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Regolith geochemical exploration in the Girilambone District of New South Wales

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ABSTRACT

This study examines the distribution of geochemical elements in the surficial and regolith profile environments, about two copper sulfide deposits in the Girilambone district of New South Wales. Multi-element geochemical and mineralogical investigations of regolith, rock and mineralised samples from the Larsens East and Hartmans prospects of Girilambone North and the Tritton copper deposits, were conducted to determine the geochemical expression of mineralisation and mechanisms of geochemical dispersion within the regolith environment. Host metasedimentary units and intrusive mafic rocks can be discriminated geochemically at various levels within the regolith and primary environments, particularly on the basis of REE geochemistry and several other key elements, thus establishing a ‘background’ geochemical variance of non-mineralised lithologies. Geochemical data were examined within a regolith-landform context, following investigations of regolith architecture and development, which identified two prominent regolith-landform examples within an otherwise low-relief, erosional regime. At Girilambone North, weathering of greater intensity has developed a moderately ferruginised upper regolith and poorly developed ‘lateritic’ profile, resulting in preservation of surface regolith horizons, while within the Tritton study area, upper regolith horizons have been partially truncated by erosive stripping, with residual soils developed directly on weathered saprolite. Each instance forms an individual case from a geochemical exploration viewpoint, for which strategies for further exploration have been developed.

Primary Cu mineralisation within the Girilambone district occurs as massive pyrite-chalcopyrite mineralisation within a pyritic envelope. Mineralisation is generally associated with intense silicification and may be associated with mafic volcanism and characterised by anomalously higher occurrence of the elements Sb, As, Bi, Br, Cd, Co, Cu, Au, Fe, Pb, Mo, Ni, Se, Sr, S, Te, Sn, W and Zn. At Girilambone North, primary mineralisation occurs within and below the extent of regolith development, and secondary mineralisation has formed as laterally extensive secondary chalcocite, copper oxide and copper carbonate zones above the weathering front, which extends to approximately 90 m below the present land surface. Moderate surface ferruginisation has retained primary mineralised elements such as As, Bi, Ba, Co, Cu, Au, Hg, Mo, Ni, Ag, Te and Zn within the vicinity of primary mineralisation, while these elements are also enriched in soil geochemical analyses. Strong leaching due to acidic weathering solutions borne from oxidation of sulfide minerals, has formed a displaced geochemical
anomaly to the north of known mineralisation in saprolite and soil samples, while these same media did not necessarily display anomalism directly above mineralised zones. Geochemical dispersion has been predominantly by hydromorphic dispersion and migration of groundwaters through north-trending late-stage faults and structural zones. This study also examines the surface geochemical expression of mineralisation over the concealed Tritton Copper deposit in regolith (at the time of sampling) relatively undisturbed by prior mining activities. It is in effect a retrospective study granted that the position of sulfide mineralisation at depth has been well defined by exploration and resource delineation drilling. Subtle multi-element geochemical anomalism coincident in residual soil and saprolite sampling, from this study and re-analysis of previous geochemical exploration data, has been identified at the up-plunge and up-dip extensions of Tritton mineralisation. Geochemical dispersion about the Tritton copper deposit is almost entirely mechanical, and limited to residual soils and saprolite regolith materials at the up-plunge and up-dip extension of concealed mineralisation. Coarse-fraction residual soils show anomalous Sb, As, Cu, Au and lesser Bi, Cd, Mo and Zn in soil sampling traverses, and saprolite sampling displays a subtle multi-element As, Cu and Pb response. Erosive stripping of the upper regolith profile and relative resistance of host quartzite lithologies to weathering has resulted in geochemical anomalism of only limited extent at the surface level.

A multi-element analysis approach and sampling of common regolith materials is recommended for further geochemical investigations of the regolith. Subtle geochemical associations are best identified by multi-variate data analysis methods, which when viewed spatially in conjunction with other geochemical, geophysical or geological information forms an effective approach to regolith geochemical exploration.

The Girilambone district of New South Wales represents an area of relatively un-explored, yet potentially prospective, mineral wealth. Increased interest in the region has arisen from recent government research initiatives, renewed mining and exploration activities and rising commodity prices. The future of exploration for Girilambone-style mineralisation may depend heavily on regolith geochemical investigations, of which this study provides a timely account of two mineralised occurrences in the Girilambone district.

