Clay mineral assemblages in valley floor soils in south-west Australia

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Introduction

The landscape of the Western Australian Wheatbelt is characterised by a long history of weathering, changes in climate and geological stability. The region sits atop the Yilgarn Craton dominated by Archaean mostly granitic and gneissic rocks that have been altered into deep lateritic profiles that have subsequently been dissected (Johnston 1987). The landscape is of low relief and soil materials formed under humid conditions are now experiencing a semiarid climate. Typically; the lateritic profile consists of rock overlain by saprolite, the kaolinitic pallid zone, mottled zone, iron oxide rich duricrust and sandy topsoil (McArthur 1991). The landscape is dominated by the ubiquitous products of intense weathering; primary quartz and kaolinite. However the current semiarid climate has led to the formation and accumulation of many evaporite minerals including gypsum, carbonates and clay minerals. Figure 1 illustrates the stratigraphic organisation of materials and some of the processes that have taken place in this complex landscape. A diverse array of materials show evidence of alteration by solute-rich groundwater under the semiarid conditions that have dominated the region within the past one million years. The focus of this paper is to identify variations in clay mineralogy in valley floor materials and develop an understanding of the causative processes.

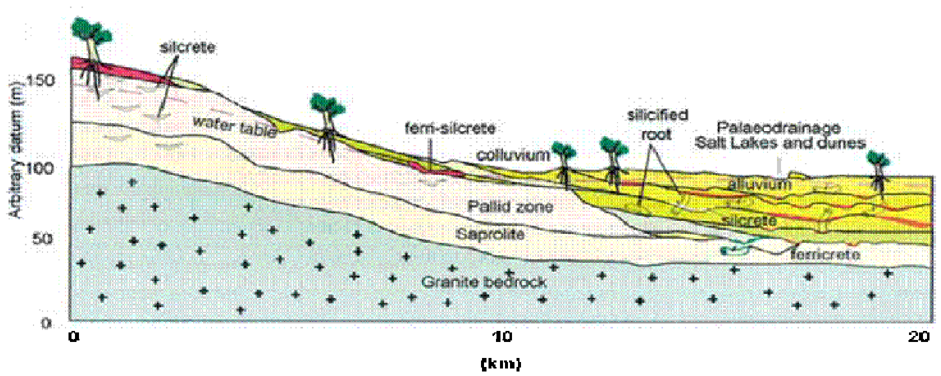

Fig. 1. Illustration showing the materials present in valleys in SW Australia. From Gilkes *et al.* (2003).

Methods

Sample location and sampling method

Six sites in the Wheatbelt of W.A. were sampled with pit profiles recorded every 200 metres along deep drains ranging in length from 2 km – 25 km. At least 10 replicates of each morphologically distinct material type were taken.

Analytical methods

Samples were air-dried and discrete morphological components (matrix, mottles, and coarse fragments) separated. All samples were ground manually using an agate mortar and pestle. Soil minerals were identified using powder x-ray diffraction (XRD). Traces 5.0.5 (Diffraction Technology 1999) and XPAS version 3.0 (Singh and Gilkes 1999) were used for mineral identification and data manipulation and Brindley and Brown (1980) for mineral identification.

Polished thin sections were prepared by impregnating undisturbed soil with resin and kerosene was used as a lubricant in order to preserve soluble salts. Optical microscopy was used to describe fabric following criteria and nomenclature of Bullock *et al* (1985) and Stoops (2003). Scanning electron microscopy was used for imaging, microprobe analysis and element mapping. TEM was used for imaging and compositional analysis of clay mineral crystals.

Results

Field Morphology

Photographs of soil profiles were taken at each position along the drain. Field and laboratory information recorded included structure, texture, strength, type and percentage of coarse fragments and other morphological data such as nature of quartz grains, the presence and type of biological activity and characterisation of features such as argillans and voids. Representative profiles from each site are shown in Figure 2. At Three Springs and Morowa (profiles one and three) the soils were dominated by coarse fragments with some horizons containing up to 90%; the result of cementation by various minerals. Many of the profiles show mottling characteristic of the deep lateritic profiles of the region. At all these sites loam texture in the top of the profiles trended to clay by 60cm and ranged from light silty clay – medium heavy clay. Mottling increased with depth and trended to coarse fragments (cemented by iron oxides) by the time the water table was reached.

