of samples were analyzed using Instrumental Neutron Activation Analysis (INAA) at Becquerel Laboratories, Lucas Heights, New South Wales (Table 1). Approximately 20% of samples, mainly from the southern Yilgarn, were analyzed by commercial laboratories using XRF and/or ICP-MS and/or ICP-OES. The latter analyses are included in the attached database without further discussion of the analytical methods and quality control used by the company.

XRF analysis at CSIRO was on fused discs in a $B_4Li_2O_7$ flux for ten major elements and 18 trace elements. INAA was completed for 32 elements. Loss on ignition was not determined.

Quality control for CSIRO XRF and INAA was by four CSIRO standards that were analysed at approximately one per 20 unknowns. Two standards ("Hyden Standard 1" and "Hyden Standard 2") are lateritic gravel formed on granite/gneiss near Hyden, Western Australia, the third one ("Aries Standard") is a composite sample of lateritic residuum from the Aries pipe, Western Australia, and the fourth standard ("CSIRO Standard 9") is a composite lag sample from Beasley Creek, Western Australia. All standards were prepared and homogenized by a commercial laboratory in Perth. One of the Hyden standards showed poor precision for Fe, K, Cr, V and Zr, possibly indicating inadequate homogenization during sample preparation. These analytes were therefore excluded from the quality control for this standard. In addition to the listed CSIRO standards, internal laboratory standards, blanks and duplicates were used at the rate of approximately 1 per 10-20. The calibration of the XRF was by international reference material.

Table 1. Breakdown of analyses

Analytical technique	Digest	Number of samples	Laboratory
XRF	Fusion	3826 528	CSIRO Exploration and Mining ALS Laboratories, Perth
INAA	N/A	3297	Becquerel Laboratory, Lucas Heights
ICP-MS	Hydofluoric, nitric, perchloric, hydrochloric	876 85	ALS Laboratories, Perth Genalysis Laboratories, Perth
ICP-MS	Aqua regia	226	ALS Laboratories, Perth
ICP-MS	Fusion	104	Genalysis Laboratories, Perth
ICP-OES	Hydofluoric, nitric, perchloric, hydrochloric	85	Genalysis Laboratories, Perth
ICP-OES	Fusion	51	Genalysis Laboratories, Perth

The precision (Table 2) was deemed acceptable if ≤20% [2 x standard deviation / mean x 100] at 10 times the lower limit of detection (LOD). Three analytes, Ce, Cl and SO_3, did not achieve the required precision (27%, 32% and 21% respectively). Chlorine and SO_3 were considered of little importance in laterite for kimberlite exploration. The poor precision for Ce by INAA at concentrations of around 50 ppm is cause for concern, however, at higher concentrations (Aries Standard), the precision is good. The poor precision of 65% for Au in CSIRO Standard 9 is due to a well-established nugget effect in this sample (Robertson, pers. comm.). Blank values were deemed acceptable if they were less than three times the limit of detection.

The accuracy of XRF and INAA analyses was checked using CSIRO Standard 9 that had previously been analysed by different methods and laboratories. Analyses were deemed acceptable if the analysed value and the consensus value agreed to within 20% for analyte concentrations greater than ten times the lower limit of detection. The results are listed in Table 2 and generally are less than 20%. Exceptions are V and Zr analyses by XRF. However, the analyses of CSIRO Standard 9 compare well with ICP-MS analyses and it appears, previous XRF analyses of CSIRO Standard 9 may have been inaccurate.

6. Statistical Analysis

The suite of elements, detection limits, analytical techniques and quality control requirements, (i.e. accuracy and precision) were determined by the project objective to develop and test new methods of diamond exploration for the Yilgarn Craton. The data evaluation was based on the statistical analysis and comparison of elemental concentrations for laterite on kimberlite or alkaline ultramafic rock, and laterite on granite-gneiss. Thus, the precision of analyses, monitored by internal standards, was more important than absolute analytical accuracy.

A selected number of samples from this sample set will be reanalysed as part of an initiative, commenced in 2004, to produce a laterite geochemical map of the Western Yilgarn Craton. This is a joint project between CSIRO, CRC LEME, Geological Survey of Western Australia (GSWA) and MERIWA. This new project will generate data on 53 elements analysed by XRF and ICP-MS/OES, based on a broad 9 km sampling grid. The first part of this new dataset is expected to be released in mid 2005.

