PROPERTIES OF SOILS AFFECTED BY SALINE AND ACID SEEPS, WEST DALE, SOUTHERN WA

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INTRODUCTION

Saline and acid seeps are being increasingly recognized in inland Australia, and many of the seeps are responsible for formation of potential acid sulphate soils (Fitzpatrick 2002). Although the formation mechanisms, processes and environmental impacts of coastal acid sulphate soils in Australia have been well documented and publicised, the inland soils have only recently begun to receive attention (Fitzpatrick *et al.* 1996, Fitzpatrick 2002). Two areas where inland potential acid sulphate soils have been documented are the Mount Lofty Ranges in South Australia (Fitzpatrick *et al.* 1996) and the eastern Dundas Tableland region in Victoria (Brouwer & Fitzpatrick 2002), although Fitzpatrick (2002) indicated the presence of other inland sites around Australia. In Western Australia, potential and actual acid sulphate soils in the coastal areas around Perth have been documented and publicised, but the inland acid-saline seeps are as yet not well documented nor studied. The scarcity of information regarding potential saline-cum-acid sulphate soils in inland southern WA is addressed in this paper, with documentation regarding soil morphological and mineralogical properties being provided with other detailed results on water chemistry and mineralogy to follow.

The main factor responsible for the formation of inland acid sulphate soils is the onset of waterlogged conditions in valleys underlain by deeply weathered regolith. This results in the mobilization of S and Fe from the deeper regolith and accumulation of these ions in the groundwater discharge sites and in the waterlogged marshes (Fitzpatrick *et al.* 1996). Waterlogging in winter months results in the combination of Fe, S and organic matter, catalysed by microbial metabolism in the marshes, to form framboidal pyrites. When exposed to oxidizing conditions with a drop in water tables during summer, these result in the formation of fine-grained iron-sulphur minerals as gelatinous precipitates and an increase in acidity. Similar features to those described by Fitzpatrick *et al.* (1996) and Brouwer & Fitzpatrick (2002) are observed in selected areas of the West Dale catchment, especially in a large seepage area with a waterlogged valley. This seepage site forms the framework for this study.

LOCATION AND SETTING

The study area lies in the West Dale catchment, which is approximately 100 km ESE of Perth (Figure 1). The toposequence studied is located 2 km southwest of the intersection of Shillings Road and the Brookton Highway, and was first noticed as a saline acid seep by Agriculture WA. The climate of the region is Mediterranean, with wet winters and hot dry summers. The major land use activity is grazing and cropping. Topographically, the area lies between 320 m and 280 m elevation. The studied area is one of the several waterlogged ground water discharge sites identified by Edkins (1998). Land change observations by landowners indicate the valley bottom seeps to have originated in the early 1970s, with gradual upward migration.

The basement in the region is composed of Archaean granitoids cut by NW-SE trending multiple dolerite dykes. Locally, the only outcrop is of dolerite on an adjacent high. Magnetic intensity images of the catchment indicate the presence of two NW-SE trending dolerites dykes and a fault approximately 500 m to the north of the sampling locality. Most of the area is mantled by a > 3 m cover of regolith, which can reach thicknesses up to 30 m in some valleys (Edkin 1998).

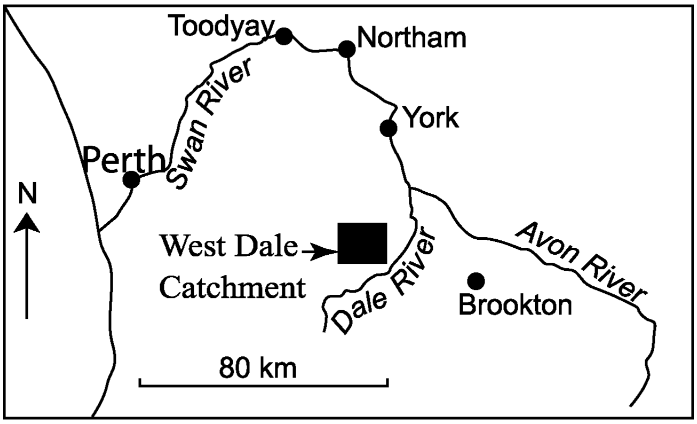

Figure 1: Location of the West Dale catchment in Southwest WA.

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METHODS

Samples were collected in the wet winter month of August and will be followed up with spring and summer sampling for mineralogical, water table and chemistry comparisons. Soil samples were taken along the toposequence with hand augers and PVC tube cores.

Soil pH, EC and Eh were measured in distilled water (5 g in 25 ml). X–ray diffraction (XRD) was performed on random powdered samples of bulk samples as well as iron-rich morphological features, mainly nodules from different horizons of the soil.

