Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

CRC LEME Minerals Brief

Regolith Science in Mineral Exploration

No 2 - June 2004

CONTENTS

FROM THE CEO

This second electronic Minerals Brief contains 14 short items on current LEME research of relevance to mineral explorers. It includes summaries of work presented at the recent Cobar Field Workshop (24-27 May 04) as well as other projects. I hope 'explorers' find this material of use, and I urge you to keep up to date with our current work by consulting our web site, under RESEARCH. The web also contains information on MTEC regolith training courses of direct relevance to mineral explorers.

The next edition will include summaries relating to presentations on the recent LEME Minerals Exploration Seminar, held 2 June 04 in Perth. The Abstract Volume and PowerPoint presentations from that Seminar are also available on the LEME website under EVENTS.

I specifically draw your attention to the series on our web site under PUBLICATIONS-Monographs, entitled ***Regolith Expression of Australian Ore Systems.*** In addition to basic data, the series includes information on exploration procedures, terrain analysis, sample type, sampling interval, analytical procedure, element selection and data interpretation. It will provide an improved understanding of the impact of weathering and regolith on exploration methods, leading to reductions in the cost of exploration for concealed mineral deposits.

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CRC LEME WEB SITE: http://crcleme.org.au

Aeolian geochemical diluents in Girilambone landscapes

Susan Tate (GA) and **Richard Greene** (ANU) have looked at the quantity and form of aeolian diluents in the regolith-covered Girilambone belt, and examined the implications for mineral exploration. It has long been recognised that aeolian materials are being continuously deposited on the land surface, becoming mixed both with residual soils and existing alluvial and colluvial sediments. This has the potential to adversely affect geochemical exploration, by diluting the signature of mineralisation. This study involved a comparison of soil components from a variety of alluvial / colluvial covered areas, with a control site of natural dust traps with shallow soils and a distinctive bedrock signature. A wide range of techniques, including semi-quantitative XRD, XRF, particle size distribution and grain morphology by SEM have been used to quantify the aeolian component. The study has shown that aeolian material constitutes more than 70% of near-surface soils in the region, and is principally represented by rounded quartz grains in the 70 micron mode, although there is evidence for a regional coarsening up-source (westerly). It is possible to enhance the anomaly by removing the minus 70 micron fraction; partial analysis can also effectively bypass the aeolian fraction.
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South Australian calcrete

Mel Lintern (CSIRO EM) has reported on the regolith-geochemical expressions of 19 mineralised sites in South Australia in the recently released **LEME Open File Report 156** (March 2004): ***The South Australian regolith project final report - summary and synthesis***. This focussed on calcrete as a favourable medium for geochemical exploration. This project was established in recognition that the distinctive SA regolith is characterised by duricrusts of calcrete and silcrete, compared with the predominantly ferruginous duricrusts of the Yilgarn Craton. The study summarises regolith profiles and 3-D distributions of gold at various sites in the central Gawler Craton that have different degrees of erosion of the residual profile, and different thicknesses of transported regolith. The typical profile consists of saprolite capped by residual silcrete, commonly overlain by transported overburden of fluvial, colluvial and aeolian origin. Calcrete has intergrown with these upper materials, generally within the top 5m; the most important calcrete unit is that developed at the top of the silcrete, which forms a permeability barrier. Major conclusions are:

- anomalous gold in calcrete registers well with underlying gold mineralisation where calcrete is formed immediately above residual silcrete, irrespective of the extent of current exhumation or burial
- where thickness of transported regolith is greater than 5m, basement gold signatures are totally suppressed in near-surface calcrete
- highly anomalous concentrations of gold (hundreds of ppb) may occur in calcrete at the saprolite interface
- in erosional and depositional regimes, gold may be dispersed laterally in both degraded silcretes and younger calcrete, thus providing false anomalies.