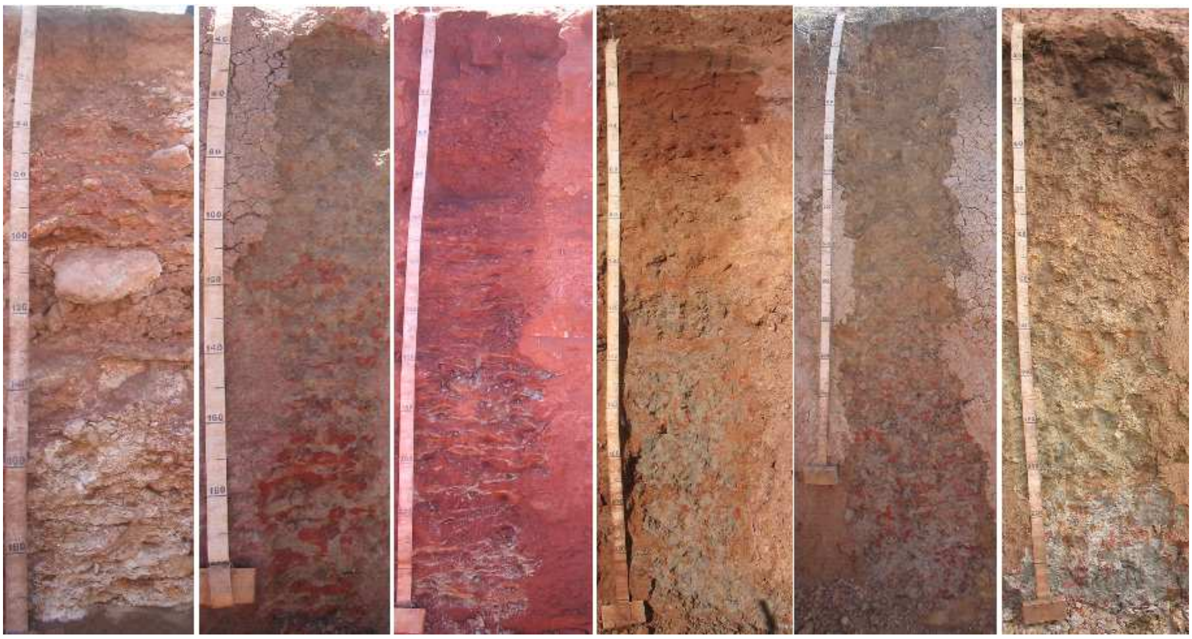

Fig. 2. Representative soil profiles from the six sites (from left to right); Three Springs, Pithara Morowa, Mongers 55, Dumbleyung and Wallatin Creek.

Mineralogy

The XRD patterns of representative whole materials in Figure 3 demonstrate the variations in mineralogy over the six sites. All sites other than Three Springs were dominated by quartz and kaolinite with mostly smaller amounts of other minerals present. The clay fraction mineralogy of these soils is dominated by kaolinite even when illite or smectite are present. Carbonates (calcite and dolomite) were the major constituents at Three Springs. Palygorskite, illite and trace kaolinite are present at this location with palygorskite being present in dolomitic materials.

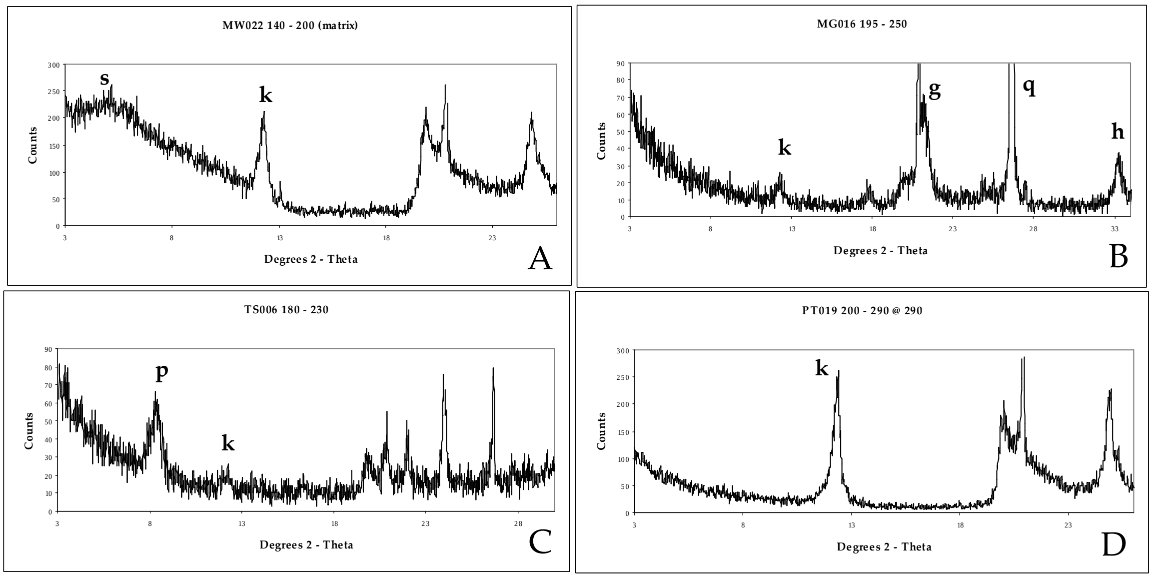

Fig. 3. XRD patterns of whole soil showing the diversity of minerals in valley floor soils. Kaolinite (k), smectite (s), palygorskite (p), goethite (g), hematite (h) and quartz (q).

Microscopy

Figure 4 is a BSE image of a matrix support sample containing angular quartz. An XRD of the sample in Figure 3A indicates that the matrix consists of a mixture of smectite and kaolinite. It is proposed that the smectite is authigenic and the kaolinite is residual. The soil contains a thick indurated horizon; possibly cemented by secondary silica. Although red in colour the iron oxide content of the matrix is not sufficient to be responsible for the induration. This is indicated in Figure 4 by the absence of a homogenous iron distribution through the matrix.

