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Research paper

Effect of plant growth on the occurrence and stability of palygorskite, sepiolite and saponite in salt-affected soils on limestone in South Australia

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ABSTRACT

The Mg-rich clay minerals, palygorskite, sepiolite and also Mg-smectites are generally rare in soils. When they occur they are usually concentrated in subsurface horizons and become replaced by other minerals, e.g., dioctahedral smectites in near-surface horizons. Salt-affected soils on limestone in a flat landscape in southern Australia showed patchy pasture growth, including areas in which almost no growth occurred. Chemical and mineralogical analyses of deep profiles of the soils revealed two main types and that the extent of plant growth reflected their mineralogical composition. The soil type in which plants grow well ('Chromosol', an Alfisol) contains dioctahedral smectite (montmorillonite and/or beidellite) but only in substantial amounts at depth. The soil type in which little or no plants grew ('Vertosol', a Vertisol) has substantial concentrations of a trioctahedral Mg-smectite, saponite, in its surface horizons along with dioctahedral smectite in lower horizons. Both soil types contain sepiolite and palygorskite, largely in the lower horizons of the Chromosol, but also in near-surface horizons of the Vertosol. Both types of soil also contain illite and kaolinite, which are each concentrated in the upper horizons of the soils and are considered to be detrital. The genesis of the two main types of soils can be explained by the depositional history of the basin. On the eastern side of the basin, palustrine limestone formed when the sediments became exposed, possibly from uplift. The Chromosol formed on this material. On the western side, by contrast, lacustrine sediments on lowland adjacent to a stranded beach ridge, experienced prolonged seasonal inundation by water leading to the formation of the Vertosol. This soil is strongly sodic and strongly alkaline throughout and it is concluded that the high concentration of saponite in the surface swells and thereby ensures that the soil remains wet. Together with its high pH, this soil has very poor conditions for plant growth. The persistence of the Mg-rich clay minerals, especially saponite, at the surface of the Vertosol, suggests that the relative lack of plants has preserved these minerals throughout the profile.

1. Introduction

A detailed analysis of the mineralogical composition of soils from a calcareous area of south-eastern South Australia was undertaken in order to determine whether minerals such as palygorskite, sepiolite and Mg-smectite might occur there as in other soils in calcareous environments and, if present, to investigate their origin.

Whereas some palygorskite and also sepiolite in soils may be detrital in origin, it is also thought that palygorskite can form within soils (Singer and Norrish, 1974; Singer, 1984; Galán, 2006). Generally, this process is referred to as pedogenic, i.e. by "natural processes involved in the formation of soils" (Schaetzl and Anderson, 2005). In this scenario, rising groundwaters of pH 7–8 with abundant salinity give rise to palygorskite at sharp textural transitions and within calcretes (caliches). However, these minerals apparently give way in the upper horizons of soils to dioctahedral smectites (Paquet and Millot, 1972; Khormali and Abtahi, 2003; Owliaie et al., 2006; Bouza et al., 2007; Churchman and Lowe, 2012) or to kaolinite in some cases (Khademi and Arocena, 2008). Evidence for the pedogenic formation of sepiolite is often more equivocal (Singer, 2002; Churchman and Lowe, 2012).

The most widespread soils in the region were derived either mainly from calcareous beach sands, or from estuarine and lacustrine deposits, according to Blackburn et al. (1965) and Blackburn (1983). They considered that calcareous beach sands gave rise either to "Terra rossa" soils by the Great Soil Group (GSG) classification (Stephens, 1962), or a "Xeralf", Soil Taxonomy (ST) (Soil Survey Staff, 1975), or "Chromosol", Australian Soil Classification (ASC, Isbell, 2002), or to "podzol", "Spodosol"or "Podosol" soils respectively by these three soil classification systems.

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Blackburn and co-authors considered that estuarine and lacustrine deposits gave rise more recently either to "ground-water rendzina" (GSG), "Vertisol" (ST) or "Vertosol" (ASC), or to "solodized solonetz" (GSG), "Natrixeralf" (ST) or "Sodosol" (ASC) soils on the inter-dunal plains; this study focuses on Chromosols and Vertosols, which we will name by their ASC classes.

The Chromosol, but not the Vertosol, exhibits textural contrast between the organic-rich A and more clay-rich calcareous B horizons. A hard, dense capping of calcium carbonate at the A horizon/B horizon interface was considered to be a secondary accumulation (Blackburn et al., 1965).

A particular feature of the soils studied is that the Vertosol supported very little or no plant growth, whereas the nearby Chromosol supported excellent plant growth. This observation led to the study of the effect of plant growth on clay mineral formation and stability being the major objective of this work.