This project has a bearing on the on-going questions of exactly where and why calcrete geochemistry works. Possible mechanisms for gold concentration in calcrete include evapotranspiration, chemical precipitation, residual concentration, transport by soil biota, root uptake and microbial deposition. This diversity is the subject of Mel Lintern's ongoing research. mel.lintern@csiro.au

Biological processes in weathering

Sue Welch at ANU is looking at some specific biological influences on mineral weathering and element mobility. Initial laboratory experiments are focussing on a range of major element (Si, Al, Fe, Ca, K, and Na) and trace elements (Ge, Ga, P, REE). Rates and phases of mineral dissolution reactions using soil, groundwater micro-organisms and microbial ligands will be compared with inorganic abiotic reactions. One particular aspect will look at the dissolution of Al and Fe – normally considered as "non soluble", and the fractionation of Ge from Si, and Ga from Al. Normally Ge will follow Si and Ga will follow Al in weathering. But previous work suggests that in organic media, Ge will preferentially leach compared to Si, and Al preferentially leaches compared to Ga. Thus Ge/Si and Ga/Al provide indicators of biological activity. Recent laboratory work shows that in granite samples, there is a two to ten-fold increase in the release of major ions like Fe and Al in organic solutions compared to inorganic controls. Presumably this is due to the formation of metal-organic complexes. Analyses of trace elements Ga, Ti, Li and REE show preferential mobilisation by organic acids. This work is one of a number of inter-related LEME projects contributing to an understanding of the role of biological processes in metal mobility during weathering. susan.welch@ems.anu.edu.au

REGIONAL GEOCHEMICAL STUDIES

Northern Territory regoliths

The Northern Territory regolith project team - **Mike Craig (GA),** Ian Robertson and Ravi Anand (CSIRO EM), with collaborators Chris Edgoose and Roger Clifton of the NT Geological Survey - completed an observation traverse across the Northern Territory during September-October 2003. The Stuart Highway was the major access route from south of Alice Springs through to the Darwin coastal plain. The objectives were to assess a provisional landform interpretation, based on some of the best high-resolution regional airborne geophysical datasets in Australia, and to identify selected areas for detailed study of regoliths and landforms. The regional study will assist in reconstructing the Mesozoic and Cainozoic landscape evolution history of a large part of continental Australia, which will in turn provide a sound basis for mineral exploration, including diamond. The major fieldwork phase commences June 2004. Early results suggest that particular regolith materials and landscapes have complex relationships, and that some materials are likely to be more widely distributed in some areas than has been previously recorded. mike.craig@ga.gov.au

Yilgarn regolith map

Mike Craig (GA) and **Ravi Anand (CSIRO EM),** with the collaboration of former LEME colleague, Max Churchward, have completed a regolith map covering much of the Yilgarn Craton, an area of considerable interest not only to mineral explorers but

to environmental managers tackling the problems of salinity in the Western Australian wheatbelt. This new map provides a much needed overview of regolith units across this very large area and will be a useful supplement to published large-scale regolith maps. The map complements the review of the regolith geology of the Yilgarn Craton published by Ravi Anand and Mark Paine in the Australian Journal of Earth Sciences in 2001. ravi.anand@csiro.au

Tibooburra Gold

Steve Hill (au) is applying regolith mapping and landscape evolution models to unravelling the gold distribution in the historic and enigmatic Tibooburra goldfield in western New South Wales. The Tibooburra Inlier Regolith-landform map at 1:25k can be obtained via the LEME website http://crcleme.org.au.

In this area, heavily cemented residual and transported materials drape over Palaeozoic metasediments and intrusives of the Tibooburra and Waratta Inliers. The sediments include marginal marine Mesozoic granule sands and pyritic shale of the Eromanga Basin, plus Cainozoic sediments of the Lake Eyre Basin. Gold nuggets up to one centimetre in size are found in the extensive and complex colluvial regoliths that fringe the basement inliers. However, no evidence of primary gold has ever been seen in the basement. Recent work has shown that the eluvial and alluvial gold particles are spatially associated with the base of the Mesozoic sediments. The basal beds are heavily duricrusted with silcrete, calcrete and ferricrete, with cements of opal, anatase, dolomite, barite, and gypsum. This is a veritable “polycrete” that contains low-level but clearly anomalous gold (up to 60ppb). The form of the gold is yet to be determined. Degradation and redistribution of the gold-bearing “silcretes” creates a large diffuse and spurious anomaly. But when the original distribution of silcrete is reconstructed from the regolith map, and the gold in silcrete is normalised against iron, then vectors emerge that indicate the possible primary dispersion patterns. The real primary source of the gold is still uncertain – but it could equally come from the Mesozoic sediments as much as the basement. There may well be future surprises at Tibooburra. steven.hill@adelaide.edu.au