Table 2. Analytes and accuracy/precision for four standards

INAA			XRF - CSIRO			Hyden Standard 1		Hyden Standard 2		Aries standard		CSIRO Std 9					
Analyte	Unit	LLOD	Analyte	Unit	LOD	INAA[1] Precision %	XRF[1] Precision %	INAA[1] Precision %	XRF[1] Precision %	INAA[1] Precision %	XRF[1] Precision %	INAA[1] Precision %	XRF[1] Precision %	XRF[1] vs XRF[2] Accuracy %	XRF[1] vs ICP[2] Accuracy %	XRF[1] vs INAA[2] Accuracy %	INAA[1] vs INAA[2] Accuracy %
Ag	ppm	5						*				0					
			Al₂O₃	%	0.05		5		6		1		3		1.2		
As	ppm	1				13		13		5		7					2
Au	ppb	5						*		*		65					9
Ba	ppm	100	**Ba**	ppm	20			*	*	*	11	*	13	20.1		4.4	9.6
Br	ppm	1						*		*		*					7
Ca	%	1						*		*		*					
			CaO	%	0.001				*		*		5				
Ce	ppm	2	Ce	ppm	15	18	20	27	_20_	5	5	10	*	*		*	*
			Cl	ppm	20				*		32		13				
Co	ppm	1	Co	ppm	10	_20_		_19_	*	7	*	7	*	*	_16_	*	1
Cr	ppm	5	**Cr**	ppm	10	34	31	7	21	6	1	7	19	13.0	4.0	4.2	1.9
Cs	ppm	1						*		*		*					*
			Cu	ppm	10				*		*	*	13	14.2			
Eu	ppm	0.5						*		*		*					14
Fe	%	0.02				43		8		5		6					
			Fe₂O₃	%	0.005		31		7		1		3	5.8	1.5		
			Ga	ppm	3		8		9		_20_		20	_8_			
Hf	ppm	0.5				19		10		19		_10_					1
Ir	ppb	20						*		*		*					
K	%	0.2						*		*		*					
			K₂O		0.001		49		13		10		3				
La	ppm	0.5	La	ppm	10	18		12	*	5	6	7	*	*		*	6
Lu	ppm	0.2						*		_17_		*					
			MgO	%	0.01				*		12		15		6.7		
			MnO	%	0.002				*		_6_		4				
Mo	ppm	5						*		*		*					*
Na	%	0.01						*		13		*					
			Na₂O	%	0.01				*		*	*	*	*	*		
			Nb	ppm	4				*		4	*	*	*			
			Ni	ppm	10				*		2	*	*	*			
			P₂O₅	%	0.002				*		1	5					
			Pb	ppm	5				*		*		*		_12_		
Rb	ppm	20	**Rb**	ppm	5			*		*	*	*	*	*		*	
Sb	ppm	0.2						*		14		*					10
Sc	ppm	0.1						9		5		7					3
Se	ppm	5						*		*		*					*
			SiO₂	%	0.01		7		4		1		3	2.0			
Sm	ppm	0.2				_12_		*		6		9					7
			SO₃	%	0.002				14		21		8	9.8			
			Sr	ppm	5				*		8		*	*			
Ta	ppm	1						*		17		*					*
Te	ppm	5						*		*		*					
Th	ppm	0.5						15		6		9					12
			TiO₂	%	0.003		17		4		2		3	17.5	9.5		
U	ppm	2						_17_		8		*					*
			V	ppm	5		57		9		2		5	25.8	10.5		
W	ppm	2						*		*		*					2
			Y	ppm	5				*		_16_	*	*				
Yb	ppm	0.5						*		13		14					22
Zn	ppm	100	**Zn**	ppm	5			*	*	*	11	_10_	5	14.9		14.3	4.1
Zr	ppm	500	**Zr**	ppm	5		24	*	7	*	5	*	9	25.0	7.8	*	