2. Environmental setting

The South East region of South Australia is characterised by a series of stranded coastal beach ridges (dunes) that are aligned sub-parallel to the current coastline (Fig. 1), flanked on the western side by the ocean and the State of Victoria to the east. Part of the Bridgewater Formation (Firman, 1973), the barriers consist mainly of biogenic, skeletal carbonate and subordinate quartz sands with distinctive subtidal, intertidal and aeolian dune facies (Murray-Wallace et al., 1996). Fossil mollusc-bearing intertidal, estuarine lagoon and lacustrine sediments occur on the landward sides of the dunes (Murray-Wallace et al., 2001). Following regression of the ocean, continental sediments were deposited on the inter-dunal plains in the series of lakes that developed along the corridors, supplied with detritus via fluvial and aeolian processes (Padthaway Formation). The lacustrine sediments deposited in the inter-dunal corridors include the limestone underlying the soils

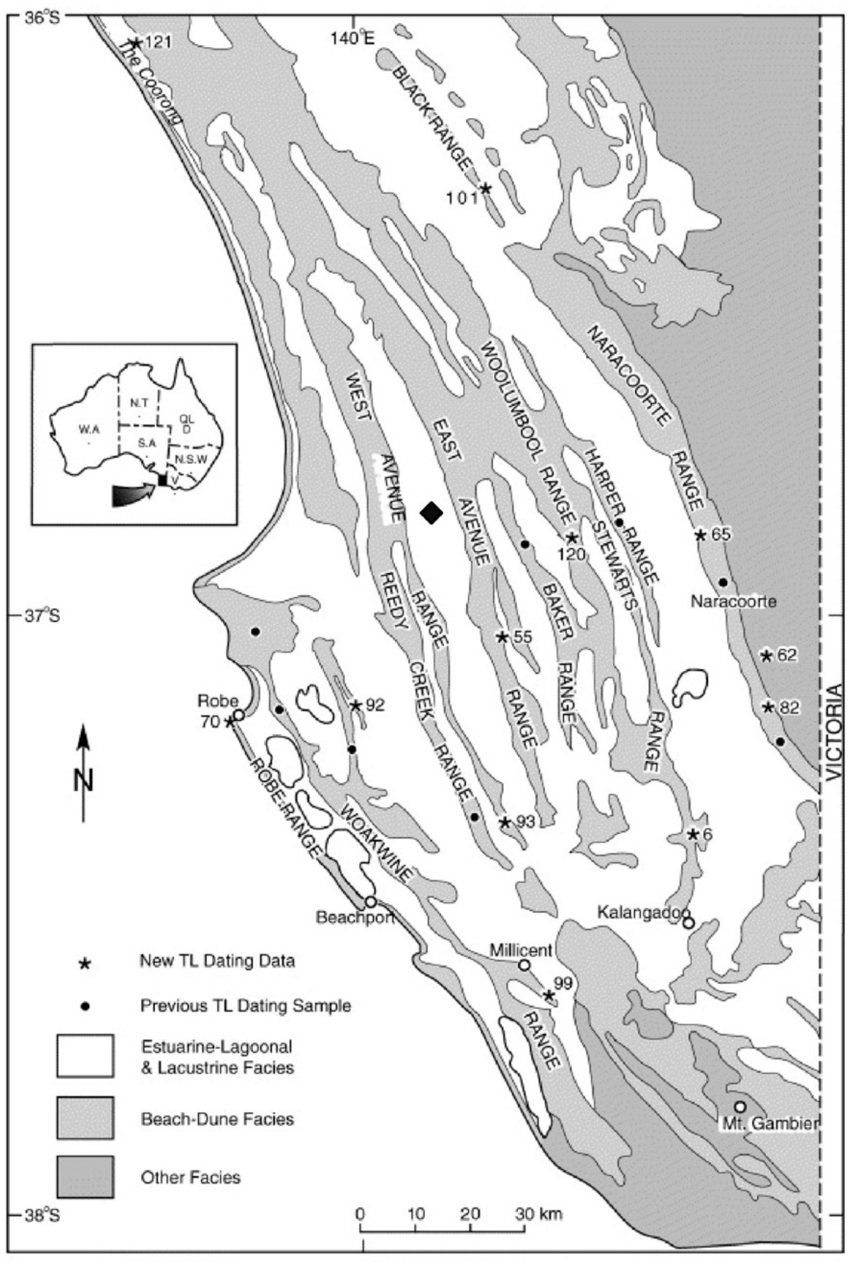

Fig. 1. Map showing the position of relic coastal barriers in South East South Australia, from Huntley and Prescott (2001). The location of the Keilira District on the Avenue Plain is denoted by ♦, in the area locally referred to as the Keilira district, flanked by the East and West Avenue Ranges.