COBAR - GIRILAMBONE REGOLITHS

Supergene oxide geochemistry

Peter Williams (UWS) and co-workers have examined the thermodynamic models for the dispersion of Cu and As in the oxide and supergene zones of the Cu-Au (Bi-As) systems at Cobar. They provide an explanation of the commonly observed pattern of relatively broad Cu anomalies encircling linear, more precise Pb and As anomalies over near-surface truncated oxide zones. They looked at two oxide mineral systems, the proximal Cu-Pb arsenides, and the overprinting secondary Cu carbonates. They predict thermodynamically that total dissolved Cu in the ambient groundwaters is two orders of magnitude greater in solutions associated with carbonate supergene events than it is in the arsenate event. In this situation there is enough As to fix all of the Pb, but not enough for all of the Cu which remains mobile to eventually report in the hydroxy carbonate/malachite/azurite phases. Consequently in the truncated and exhumed oxide zone, Cu provides the broader footprint which can be sharpened by the Pb anomaly. p.williams@uws.edu.au

Talingaboolba

Keith Scott (CSIRO EM) has highlighted the contrasting geochemical expressions of different types of base-metal deposits in the semi-arid environment of the Lachlan Fold Belt of western New South Wales. He has demonstrated that the composition of gossan and residual soils is controlled by the pH conditions at the time of weathering. The ore at the Zn-Pb-Ag deposit at Elura, (43 km northwest of Cobar) is pyrite-rich, generating highly acidic conditions during weathering, resulting in strong depletion of Cd and Zn throughout the profile, whereas As, Ba, Pb and Sb remain highly anomalous in surficial ironstone and soil. There may be local concentrations of Ag, As, Ba, Cu, Hg, Pb, Sb and Sn in the profile. In contrast, at Parkers Hill, in the Mineral Hill field (65km north of Condobolin), the primary Pb-Zn mineralisation has a carbonate association and is pyrite-poor, resulting in much less acid conditions during weathering. In consequence, Cu and Zn (as well as As, Pb and Sb) are retained in surficial ironstones in essentially the same abundances as the primary mineralisation. Silver, As, Cd, Cu, Sb and Zn may be also concentrated at various levels in the weathering profile. Thus, variations in the suite of geochemical indicators present in ironstones and residual soils are likely to reflect differences in the original mineralogy and the degree of acidity produced during weathering of base-metal mineralisation. keith.scott@csiro.au

Girilambone geochemistry

Ken McQueen (ANU), **Dougal Munro** and co-workers have examined the distribution of ore and pathfinder elements in residual and transported lags related to Cu-Au systems in the Cobar Goldfield. In the insitu regolith, goethite is an important host for Zn, Cu, As and to a lesser extent Pb, Bi and Sb. Hematite is the predominant host for Cu. Thus in goethite-dominant near-surface caps there is a strong correlation of As and Zn with Fe, whereas in hematite-dominant phases there is a strong correlation of Cu with Fe. However in the redistributed lags there is a progressive conversion of goethite-hematite phases to hematite-maghemite phases. At the same time there is an increasing correlation of Pb, As, Sb, Bi, Ba, Cr and Th with Fe, as these pathfinder elements increase in the mature lags. Significantly Zn, Cu and Au do not increase in the mature lags. Thus the actual ore elements fail to report, and the normally immobile Pb, once fixed into hematite, can become widely dispersed by mechanical methods. These results indicate that pathfinder elements should be normalised against Fe for their correct interpretation. kmq@ems.anu.edu.au

Regolith-landform maps

The NSW Geological Survey, a participant in LEME, has released four standard series 1:100k scale Regolith-Landform Maps of the Byrock, Hermidale, Coolabah and Sussex 1:100k sheets. These cover the periphery of the Cobar mineral field.

Peter Buckley (NSW DMR) constructed the Byrock regolith-landform map, which sets the new standard in digital construction. It lies on the northern end of the Girilambone belt and covers the transition from residual/erosional regimes to largely depositional regimes. It is based on new 60m altitude geophysical datasets (magnetics, radiometrics, and DTM), augmented by Landsat 7 and field mapping. It is constructed by the aid of on-screen digitising which facilitates a rapid and systematic approach. The polygons are coded using the RTmap scheme which portrays both the landform and the regolith materials. From an exploration viewpoint

the value of any regolith landform map is to assist planning geochemical surveys. But equally it is a most useful tool in assessing the value and effectiveness of previous geochemical exploration work – an increasing amount of which is being released into pre-competitive delivery systems in digital format compatible other GIS datasets. buckleyp@minerals.nsw.gov.au

Regolith Landform maps complement interpreted solid geology and outcrop maps.

