# GEOLOGY AND GEOCHEMISTRY OF REGOLITH CARBONATE ACCUMULATIONS OF THE SOUTHWESTERN CURNAMONA PROVINCE, SA: IMPLICATIONS FOR MINERAL EXPLORATION

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## INTRODUCTION

The use of regolith carbonate accumulations (RCAs) in Australian mineral exploration programs has escalated rapidly in the past decade (e.g., McQueen *et al*. 1999, Lintern 2002). The application has revolved around the utility of RCAs as a geochemical sampling media for Au. The technique has been highly successful in the Yilgarn and Gawler Cratons (e.g., Lintern 2001), but to date, less so in other Precambrian terranes.

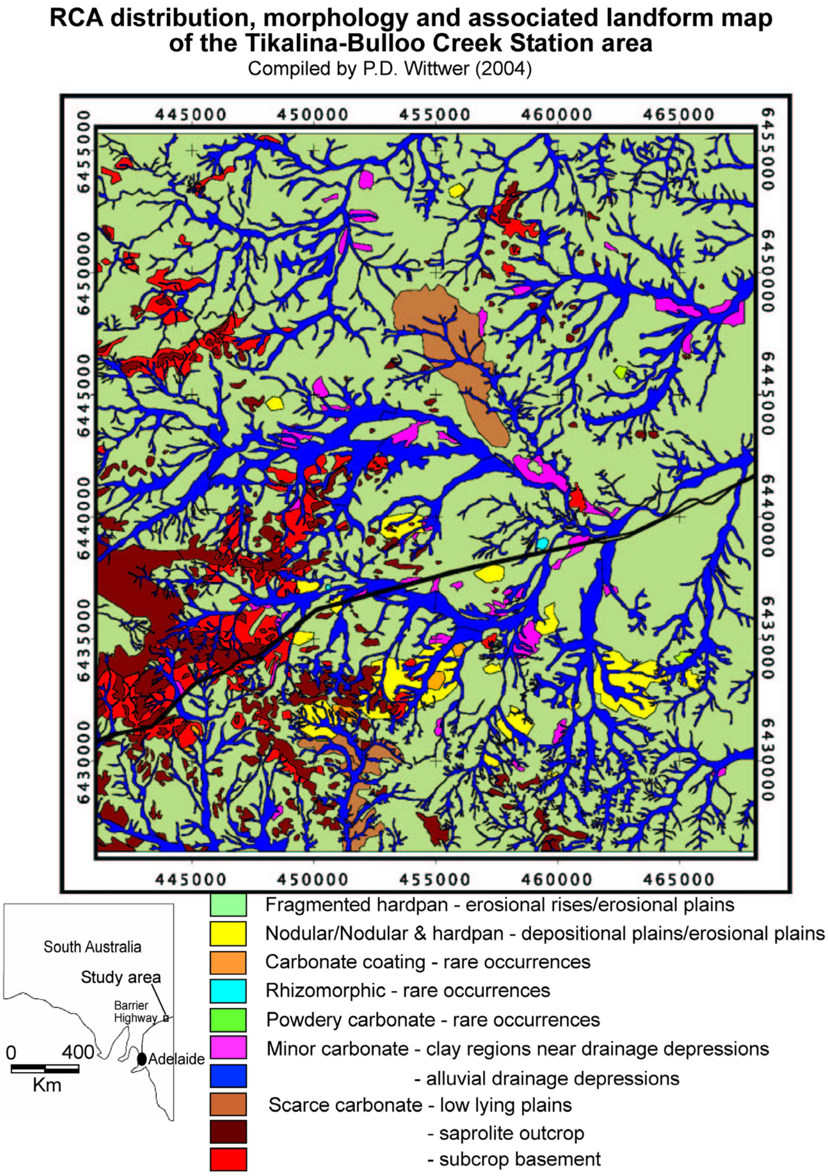


**Figure 1:** Study area location and RCA distribution map highlighting the areas where RCAs are most likely to occur. Also shows the various RCA morphologies found in the area including the dominant fragmented hardpan, nodular/nodular & hardpan, as well as minor carbonate coatings, rhizomorphic and powdery carbonates.