RESULTS

Six soil profiles were sampled along a toposequence and the locations and morphological properties are shown in Figure 2. The toposequence (soil-landscape sections) is an established method for studying regolith and water processes, from which regolith-based processes can be explained and predicted (Fitzpatrick 2002). The surface of the area can be divided into unaffected land, seepage area and permanently waterlogged area or marsh area. Many parts of the lower seepage zone have hardened, bare, localized patches or scalds with rills and gully erosion. The rills are a few centimetres in depth and occur along the slopes where seeps emerge, and gullies around 2 m wide and up to 1 m deep dominate the valley floor. According to property owners, a new seep has originated this year (2003) 5 m above the valley base. The emergence of new seeps occurs higher up the valleys. During the sampling month of August, there were no red to reddish-brown iron gelatinous precipitates, that were a common feature of the seep areas and dam just after summer of April 2002 (M. Aspandiar *pers. comm.*). During the sampling month, the solum water table in the higher area was 90-100 cm deep, and gradually became higher towards the seep. It is possible that two water tables exist: one a deeper, permanent water table; and the one shallower within the lower soil B horizon.

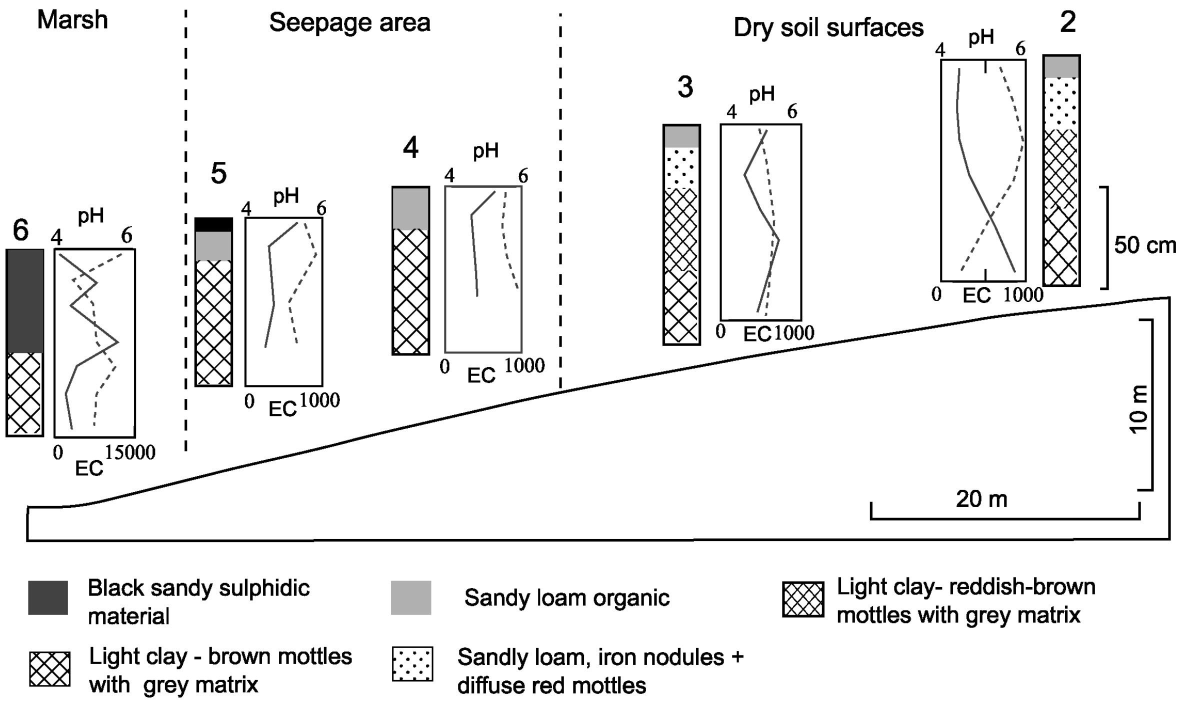

Figure 2: Soil toposequence showing the soil morphological properties with conductivity and pH parameters.

Soil Morphological Properties

Most of the solums unaffected by seeps are dominated by massive, sandy loam, reddish A and Ab horizons gradually changing to moderately structured, light clay, strongly mottled B horizons. The soils are duplex, with sandy loam upper horizons with light clay subsoil horizons. Iron glaebules as 0.5-3 cm sub-rounded ferruginous nodules are common in the A and AB horizon and decrease downwards. Mottles dominate the B horizon with reddish brown colours higher up the profiles gradually changing lower down the profile to strong brown to brownish-yellow colours with grey matrix, especially in the completely saturated part of the profile (> 80 cm). The profiles collected in the seepage areas have a comparatively thicker and darker A horizon with much of the subsoil B horizon dominated by strong red-brown mottling that changes to a yellow with grey matrix colours with depth. The marsh or water-logged area has 30-60 cm thick black “ooze”-type material which, when disturbed, emits a strong rotten-egg smell, indicative of black sulphidic material as observed by Fitzpatrick *et al.* (1996). Below the sulphidic layer, reddish-brown mottles are present and an increase in grey matrix colours with depth is observed. The reddish-brown, strong brown, yellow-brown mottles with grey matrix colours in the subsoil units of most of the profiles are indicative of redoximorphic features—both depletions and accumulations—that arise in response to saturation conditions (Vepraskas 1996, Bingham *et al.* 2001). Similar features have been documented in other periodically waterlogged soils (Fitzpatrick *et al.* 1996, Brouwer & Fitzpatrick 2002).