Figure 5 shows TEM images of acicular palygorskite crystals up to 10 μm in length from a dolomitic valley floor soil. Palygorskite only occurs in the presence of dolomite (and complete absence of calcite).

Conclusions

Valley floor soils exhibit large compositional and clay mineral variations reflecting the complex history of weathering and climate change experienced by these materials. In particular authigenic clay minerals have formed under the evaporitic conditions present in valley floor locations.

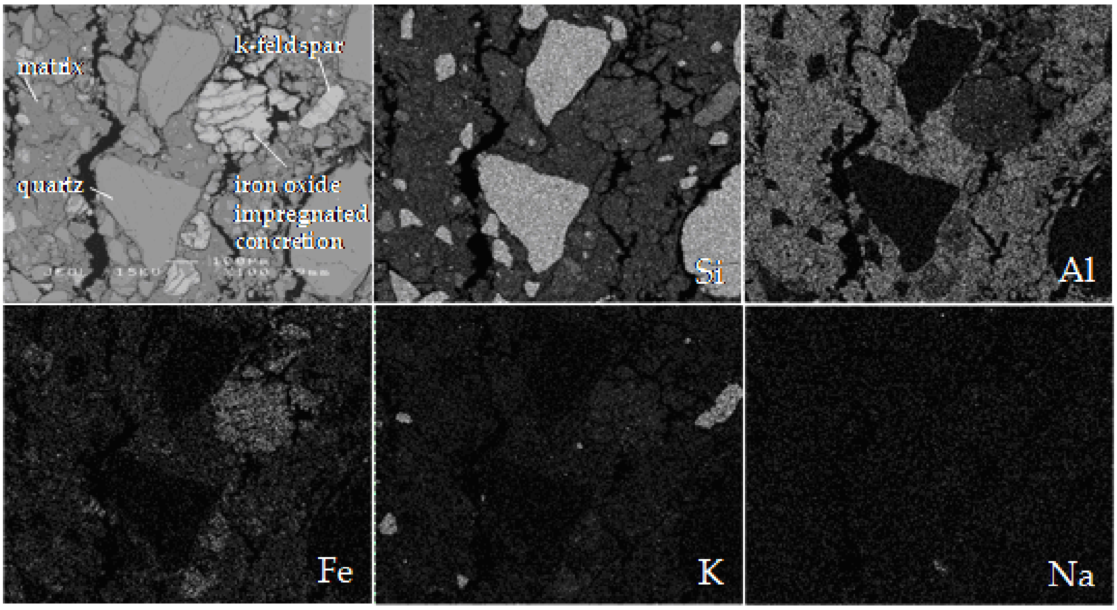

Fig. 4. Back scattered electron (BSE) image of a kaolinitic/smectitic sample and associated element maps. Note the identification of several features in the image.

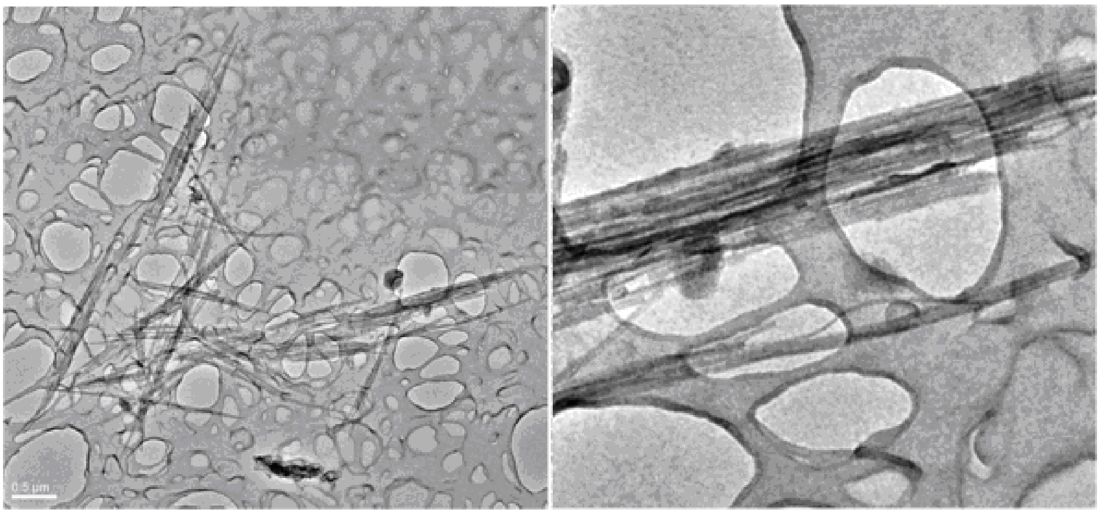

Fig. 5. Transmission electron microscope (TEM) image of acicular palygorskite crystals. Crystals were up to 10 µm in length.

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