The aim of this study is to characterise a range of RCAs in the Olary Province, South Australia, particularly in the highly prospective Cu-Au region in the southern part of the Province. The study is designed to give an insight into whether RCAs are an effective tool for detecting mineralisation and distin-guishing it from 'back-ground' settings at both a regional and a tenement or prospect scale in the southern Curnamona Pro-vince. We have also examined the potential for RCA geochemistry to serve as an aid to geological mapping in areas of shallow cover.

## GEOLOGICAL SETTING AND SAMPLE AREA

The Curnamona Province is located in eastern South Australia and western New South Wales. It is com-posed of Paleoproterozoic meta-sedimentary and meta-igneous rocks (Will-yama Supergroup) intrud-ed by early Mesoprotero-zoic granitic intrusives and felsic volcanics. Extensive Neo-proterozoic cover sequences unconformably overlie the basement.

The area for the RCA study (Figure 1) was chosen specifically because it is prospective for Au, including such mines as Luxemburg, Wilkins and Green and Gold, and the White Dam deposit. The region is also currently an exploration target area for Au mineralisation, after the recent discovery of the White Dam deposit (Cooke 2003).

## METHODS

The sampling strategy involved a 3-tier approach that is equivalent to different scales of mineral exploration undertaken in the Province: 1) a regional RCA dataset of 161 samples over an area of approximately 840 $km^2$, which encompassed four known mineralisation sites—Luxemburg, Wilkins, Green and Gold and White Dam; 2) 20 samples collected at a spacing of about 250 m in the area of the Wilkins prospect; and 3) sampling transects at about 50 m spacing over the 4 mineralisation sites, yielding a further 38 samples.

RCAs were collected from surface exposures within the study area, which mostly includes rabbit warrens that were occupied and intact, or old rabbit warrens that had caved in and appeared as slight mounds on the land surface. They were ideal sites because the RCAs were brought to the surface when the rabbits dug their burrows, and the original morphology of the RCA sample could still be identified. In addition to the collection of samples, various other attributes were noted at each site, including: the morphology and lithology of RCAs; vegetation community and dominant species; and landform setting. Samples were analysed at Amdel Laboratories, Thebarton SA, by ICP-MS, ICP-OES and AAS (graphite furnace).

## RESULTS AND DISCUSSION

### RCA morphology and distribution map

The field observations form the basis for the production of a regional RCA distribution map (Figure 1). This map serves as a 'go-to map' for mineral explorers planning RCA sampling programs. The dominant RCA morphology recorded was fragmented hardpan. The other major types were nodular, or a mixture of nodular and hardpan, along with rhizomorphic and powdery carbonates and minor carbonate coatings on detrital clasts. Minor carbonate occurrences were noted in clay-rich settings near drainage depressions and in alluvial drainage depressions. A large depositional plain forms the upper central part of the study area, dominated by sheet flow sediments with a ferruginous surface lag. There were no RCAs found in this part of the study area, and this could reflect the well-drained and highly leached nature of the regolith here.

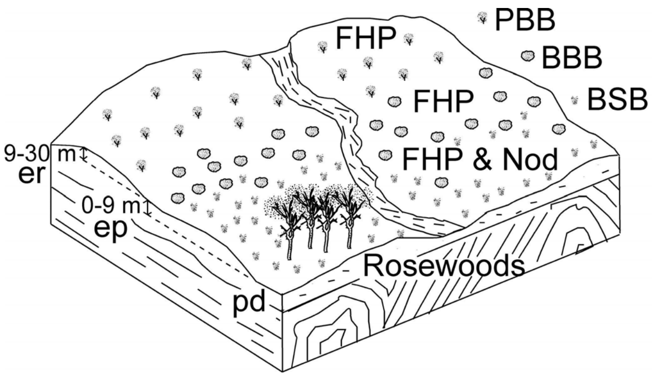


**Figure 2:** Catenary diagram showing the general observations of RCA morphological facies grading from fragmented hardpan style (FHP) on higher relief to nodular (Nod) on the plains. The transition from pearl blue bush (PBB) to black blue bush (BBB) to bladder salt bush (BSB) was also noticed over these landform changes.

