Advances in regolith research with respect to locating mineralisation

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Regolith is the surficial blanket of material including weathered rock, sediments, soils and biota that forms by the natural processes of weathering, erosion, transport and deposition. It has complex architecture, and may vary in thickness from a few centimetres to hundreds of metres. It hosts or hides valuable mineral deposits, we live on it, we grow our food in it, it is the foundation of many major engineering works, and much of our water supplies are stored in it. It underpins our economic, social and infrastructure systems.

Prolonged deep weathering over the last 10 to 250 million years, on a predominantly stable continent of antiquity, has created a unique Australian regolith. An understanding of regolith architecture and the processes that act within it are essential to address the challenges of sustainable economic development. Regolith science has important applications in the fields of mineral exploration and natural resource management. However, the uniqueness of the Australian regolith means research has to be done here and cannot be borrowed from anywhere else in the world.

Despite some impressive advances in exploration technology in the last two decades, geochemistry remains the prime direct sensor in the armoury of explorers. This is because many mineralisation styles have polar symmetry – that is pipe or sheet-like bodies of generally vertical dimension. Inevitably, they cut the Earth's surface and become disturbed in the regolith. However, most surface expressions of mineralisation in residual regolith terrains have been identified and tested by explorers, many of them with considerable success. There remains now only the subtle expression of near surface ore bodies, and most importantly, the undiscovered mineralisation under sedimentary cover which presents a special challenge. Of even greater challenge, from the geochemical viewpoint, are the non-polar blind ore bodies that are encased in lithified rock.

There is growing need to make surface geochemistry effective for exploring across depositional landscapes with shallow to deep transported cover and often complex regolith, using techniques such as partial and weak selective extractions and gas analysis. However, these techniques have been found to be only partly successful in delineating buried ore bodies, especially in Australia. The particular mechanismsm (s) and their effectiveness in transfering metals associated with mineralisation upwards through the often complex transported overburden is poorly understood. This lack of understanding complicates and limits the interpretation of geochemical datasets, and precludes the discrimination of negative from null results. The different transport mechanisms, based on the main transport medium, can be grouped into four categories: *hydrogeochemical, gaseous, vegetation and bioturbation*. Most of these mechanisms are influnced by microbial reactions and the nature and evolution of the transported cover.

All groundwater mechanisms are limited by the upper level to which groundwater can rise, which is the water table and the capillary fringe, except for seismic pumping. Dilatancy pumping - the effusion of mineralised groundwater at the surface following earthquakes – is the most likley mechanism that can bypass the limitation of the depths of the water table, but appears restricted to active neo-tectonic areas. In arid terrains, such as theYilgarn Craton, the groundwater table is generally below 10 m depth. Thus, groundwater is unlikely to be involved in any upward metal transport. Gas-based mechansims can operate rapidly through the entire transported cover. However, these mechanisms are all strongly affected by the presence of preferential pathways in the ore body, such as structural conduits, and the nature of the overlying cover. The migration of gas and volatiles along conduits is well documented and suggests 'leakage' along tectonic structures.

The vegetation biogeochemical cycle, where plants bring metals from the subsurface to the surface, has long been advocated as a predictive metal transfer tool in the northern hemisphere and parts of the tropics. The greatest potential for biogeochemistry lies in areas of transported overburden, where tap roots and, if the cover is shallow, some lateral roots, may access weathered bedrock and deep groundwaters (Figure 1). There is widespread vegetation cover across nearly all climatic, geological and regolith-landform environments in Australia and, consequently, a wide choice of plants for biogeochemical sampling. However, this choice is constrained by the need for the plants to have (i) deep tap roots and (ii) a sufficiently extensive distribution at the scale of the survey. Plants have evolved to mitigate the stress caused by the dry climate and nutrient-poor soils that prevail over much of Australia. One adaptation is dimorphic root systems with shallow lateral and deep tap (or sinker) roots. The latter may reach depths of 40 m or more and are able to access water and nutrients deep in the regolith, especially during dry periods. Uptake of trace elements by plants is facilitated by production of organic ligands by plant roots. Australian native plants produce cyanide, oxalate and citrate and it is likely that these and other compounds dissolve trace elements.

This paper presents findings of studies on vegetation that show geochemical anomalies in plants over several buried gold and base metal deposits in the semi-arid and arid terrains of Australia. At these locations, transported overburden is up to 20 m thick and varies in age from Quaternary to Permian. The geochemistry of the soils and other regolith materials is compared with that of vegetation (litter, bark, phyllodes, roots, branch wood) and the dispersion models will be presented. These studies are part of a wider geochemical and regolith project that investigates mechanisms of metal transportation, particularly through transported overburden.

