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Influence of relative surface age on hydraulic properties and infiltration on soils associated with desert pavements

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Abstract

Av horizons found in desert pavement environments are known to evolve pedogenically over geologic time. This study was conducted to determine whether increased pedogenic development of the Av (vesicular) horizon over relative time impacts the hydraulic properties of individual soil peds and the mechanism of infiltration as inferred by dye patterns. We examined peds from the Av horizons associated with desert pavements that mantled three different alluvial deposits with different relative surface ages (Qf5 (∼10 ka), Qf3 (∼50–100 ka), and Qf2 (∼10–50 ka)) and included an additional surface (Qf6 (∼4 ka)) for the dye studies. We hypothesized that increases in the development of the Av over time would lead to a more structured soil surface with greater potential flow between soil peds and lower hydraulic conductivity of the soil peds themselves. Results showed that average K_s and α of the Qf5 peds were significantly greater than estimated for the Qf2 and Qf3 peds. Although K_s was greater for the Qf5 peds, the steady-state infiltration rate was equal for the Qf3, Qf2, and Qf5 surfaces, perhaps indicating a reduction in matrix flow through soil peds and an increase in interped flow between soil peds.

Studies were also conducted using dyed water and a tension disc infiltrometer, set to saturation. Following the tests the soil was excavated in 2-cm increments and photographed. The dye patterns for the Qf6 indicated that the water moved rapidly through the soil matrix into deeper soil, and without any preferential flow around peds. The Qf5 exhibited more dye-stained soil at depth than seen in the Qf2 and Qf3, perhaps due to higher ped conductivity. Qualitative observations on the Qf2 and Qf3 suggest that water flowed primarily along the ped faces and then toward the ped interiors. The results suggest that infiltration through Av horizons evolves from a matrix-dominated process on the younger soils to a preferential flow-dominated process on older surfaces.

Keywords: Desert pavement; Hydrology; Pedogenic development; Preferential flow; Av horizon; Soil peds

1. Introduction

The movement of water is one of the most basic and important processes in arid regions because water is the primary limiting factor for plant growth in desert regions (Smith et al., 1997). Water is also a major transporter of nutrients and resources through and across ecosystems (Noy-Meir, 1973; Belnap et al., 2005) and plays a critical role in pedogenic development of arid soils (McDonald et al., 1996; McFadden et al., 1998). Two critical mechanisms of transport are overland flow and infiltration. The processes of infiltration and overland flow strongly affect the redistribution of sediment, plant litter, and seeds, vertically into the soil profile and laterally across the landscape. However, to quantify and predict the movement and distribution of water in arid regions, a thorough understanding of the pedologic controls on the near-surface hydrologic processes is necessary.

Desert pavements (also commonly referred to as reg soils) are common, landscape-scale features found in arid regions worldwide. Evenari et al. (1985) stated that stone pavements cover approximately one-half of arid lands in North America. These naturally occurring surfaces are found on a variety of landforms that range in age from Tertiary to Holocene (Bull, 1991; Cooke et al., 1993). Given the widespread occurrence of desert pavements, an understanding of the hydrology of these features is important for understanding many geomorphic and