The nodular RCAs tended to occur on the plains, and the morphological facies appeared to grade towards more of the fragmented hardpan style as the relief increased (Figure 2). This does not mean that only nodular RCAs occurred on the plains, as there were also many fragmented hardpan RCAs in this landform setting. The reason for this may be due to erosion, with the nodular RCAs originating from a landform setting higher in relief, and then rounded with progressive down slope transport. However, the mixture of nodular and hardpan morphological facies within depositional plain settings suggest that this may only be partly the case, and that some hardpans have also reformed in low-lying depositional plains. This interpretation is significant for understanding how trace metal assay results are monitored through dispersion pathways in the landscape, and it raises the potential for nodular morphologies to include geochemical signatures derived from broad areas of the scale of at least several hundred metres. This also increases the probability for these materials to host enlarged anomaly 'footprints' that translate to being larger area exploration targets (although in this case the 'anomaly' magnitude may not be as great).

## GEOCHEMISTRY: REGIONAL AND PROSPECT-SCALES

The reconnaissance sampling program was designed to link RCA whole rock chemistry values with the morphology and landform setting. In general, the values for anomalous element assays increased as the relief of the landscape decreased, and that fragmented hardpan RCAs generally showed higher trace metal assay values than the nodular morphological facies. There were, however, fewer nodular samples in the dataset, decreasing the confidence in this suggestion.

The geochemical results from the regional data set provide a view of the background levels of Au and associated pathfinder elements. When exploring for Au mineralisation using RCA samples, the best pathfinder indicator element is Au, however, given the low absolute concentrations of Au in many samples, other pathfinder elements may also be useful. Butt (1997) identified some pathfinder elements for Au, including As, Sb, Mo, Bi and W. Figure 3 shows graphs of these trace elements versus Au, and in general there are poor correlations between them in the regional RCAs.

Elements such as Cr, As, Ga, Sc, V and possibly Au, are known to have an association with Fe-oxides (Butt 1997, Butt *et al*. 2000), although this is typically emphasised for 'lateritic' terrains. Correlations between these elements were tested, and it was found that there were poor correlations between these elements in the regional RCAs (except for Cr and possibly V).

After establishing a RCA geochemical map for the region, we then compared the RCA data at the prospect scale from the Wilkins area. The ranges of results at both scales were similar, but the values for 'anomalous' elements increased when the sample locations were near the mineralisation, or part of dispersion pathways within tens of metres away from it. More steeply sloping landform settings directly influenced these pathways, where upslope values reasonably close to the mineralisation were not very high, but further down slope there were anomalous values recorded.

Transects over mineralisation at the four prospects showed an increase in Au assay values in the RCAs closer to mineralisation. This trend was also noticed with other elements, including Zn, Pb, Fe, Cu, Bi, Co, Mo, V, W and Ni. The association between Au and its pathfinder elements was also much stronger in the RCAs over mineralisation than in the regional samples (Figure 4). Likewise, a similar trend was observed with the elements associated with Fe in the RCAs over mineralisation, where Ga and V were the dominant accumulative elements.

## REGOLITH GEOCHEMICAL MAPPING RESULTS

In order to evaluate the potential of RCA geochemistry as an indicator of the underlying basement geology, we compared the RCA whole rock data with the interpreted solid geology maps and/or surface geology. The dominant lithologies in the study region include non-magnetic granitoids, variably magnetic mica-bearing granitoids, the Willyama Supergroup sequences and the various Adelaidean sediments. An important difference was noticed in the RCA geochemistry between the non-magnetic granitoids and the other variably magnetic biotite-muscovite granitoids, with the former plotting in distinct fields on a plot of Fe/Mg versus K and Ca/Mg versus Fe. This could possibly be attributed to the lack of magnetite, for example, in the non-magnetic granites, rather than an abundance of other Fe-bearing non-magnetic minerals. Additionally, some RCAs mapped over the known anomalous Bimba Formation showed, in

