PIT EXPERIMENTS: AN UNDERSTANDING OF METAL MIGRATION THROUGH TRANSPORTED COVER IN AUSTRALIA

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Introduction

As mineral exploration moves into regions dominated by transported cover, conventional techniques may not be applicable and thus increasingly there is a requirement for new innovative approaches to geochemical exploration. But to develop such new approaches there is a major need to identify the operating mechanisms capable of transferring elements from buried mineralisation upwards through cover to the surface. With this objective in mind, the pit experiments were developed to test the vertical mobility of elements through transported cover.

Methods

The pit experiments were carried out at the Australian Resources Research Centre (ARRC) in Kensington (Western Australia), February 2007 (Figure 1). Pits were excavated to approximately 2 m depth. About 10 kg of 3 metal-rich materials were separately placed in trays: (1) coarse crushed Cu-Pb-Zn ore from the Teutonic Bore VMS deposit; (2) Au ore from the Kalgoorlie Super Pit; and (3) salts of Pb, Ni, Cu and Zn nitrate.. Holes (~5 mm diameter) were made in the trays to allow for free drainage to compare the seasonally saturated (pooled water) versus unsaturated environments (free draining). The average annual rainfall is approximately 850 mm. Two pits had the VMS ore material on trays with and without holes and one pit had Au ore on a tray without holes. Two pits had no ore material (background), but had trays with and without holes. All the pits were refilled with the sand that was excavated. Surface soil samples (0-5 cm) near and away from the pits were collected from the pit experiment site from February 2007 (start of the experiment) to September 2012 from the two traverses named as northern and southern traverse. Sampling was done in September (after winter rainfall), March (after hot summer) and December (mid summer). Much of the changes in element chemistry, pH, electrical conductivity (EC) and to a lesser extent gases were monitored using surface soils and collector devices. Surface soil and vegetation samples were used to detect elements transported to the surface by biota, gases or unsaturated water flow. The soil fraction used for analysis is <250 µm which forms a very small proportion (<3 %) of the total sample. At the end of the pit experiments at ARRC (November 2012), the pits were cored with a hydraulic push probe and samples collected from the soil profiles (approximately every 20 cm to a final depth of 3 m) to determine any changes in pH, EC and geochemistry.

Results and Conclusions

The 3 m core samples over the VMS and Au pits reveal both upward and downward dispersion of Cu, Zn, Au and As. Upward migration occurred 40-60 cm above from the base of the pit which is overlain by a significant “depleted zone” which in turn is overlain by some elevated concentrations of Cu, Zn, Au and As at or near-surface. The pit containing soluble metal salts did not show upward metal migration. Downward migration of metals occurred to the limit of the core sampled (3 m) in all the pits irrespective of whether the trays have holes (free draining) or not (seasonally saturated).

Significant increases in concentrations of water extractable Cu, Zn and As and aqua regia extractable Au in soil (<250 µm) in surface soils from over the mineralised pits (VMS without holes and Au with holes) suggest that there has been upward vertical migration of metals though 2 m of sand over a period of a few months. However, the similar elevated concentrations of Cu and Zn do not occur directly over the VMS pit with holes. Vertical migration is more active following winter (September) and in the seasonally saturated ore experiments for the VMS pit (without holes). This trend was not observed for the Au pit which has holes and shows similar responses both following winter and summer. The reasons for these differences are not clear. No elevated concentrations in other metals such as Pb, Ag, Sb, In, Bi, Ni and U were noted over any mineralised pit. However, some of these elements form false positives in some summer sampling periods associated with the formation of Fe oxides over both mineralised and background pits.