NOTES

Precision:
(2 x Standard deviation / mean) x 100
[For concentrations ≥ 10 x the LOD]

Accuracy:
(Mean [unknown] − Mean [standard] / Mean [standard] x 100
[For concentrations ≥ 10 x the LOD]

Bold   Preferred analyte and method (XRF or INAA)

*   Poor precision and/or accuracy due to concentrations < 10 LOD

Italics   Good precision and/or accuracy despite concentrations < 10 LOD

LOD   Lower limit of detection

XRF[1]   Analyses completed for this project

XRF[2]   Analyses by laboratories other than CSIRO and/or completed as part of previous projects

7. Presentation of analytical data

All analytical data and cataloguing information ("meta-data") are listed on the attached compact disc as a Microsoft Access 2000 database and as a series of tab-delimited text files.

The Access database structure is composed of two main tables and four authority tables listed below in Table 3. The main tables are connected in a 'one to many' relationship using the UniqueNo which is a combination of the CSIRONo and the SampleNo. A Unified Modeling Language (UML) diagram showing the relationships between the tables is represented in Figure 2.

In addition, cross table queries have been set up to extract analyses by analytical method. These include ICP-MS (4-acid, aqua regia and fusion), ICP-OES (4 acid and fusion), INAA, and XRF (fusion). These queries correspond to the series of text files included with the database. The method and regolith code description tables have also been saved as text files.

Table 3. List of tables in Astro Yilgarn Regolith database

| **Main Tables**	
Assay	Analyses of samples using various methods
Details	Sample locations and regolith codes
Authority Tables	
Method	List of analytical methods
Regolith Code Descriptions	List of regolith code descriptions
Laboratory	List of laboratories used and their contact details
Map Sheets and References	List of current 1:250000 and 1:100000 maps used in database
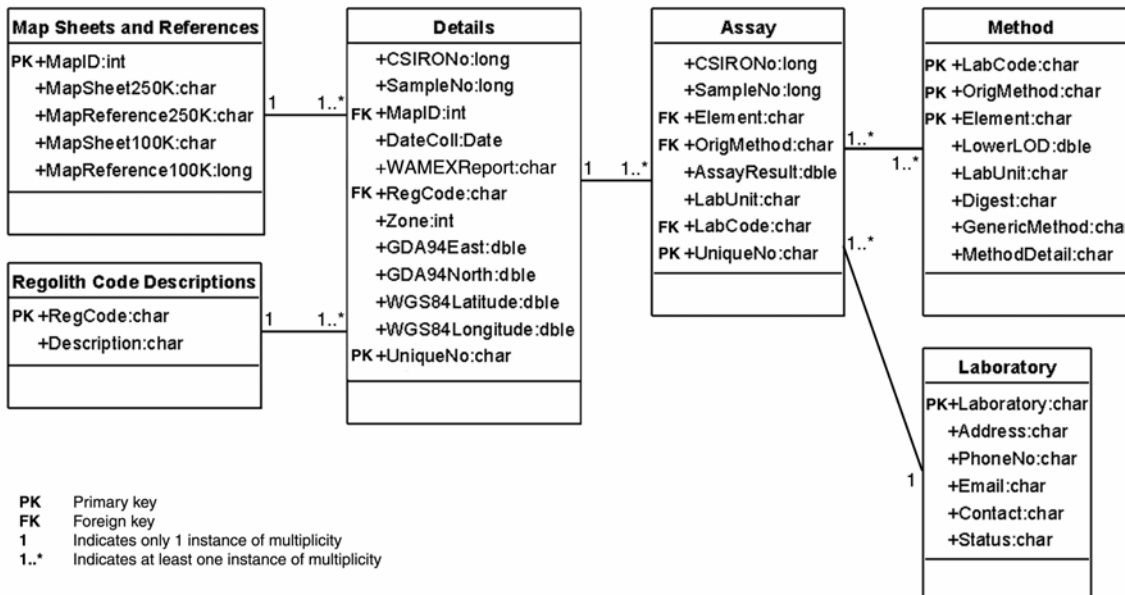
Figure 2. The UML case diagram showing the relationships between the main and authority tables in the Astro Yilgarn Regolith database.

8. Acknowledgements

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