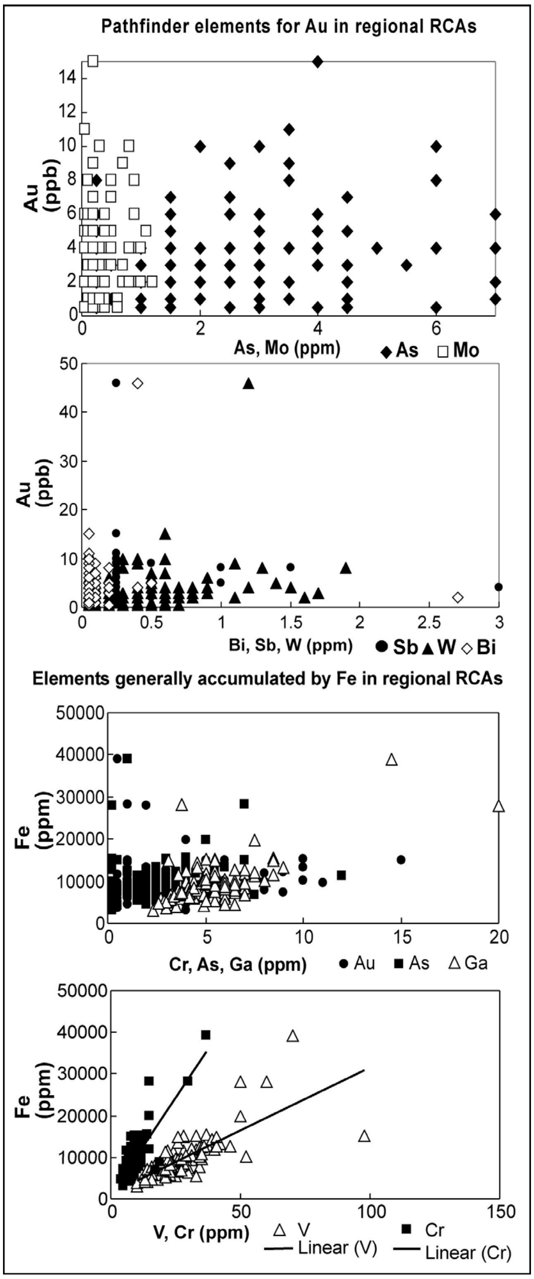


**Figure 3:** Regional RCA geochemical results, highlighting the lack of correlation between Au pathfinder elements and Au and a similar, but slightly better, scenario for Fe and the elements it normally accumulates. This is expected, as there probably aren't any regional Au-mineralised systems.

box-plot analysis:

- extreme upper outlier values for P;
- upper outlier values for Au, W, Mn, Cu, Pb; and,
- upper hinge values for As, Zn, Mo, U in the regional geochemical maps.

Also, some RCA assay values over mafic dykes showed upper outlier values for Ag, Cu, Pb, Zn, As, and upper hinge values for Au, Co. In contrast, some RCAs over Adelaidean sediments showed much lower anomalous concentrations of the same package of elements, compared to the Bimba Formation sites, with the values lying near the median, i.e., the upper box to lower box range.

