THE RELATIONSHIP BETWEEN SOIL PHYSICAL PROPERTIES AND CHEMICAL FLUXES, LOVEDAY LAGOON

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INTRODUCTION

Loveday Lagoon is a highly degraded decommissioned salt disposal basin situated in a former natural wetland of the Murray River near Cobdogla, South Australia (Figure 1). The use of the site as a case study for S and Fe cycling and salt fluxes provides a better understanding of system dynamics for scientists and managers who need to address complex issues relating to water allocation and management (Walter, 2005). One outcome of the decommissioning of the site, which coincided with drought conditions in the early 2000's, was a drying out of the basin with consequent emissions of noxious odours. In addition, there was a perceived risk of poor water quality impacting the Murray River due not only to highly salinised waters associated with the former use of the basin, but also to the presence of sulfidc materials and sulfide-rich sediments that have accumulated as a result of recent sulfate reduction (Lamontagne et al. 2004). These clay rich sediments have developed well defined, desiccation cracks and columnar pedal structures in response to wetting and drying cycles (see model described in Lamontagne et al. 2004). These structures comprise highly aggregated material with a system of discontinuities acting as conduits for water and solutes. The physical properties of the pedal structures impose controls on sediment geochemistry at a range of spatial and temporal scales.

Figure 1. Loveday lagoon and surrounding area

METHODOLOGY

Sediment samples were collected from various locations within the basin. Samples were analysed for major and trace element composition, oxidized and reduced forms of sulfur, mineralogy, total salts and ion exchange capacity. Physical properties measured in the laboratory or *in situ* included bulk density and porosity, linear shrinkage, fabric and infiltration. Details of analytical methods are described elsewhere (Beavis et al 2005; Wallace et 2005; Welch et al 2005, 2006; Beavis et al 2006).

RESULTS AND DISCUSSION

Due to wetting and drying cycles imposed on the basin, desiccation cracks with distinct columnar pedal structures occur in zones, which have experienced episodes of inundation (Figure 2). These structures become more well developed in the areas that have been affected by several cycles of wetting and drying (the wet-dry zone Wallace et al., 2005). The pedal structures each comprise 3-6 highly aggregated macropeds (~10cm wide and 25cm long), which in turn consist of blocky peds of ~0.5-2cm diameter. Thin section analysis has demonstrated that these peds are themselves made up of micropeds with a diameter <1mm (Figure 3). These 'nested' fabric elements (pedal structures, macropeds, peds and micropeds) are separated by well defined discontinuities that range in aperture from <1μm – 50mm. These discontinuities impose a secondary porosity on the sediments and represent major conduits of flow, which allows for exchange of water, solutes and gases. This results in extreme variability in redox chemistry over micron to meter scale.

Oxidation fronts are apparent along exposed surfaces of peds (Figure 3), including the horizontal and vertical faces of the pedal structures and macropeds, and adjacent to the cracks which define the boundaries of the peds and micropeds. These oxidation fronts are evident from the change in chemistry and a change in colour: ped surfaces are stained reddish-brown, reflecting iron and manganese oxyhydroxide phases, or yellow, indicating jarosite.

Figure 2. pedal structures in the wet-dry zone in the northern part of the Loveday Basin

The relatively large discontinuities that occur between the pedal structures in the northern side of the basin, are currently infilled with clays and organic matter and, as a result, reducing conditions prevail within these relatively open structures, with evidence for rapid, recent accumulation of sulfidic black ooze in the cracks (Wallace et al., 2005). Analysis of S concentrations (as total S, AVS, and CRS) in the cracks between pedal structures, on the horizontal and vertical surfaces, and the middle of the pedal structures demonstrate significant differences in concentration and in redox state.

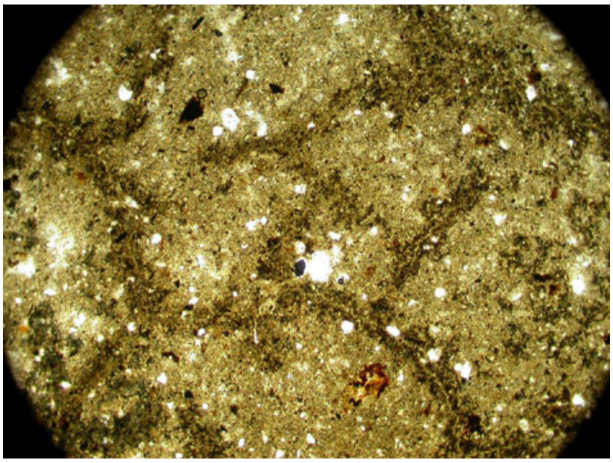

Figure 3. Preferential oxidation along the fine cracks that is apparent by the iron and manganese staining that define the structure of the micropeds that are prevalent throughout the system.

By contrast, the discontinuities between the macropeds, peds and micropeds are open, providing conditions for oxidation to occur. This is evident from the iron and manganese oxyhydroxide staining that defines these structures and the preferential distribution of the framboids along the finer crack systems. This leads to a system that is somewhat counterintuitive, where the larger openings are extremely reduced, whereas the smaller openings are oxidized.

Due to the differences in aperture, it is assumed that percolation will be the dominant process occurring between the macropeds and peds, but diffusion will dominate in the fine crack system associated with the micropeds. These different processes will generate temporal variability across small spatial scales in the fluxes of S, Fe and salts under different flooding regimes. This different reactivity will have implications for management of the site. In particular, there would be a large salt pulse out of the sediments into the overlying water in association with infiltration in the large cracks and dissolution of salt efflorescence, and a relatively continuous flux of salt and solutes associated with the fine crack networks. The total salt content of the overlying water should increase over time after the initial flooding, which could confound efforts to remediate the site.

CONCLUSIONS

The relationships between physical and chemical properties of the lagoon bed sediments are important to understanding fluxes of salts and solutes into the water column. This has implications for management of the site given the range of spatial and temporal scales at which processes occur and the associated impacts on water quality under different wetting and drying regimes.

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