POST-DEPOSITIONAL WEATHERING FEATURES AND PROCESSES IN SEDIMENTS - BASED ON SELECTED SITES IN AUSTRALIA

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INTRODUCTION

This paper presents some post-depositional weathering features of sediments from six areas: Bronzewing, WA (Discovery and Central Pits, and Sundowner); Mt Gibson, WA (Highway Pit); Parkeston, WA (adjacent to Kalgoorlie Golden Mile); Kanowna Belle, WA (Kanowna Belle Pit); North Parkes, NSW (Pit E26 and 27); and, Wannon, VIC (Wannon Quarry).

The Yilgarn classification for sediments by Anand & Paine (2002) is adapted for these studies and sediments outside the Yilgarn Craton are here informally grouped according to this classification. The classification broadly identifies five principal sedimentary groups: A) Permian: glacial to fluvio-glacial deposits of boulder clay and sandstone; B) Early to Mid-Tertiary Palaeochannel sediments of sand and clay; C) Late Tertiary massive red clays with ferruginous granules; and, D) Late Tertiary-Quaternary colluvium-alluvium.

Within these study areas, Group D is most widespread followed by Groups B and C. Post-depositional weathering features for Group B and D sediments will be discussed.

POST-DEPOSITIONAL WEATHERING FEATURES AND PROCESSES

Post-depositional weathering features observed in the study areas are associated mainly with two processes: oxidation-reduction; and, precipitation from interstitial fluids. Both processes also occur in similar terrains elsewhere in Australia.

Oxidation-Reduction

The oxidation-reduction process principally originates from differences in the redox potential in sediment, due to variable aeration and/or biochemical processes related to decaying plant roots. Aeration is affected by fluctuating water tables or moisture regimes and porosity, the latter related to texture, plant roots and bioactivity.

Mottling of sediments is most commonly associated with redox processes, as is Mn staining, gleying and dissolution/degradation of ferruginous nodules and types of Fe-oxide species present.

Mottling occurs in all groups of sediments due to pockets of impeded internal drainage. Megamottles are common in palaeochannel clay sediments (Group B), for example at Bronzewing and North Parkes. At Bronzewing, the morphology of the megamottles on the pit wall depends on the orientation of sectioning. On a vertical pit wall, the megamottles appear as two short subparallel zones of Fe oxides enclosing a bleached or Fe-Mn depleted zone. On an inclined pit wall, the megamottles are visible as oval-shaped rims of Fe oxides enclosing bleached clay. The contact between megamottles and the surrounding kaolinite of low crystallinity is commonly sharp and this may be interpreted as red ferruginous mottles formed in the matrix material of white clay. However, the field relationship indicates otherwise: the mottles form elongate patches of white clay in a matrix of red ferruginous clay. The elongate patches of white clay are probably developed by the dissolution of iron oxides around tree roots. The removal of iron around tree roots may have been affected by the microbial decay of organic matter, which generated reducing conditions under which Fe^3 oxides were dissolved and redistributed. Precipitation of the dissolved ferrous iron as hematite (as opposed to goethite or some other iron oxide mineral) in areas between the roots, which remained oxidising, may have been caused by a combination of low moisture contents, high temperatures, relatively low concentrations of organic matter and high rates of Fe supply (Schwertmann 1985). At North Parkes (NSW), megamottles in the upper part of the palaeochannel clay are attributed to the same process as at Bronzewing. However, at the base of the palaeochannel clay, megamottles show a gradational boundary with the surrounding gleyed matrix. These megamottles generally are ochre coloured and goethite-rich at the outside with a reddish, hematite-rich clay core.

Manganese staining or Mn varnish is common on well-developed hardpanised colluvium-alluvium (Group D) at Bronzewing and Mt Gibson. At North Parkes, the basal palaeochannel sandy clay facies (Group B) just above the saprolite is strongly stained with Mn-oxide, suggesting groundwater flow in the aquifer and supply of Mn ions.

The occurrence of different Fe-oxide species may be related to the moisture content and sediment textures. At North Parkes E27, a moist but aerated palaeochannel clay is ochre and goethite-rich. At Wannon, goethite formed within a ca. 6 m thick sand unit due to an increased clay content (higher water holding capacity), possibly due to illuviation from the overlying sands. At North Parkes E26, gleying is common, possibly due to very poor internal drainage within the impervious clayey palaeochannel sediments. The gleying may indicate a temporarily perched water table and reducing conditions.

Disintegration of ferruginous nodules in sediments has been observed at the base of the Group B palaeochannel sediment in Bronzewing. Such disintegration may be the result of reductive dissolution of Fe from ferruginous nodules caused by strong leaching and constantly low redox micro-environment originating from decayed tree roots or pockets of water saturated sediment. Hence, any potential geochemical signature that may be acquired by these ferruginous nodules from underlying mineralization may be lost by this dissolution. In addition, the reductive dissolution of Fe oxides may also be an important mechanism for the destruction of maghemite or hematite phases present in these ferruginous nodules.