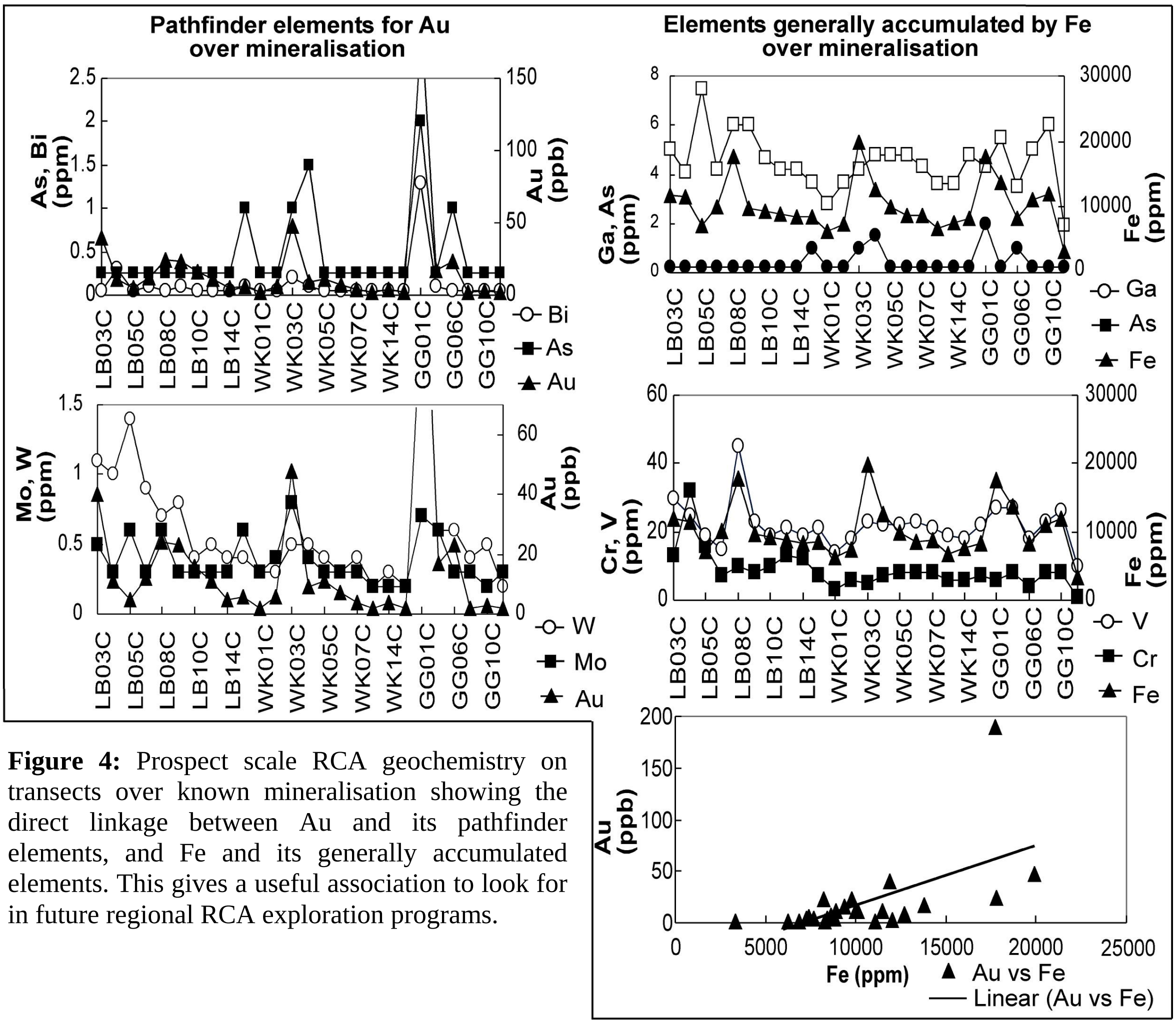


**Figure 4:** Prospect scale RCA geochemistry on transects over known mineralisation showing the direct linkage between Au and its pathfinder elements, and Fe and its generally accumulated elements. This gives a useful association to look for in future regional RCA exploration programs.

**IMPLICATIONS FOR MINERAL EXPLORATION**

The regolith geology and geochemistry of RCAs in this study revealed a number of important discoveries. Firstly, an understanding of RCA morphology, distribution and landform setting is vital when attempting an exploration sampling program. Mineral explorers need to know where and what to sample and any anomalous element values need to be taken into the context of the landform setting. Also, as the tenement-scale sampling illustrated, it is useful to include various other elements in the analysis package when analysing for Au in the RCAs, as the presence of certain minor elements, such as the pathfinders, may also be useful indicators of mineralisation. The linkage between RCA geochemical signatures in shallow cover and the underlying rock lithologies may also provide clues to refining the interpreted geology maps in areas of shallow cover, and therefore aid further mineralised system discoveries.

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