REFERENCES

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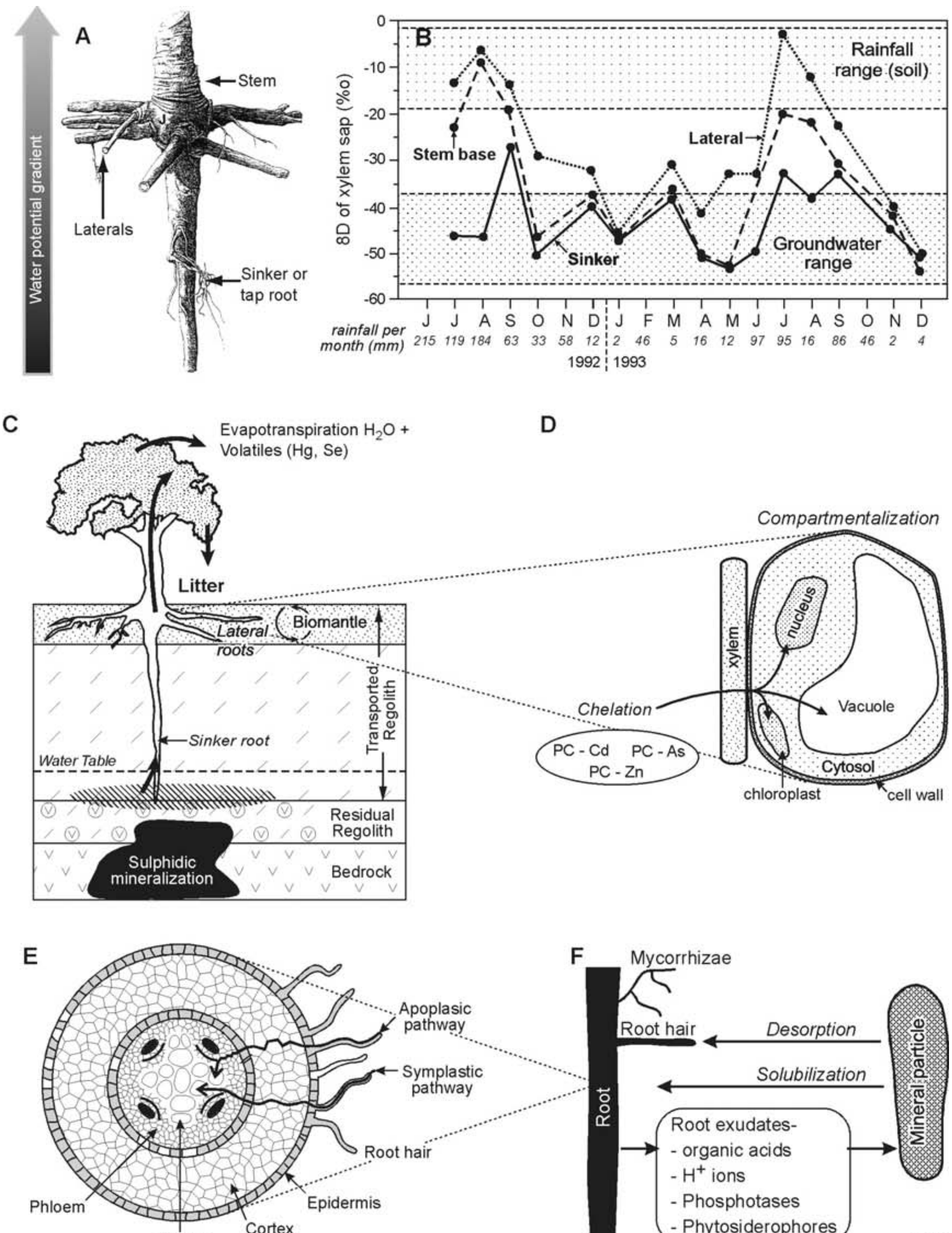

Figure 1. Plant water and nutrient uptake strategies that potentially can contribute to metal transfer from deeper subsurface to surface (after Aspandiar *et al.*, 2006).

A) Illustration of root morphology of the Banksia with lateral and sinker roots. Water potential gradient from sinker to leaf results in transfer of water and nutrients from deeper subsurface.

B) Seasonal variation in deuterium isotopic composition of stem, sinker and lateral roots demonstrating uptake of groundwater by the plant during summer months via sinker roots (after Pate *et al.* 1999).

C) Illustration of metal transfer process from deeper regolith and groundwater to plant tissues to relocation to above ground tissues (shoot, leaves).

D) Strategies employed by the plant to detoxify and store a high concentration of specific metals within its tissues.

E) Metal transfer through roots to the xylem via the apoplastic (along cell walls) or symplastic (across cells) pathways.

F) Illustration of physiological and biochemical metal acquisition strategies employed by roots, especially to acquire non bio available metals associated with insoluble oxides and hydroxides.