pH and salinity

The soil pH varies from 4.41 to 7.2, with the lowest in profile 2 (Figure 2). The soil pH does not show a clear trend, except for acidic values towards saturated zones in the profiles higher up in the toposequence. The range of EC is from 43 µS/cm to 13,260 µS/cm. The salinity (EC) increases towards the waterlogged area indicating the increase in salinity towards the valley bottom. The salinity is lowest in the unsaturated part of the solums higher in the toposequence (profile 2 and 3), indicating movement and accumulation of salts to the lower parts of the solum. The pH of the seepage and soil water varied between 4.5-5.5, however, in summer the pH of the seepage waters was 3.2 (April 2002).

Mineralogy

XRD indicated the dominant minerals to be quartz, kaolinite, feldspars and iron oxides, with some halite, aluminous oxides and sulphates. The main mineralogical difference found between profiles in the toposequence was the presence of jarosite and halite in lower parts of the waterlogged profile (5A). Halite is present in profile 6, which relates to the increase in salinity in the profile. Although pyrite was detected in only one of the samples in profile 6, the strong H_2S odour in the upper soil horizons, combined with black colour, is suggestive of wider presence of pyrite or monosulphides in the marshes and possibly the uppermost horizons of the seep affected area. The presence of halite and sulphidic minerals in the waterlogged areas is suggestive of formation of saline sulphidic soils (Fitzpatrick *et al.* 1996). Quartz, kaolinite, feldspars, gibbsite, hematite and goethite dominate the mineralogy of the profiles higher in the toposequence. The ferruginous nodules and Fe masses are composed of hematite, goethite, quartz, and kaolinite and in some gibbsite and possibly boehmite and lepidocrocite. While no hematite to goethite ratio calculations have yet been conducted, the increase in brown mottles with depth does suggest an increase in goethite content towards the saturated parts of the profile. The increase in goethite (dominantly brown colours) within the saturated parts conforms to its formation and dominance in high water activity environments (Bingham *et al.* 2001). While gibbsite is present in several of the profiles within the ferruginous nodules and matrix, boehmite is restricted to profile 2 and 4. Both these minerals are indicative of a high degree of weathering and high amounts of leaching within the original profiles prior to the regolith being affected by rising water tables. Gibbsite is common in the regolith in the surrounding regions where bauxite prevails within the regolith profiles. Differential XRD will be conducted on the redoximorphic features to ascertain whether ferrihydrite and lepidocrocite are present in addition to the identified iron oxides.

Iron- and sulphur-bearing gelatinous precipitates as noted in inland acid sulphate soils (Fitzpatrick *et al.* 1996) were not ubiquitous during the first sampling season, but observations during the summer month of December show a significant portion of the seepage area covered with reddish-orange gelatinous precipitates (M. Aspandiar *pers. comm.*). XRD data from these gelatinous precipitates collected during summer months show the presence of ferrihydrite and goethite, with possible schwertmannite (M. Aspandiar *pers. comm.*). Additional summer sampling has been planned to study seasonal changes in mineralogy and surface morphology.

CONCLUSION

Morphological and mineralogical observations along a soil toposequence that is affected by waterlogging and salinity, possibly in response to land clearing, shows the presence of redoximorphic features throughout most of the solum, with the lower waterlogged areas showing the formation of black sulphidic materials. Morphology of the soils reflects the saturation conditions, as described by Brouwer & Fitzpatrick (2002), and the soil mineralogy is also indicative of seasonal changes to the shallow watertable. Halite and sulphidic minerals in the waterlogged areas suggest the development of sulphidic soils, and the presence of reddish-brown gelatinous precipitates combined with acid pH of waters (< 3.5) in summer months is indicative of rapid oxidation of the sulphides with the lowering of water tables. These observations and interpretations point to the development of a potential acid sulphate soil in the seepage and waterlogged areas, with S and Fe being sourced from the deeper regolith. The observed seasonal changes in water parameters, groundwater movement, and soil and surface mineralogy is critical in understanding the mechanisms of formation of these potential acid sulphate soils as well as their role in influencing the land and water quality on a seasonal basis. Further work on the water parameters, mineralogy and seasonal monitoring is underway.

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