Girilambone palaeochannels

Ros Chan (GA) and several LEME co-workers have developed a method for reconstructing complex superimposed palaeodrainage patterns using aeromagnetic images and GIS-based landform reconstruction techniques, augmented by a program of 247 shallow regional air-core drillholes. In the Cobar area multiple phases of palaeochannel development are recognised, possibly ranging in age from Mesozoic to the present. Some palaeochannels are clearly charted by maghemite trails displayed on 1.5VD magnetic imagery. Of particular interest in this mineral rich area is the fact that some earlier channels have totally different transport direction to superimposed drainages, indicating a complex pattern of repeated river capture, associated with rotational tilting related to neo-tectonic activity. Reports, including data, are available on the LEME website. Drilling indicated that palaeochannels were more extensive than indicated by magnetics. This was confirmed by running two test profiles of fast-turnoff TEM profiles (john.joseph@adelaide.edu.au) which showed a useful contrast between low resistive palaeochannel sediments, and high resistivity saprolitic basement. Understanding the drainage in such a mineral province assists in the review of previous geochemical surveys, the planning new surveys, and the interpretation of transported or displaced anomalies. roslyn.chan@ga.gov.au

Girilambone regolith drilling

The program of 247 shallow air-core holes funded by NSW DMR over the Girilambone Group northeast of Cobar is reported in LEME Open File Reports 148 and 149. These are downloadable from http://crcleme.org.au. Lithological logs, 29-element analyses, PIMA spectrometer data, and selected XRF data are also freely available from the site. Interesting exploration outcomes of this drilling include:

- kaolinite crystallinity and water absorption peak are useful determinants of the transported-saprolite interface
- previously unknown mafic rocks are identified by geochemical signatures, which by association have exploration interest
- occurrences of anomalous gold are noted in calcrete at the saprolite-transported interface, and in saprolite itself
- anomalous Zn is associated with saprolitic volcanics in several buried locations beneath transported regolith
- transported material is largely devoid of recognisable gold, base-metal and pathfinder elements, as determined by total digest.

Judicious sampling of the buried transported-saprolite interface remains the main method of geochemical exploration in these areas. Contact **Keith Scott** (CSIRO EM) keith.scott@csiro.au

Nuclear magnetic resonance

Donald Hunter at CUT is developing a new sensing technique for detecting and characterising groundwater, using nuclear magnetic resonance (NMR). Software has been developed to model the physics of SNMR in 1-D conductive earths using rectangular loops in the presence of planar geomagnetic field gradients. An important capability is the depth at which water can be detected. The loop-size (50x50m to 150x150m) does not significantly increase water detection depth as ground resistivity decreases. don.hunter@csiro.au

A robust method to determine regolith mineralogy

What is it about regolith that lets the salt in one place move, but traps it in another? What are major adsorption sites for heavy metals in the regolith? Mainly it is the clays, and **Richard Greene** and **Tony Eggleton** at the Australian National University are working to develop a quick yet robust way of measuring the kinds and amounts of clay in a regolith sample. Standard methods work eventually, but they take lots of time and are costly. They are applying four quicker methods to determine the mineralogy of finely ground material - fast scan X-ray diffraction, cation exchange, microprobe X-ray analysis, water loss on heating - from which a "best fit" quantitative model of the total mineralogy can be computed. Combined with Infra-Red analysis, this promises to yield fast, accurate, and inexpensive analyses. The methodology will be of benefit to regolith scientists working in environmental management and mineral exploration. richard.greene@anu.edu.au tony.eggleton@anu.edu.au

CRC LEME REGOLITH SYMPOSIA 2004

10-12 November - ADELAIDE
18-19 November - PERTH
24-26 November - CANBERRA

Themes: Mineral exploration; microbiology of the regolith; exploration under cover; natural resource management and hydrogeology in the regolith; history of aridity and exploration in Eastern Australia.

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