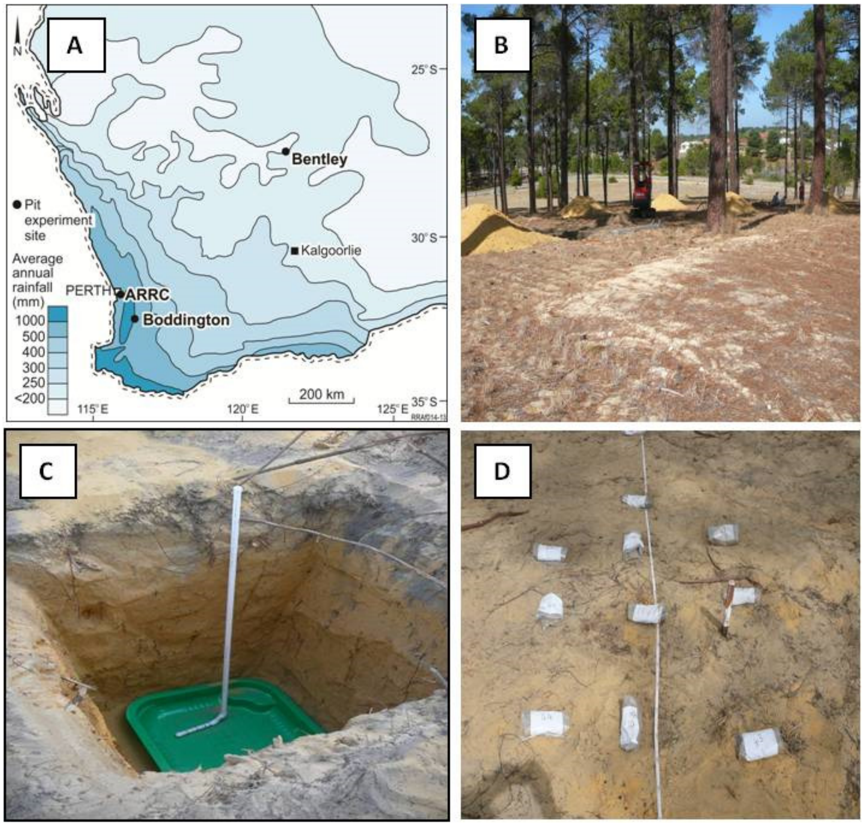

Figure 1. (A) Location of ARRC pit experiment site in southwest Australia. (B) ARRC experimental site with pits being excavated in the background. (C) Two metre deep pit showing grey sandy organic soil underlain by yellow sand. A plastic tray is placed at the base of the pit. (D) Surface soil sample distribution over a pit.

Over the period of seven months, Cu, Zn and As have been incorporated into the most labile phase and anomalies in surface soil over mineralised pits can be best recognised by the weak Water Leach. In contrast, Au anomalies are best depicted by aqua regia and probably occur as nanoparticles of Au. Copper, Zn and As anomaly formation does not appear to be an incremental process as they accumulate in a non-linear fashion and their concentrations are variable over sampling periods. In contrast, Au showed relatively linear trends compared to Cu, Zn and As possibly reflecting incremental accumulation.

There were no significant responses of mineralisation in the sampled vegetation. Hydrocarbons and metals in gas collectors near the surface were all similar except for a single sample that showed anomalous Cu and Zn over the VMS pit that exhibits the surface anomaly. No differences in surface soil pH between mineralised and background pits were observed. With a lack of significant responses in pH, gas collectors and vegetation, it is suggested that anomaly formation for Cu, Zn and As in the pit experiment is an episodic and cyclic process largely driven by capillarity with a lesser influence of biogeochemical cycling by grasses, in which batches of metals in water-soluble form are introduced (Figure 2). Soil forming processes (ferruginisation) may form false positives and the data need to be normalised with care.

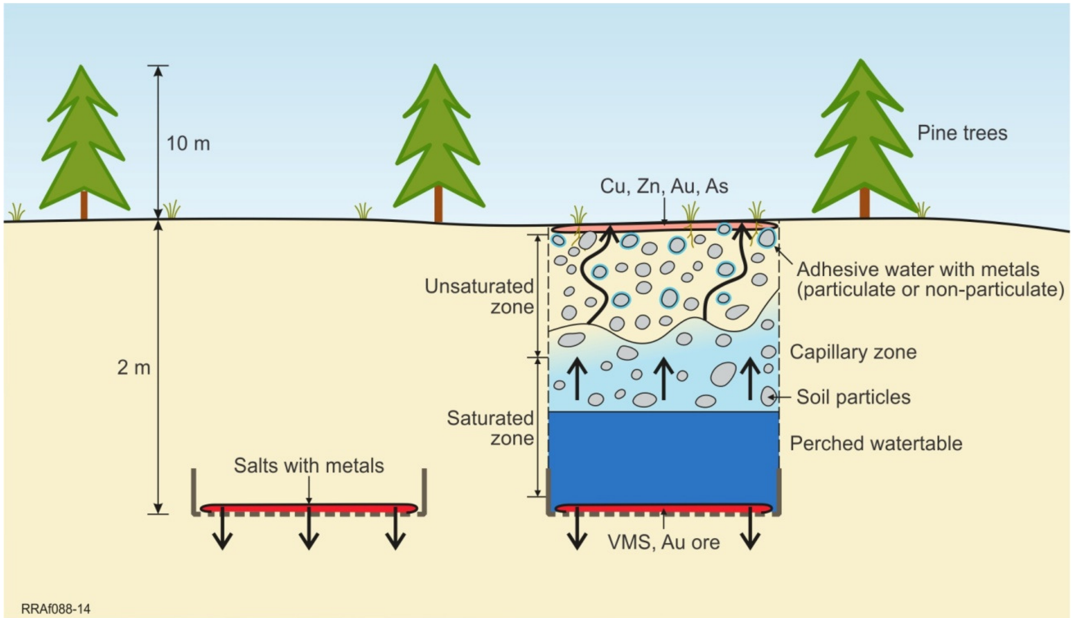

Figure 2. Role of capillarity in forming surface soil anomalies, ARRC pit experiment.