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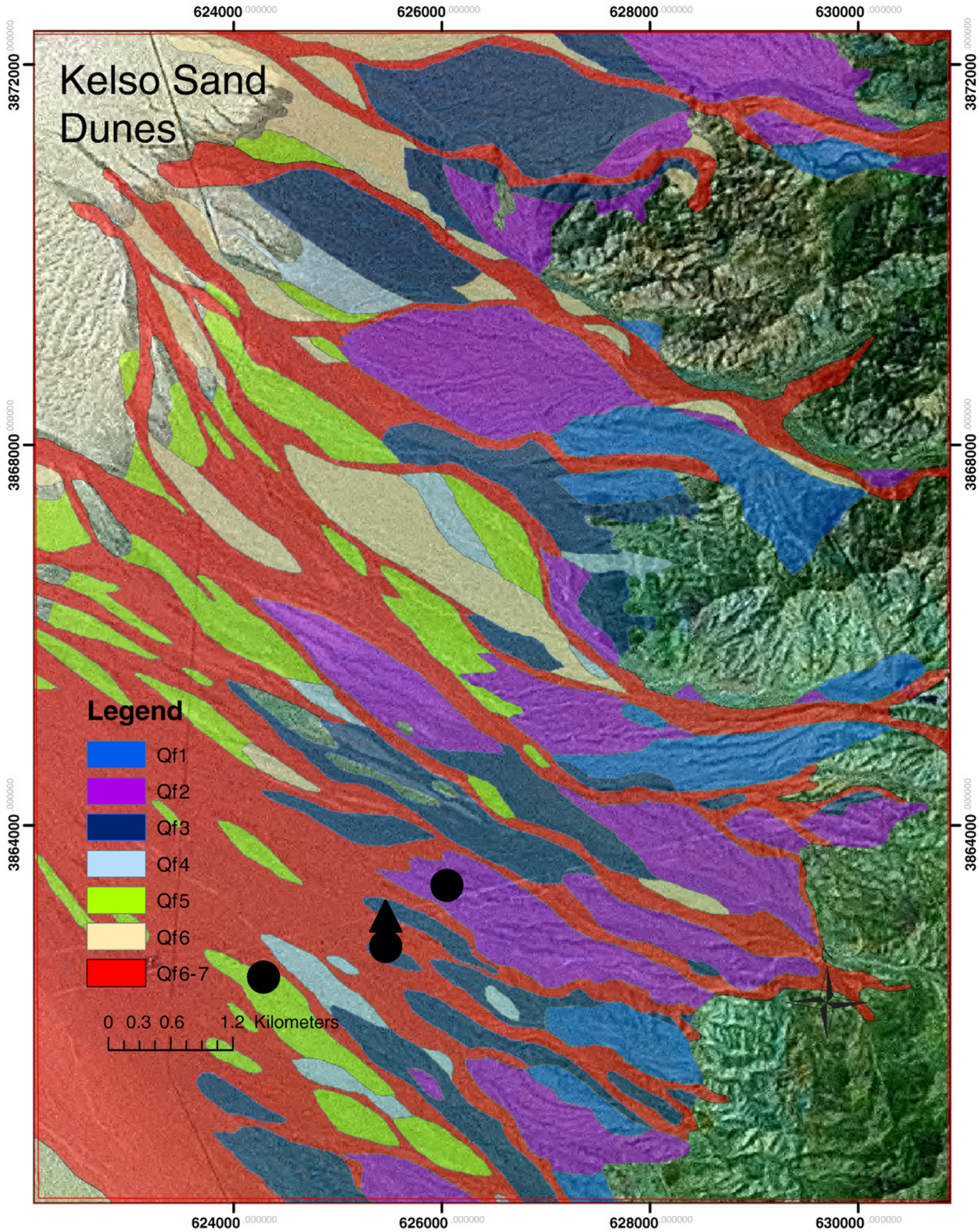

Fig. 1. Reference map of the Providence Mountains, CA (from McDonald, 1994). Dots indicate where samples were collected. Triangle indicates infiltrometer test on the Qf6.

ecological processes. However, relatively little research has been published regarding the hydrologic changes that result from pedologic development in these environments.

Desert pavements consist of a surface layer of closely packed clasts that are embedded in a fine-grained, gravel-poor vesicular A (Av) soil horizon (McFadden et al., 1998). A dark coating of desert varnish commonly covers the exposed surface of the clasts. The Av horizon below the clasts is a highly structured, thin (1–10 cm) veneer of soil. The horizon easily breaks into irregularly shaped, columnar peds. Individual peds exhibit an internal platy structure, and air vesicles are found throughout the ped interiors.

Many studies over the last 20 years have suggested that the surface clasts and the Av horizon coevolve (Wells et al., 1985; McFadden et al., 1986; 1987; 1998; McDonald, 1994; Wells et al., 1995; Anderson et al., 2002). The results of these studies