Conversely, ferruginous nodules may also form in sediments. At Sundowner, spherical pisoliths are observed in a puggy, dark yellowish brown, smectite-kaolinite clay facies near the base of the palaeochannel clay sediments (Group B). The pisoliths can be magnetic or non-magnetic and are 2-3 mm in size. The cores of the pisoliths are usually variably sized ferruginous fragments, fossilized wood or clay nodules. The cutans are micro-laminated. Concentric pisoliths in these clays have a complex history. Theories of formation of pisoliths and ooliths are numerous (Pettijohn 1975, Anand & Paine 2002). Pisoliths in palaeochannel sediments appear to have formed in a static environment described below:

1. Pisoliths in the palaeochannel environments may have originally developed within the upper part of the relict profile. They were then eroded and deposited within the grey clay facies of the channel sediments. This is indicated by incomplete or broken cutans, compound pisoliths, the presence of maghemite-rich fragments within cores and differences in the quartz grain distribution between these nodules and pisoliths and that of the grey clay;
2. Some of these pisoliths may have been partly dissolved in an originally reducing environment;
3. A second generation of pisoliths formed *in situ* within the sedimentary sequence either without a nucleus or around a detrital nucleus of fine quartz, organic debris, hematite-maghemite-rich fragments or clay. Inorganic or biogenic mechanisms may have led to accretionary growth. Ostwald (1990) attributed fine layering to organically mediated growth in a fluid medium. However, in places, it is difficult to decipher which process (inorganic or biogenic) is dominant.

Precipitation of Interstitial Fluids

Interstitial fluid can, depending on the nature of the ions it carries, affect silicification, calcification, dolomitisation, gypsification and neosynthesis of clay minerals.

The development of hardpan and carbonates is attributed to the later part of the weathering history. It is partly related to reduced leaching due to increasing aridity post-Miocene, but also to increased input of dust and dissolved components in rainfall. This is reflected within the hardpanised Quaternary colluvium-alluvium (Group D) at Bronzewing and Mt Gibson, the latter having intervening lenses of calcite. At Parkeston, calcareous colluvium-alluvium is up to 3 m depth. Calcareous/dolomitised lenses in the upper part of the palaeochannel clays (Group B) at Bronzewing, preferentially formed above the palaeochannel flanks, where, due to good drainage and high evapotranspiration, concentrations of Ca^{2+}, Mg^{+} and CO_3^{2-} ions could become sufficiently high to allow precipitation of carbonates. At Kanowna Belle, the upper colluvium-alluvium is calcareous with lenses of gypsiferous layer formed directly below.

Silicification occurs near surface and also at depth at Bronzewing. For example, at the contact between the transported/residual boundary at ca. 30 m depth, siliceous nodules that are possibly pseudomorphs after ferruginous nodules occur within the smectitic green clay facies. The yellowish-brown nodules have fissures with prismatic quartz crystals and fibrous chalcedonic quartz overgrowth. The kaolinite-goethite-hematite groundmass has a crystallitic birefringent fabric of cryptocrystalline quartz. This quartz may have formed through direct precipitation of Si from subsurface water in the pores and cracks of the ferruginous nodules in a restricted lake environment.

At the base of the palaeochannel sediment at Bronzewing is a layer of smectitic green clay above and below a 10-15 m thick dolomitic bed. The smectite is interpreted as having formed authigenically in a Ca-rich and illuviating environment. In such an illuviating or concentrating environment, it is possible that sediment materials may potentially preserve the geochemical signature they previously acquired (if any) of the underlying mineralisation.

At North Parkes E27, gypsum crystals are found near-surface in the colluvium-alluvium (Group D). The colluvium-alluvium comprises abundant, very fine quartz grains and scattered black Mn-oxide spots (ca. 0.5 mm diameter). The gypsum crystals are hematite-stained with anhydrite at the edges. The dewatering of gypsum to anhydrite along the crystal edges suggests a well-aerated, more arid environment. The formation of gypsum may have been the result of ponding and evaporation events above an impeded drainage layer of gleyed clay, resulting in fluids rich in calcium and sulphate ions.

CONCLUSIONS

Post-depositional features in sediments at the above six study areas are mainly associated with oxidation-reduction and precipitation from interstitial fluids. These weathering processes may potentially lead to the formation of geochemical signatures of the underlying mineralisation. Sediment materials related to illuviation or concentration zones may preserve a potential geochemical signature and are possibly suitable geochemical sampling media for exploration. On the other hand, sediment materials associated with an eluviation zone, such as a constantly reducing and leaching environment, for example where there is degradation of ferruginous nodules, may potentially lose the geochemical signature they previously acquired.

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