**Keywords:** geochemical dispersion; regolith geochemistry; mineral exploration; multi-variate data analysis.
CERTIFICATION

I, Benjamin R. Ackerman, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Earth and Environmental Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Benjamin R. Ackerman

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Figure 6.14 Topographic relief along the 29300N soil sampling traverse, Tritton study area. The start of the sampling traverse (0 m) represents the western extent of sampling.

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Figure 6.16 Topographic relief along sampling Line 2 soil sampling traverse of the current study, Tritton study area. The start of the sampling traverse (0 m) represents the western extent of sampling. The limited extent of Nord soil sampling conducted in conjunction with the current study, is indicated.

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Figure 6.18 Summary diagram of Tritton drill hole geochemistry.

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Chapter 7

Figure 7.1 Uniform geochemical variance of (unmineralised) quartz- and chlorite-rich metasedimentary samples of the Girilambone district. Minimum and maximum values are shown; all elements in ppm, except where otherwise indicated.

Figure 7.2 Chondrite-normalised multi-element geochemical patterns of Tritton mafic samples, which have been normalised against chondrite values of Wood (1979). At least two phases of magmatism are inferred (triangles and circles) which are indicative of relatively Th-rich and Cr- or Ni-rich phases, respectively.

Figure 7.3 Range of chemical composition in ppm of the Larsens East primary and secondary mineralised zones. The lower limits of response for selected (below detection) elements are represented as half of the detection limit.
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Figure 7.9 Plot depicting the Fe/Sc ratio of regolith samples from the Girilambone North study area. The lower limit of the Fe/Sc ratio is shown as a red dashed line, which represents the approximate Fe/Sc ratio (approx. 2140) of parent rock material, above which Fe accumulation is indicated.

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Figure 7.14 Schematic model of Cu dispersion in the Hartmans mineralised system, displaying northerly migration of Cu. Strong depletion zones in the upper profile have leached Cu in close proximity to weathering sulfides (acid conditions), and redeposited it under the influence of decreasing pH groundwaters, moving away (northwards) from the primary mineralised zones. Upper ferruginous zones and soils exhibit subtle, multi-element anomalism in close proximity to primary mineralised zones.
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Figure 7.20 Schematic model of the Girilambone district showing the regolith profile characteristics for a partially truncated residual profile (A), partially preserved regolith with ferruginous upper horizons (B) and areas of thick transported cover (C).
LIST OF UNITS, SYMBOLS, ACRONYMS AND ABBREVIATIONS

**Units**

- °C: temperature in degrees Celsius
- m: metre
- g: gram
- mm: millimetres; $10^{-3}$ m
- kg: kilogram; $g = 10^{-3}$ g
- µm: micrometres; $10^{-6}$ m
- t: tonnes; $t = 10^3$ kg
- oz: ounce (imperial); 1 oz = 28.350 g

**Symbols**

- Eh: electrical potential (millivolts)
- Kc: critical value of Kurtosis for attainment of a normal distribution
- n: number; population size
- pH: minus logarithm, base 10, of the hydronium ion (H⁺) concentration
- ppb: parts per billion ($10^9$)
- ppm: parts per million ($10^6$)
- RL: reduced level (metres above sea level)
- Sc: critical value of Skewness for attainment of a normal distribution
- $r^2$: Pearson correlation coefficient
- $\alpha$: statistical confidence interval
- $\lambda$: Box-Cox transformation coefficient
- $\rho$: significant level of the correlation coefficient

**Common Acronyms**

- AINSE: Australian Institute of Nuclear Science and Engineering
- AMG: Australian Map Grid (co-ordinate system)
- ANSTO: Australian Nuclear Science and Technology Organisation
- ARC: Australian Research Council
- BDL: below detection limit (of chemical analysis instrumentation)
- CRC LEME 1: Cooperative Research Centre for Landscape Evolution and Mineral Exploration
- CRC LEME 2: Cooperative Research Centre for Landscape Environments and Mineral Exploration
- CSIRO: Commonwealth Scientific and Industrial Research Organisation
- DEM: Digital Elevation Model
- EUROLAT: European Network on Lateritic Weathering and Global Environment
- GIS: Geographical Information System
- HREE: Heavy Rare Earth Elements
- ICP-AES: Inductively Coupled Plasma Atomic Emission Spectrometry
- ICP-MS: Inductively Coupled Plasma Mass Spectrometry
**Chemical Elements**

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