Chapter 5

Aridic Soils, Patterned Ground, and Desert Pavements

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Introduction

Pedogenic and geomorphic processes operating in deserts are inextricably linked. These linkages are particularly well expressed in the development of patterned ground and desert pavement. In addition, the nature and efficacy of hydraulic, gravitational, and aeolian processes on desert surfaces are strongly influenced by the physical and chemical characteristics of the underlying soils. As a result, the evolution of a diversity of desert landforms is either directly or indirectly linked to pedogenic processes.

The significant role played by pedogenic processes in desert landscape evolution is also strongly reflected in the development of duricrusts – indurated accumulations of calcium carbonate, gypsum, and silica. These essentially pedogenic materials impart considerable relief in the form of tablelands, mesas, and buttes to otherwise low-relief landscapes. Erosion of these topographic eminences in turn provides the coarse debris for the formation of patterned ground and desert pavement.

In this chapter the nature and genesis of soils in arid and semi-arid environments are examined. This discussion is followed by an examination of the major types of patterned ground and the processes responsible for its formation. Finally, the nature and origin of desert pavements are examined. The nature and origin of duricrusts are discussed in Chapter 6.

Aridic Soils

Distribution

Desert soils occupy approximately 46.1 M km$^2$, or 31.5% of the Earth’s surface (Dregne 1976). They are most widespread in Australia, occupying some 82% of the continental surface (Stephens 1962), and are also the dominant soils of Africa, covering some 59% of the continent. Arid soils cover substantially smaller areas of the remaining continents: 33% of Asia, 18% of North America, 16% of South America, and just under 7% of Europe (Dregne 1976). Desert soils are dominated by five soil orders (U.S. Comprehensive Soil Classification): Entisols (41% of arid zone), Aridisols (36%), Mollisols (12%), Alfisols (7%), and Vertisols (4%) (Dregne 1976). These soil orders are subdivided into thirteen suborders discussed in greater detail later in this chapter.

Characteristics

Aridic soils display a variety of distinctive morphological features. Among these are the presence of gravel-covered surfaces, the development of surface organic and inorganic crusts, and the widespread occurrence of vesicular A horizons. In addition they commonly display the development of ochric and mollic epipedons and are characterized by the formation of a variety of diagnostic subsurface horizons including cambic, argillie, calcie, petrocalcie, gypsic, petrogypsic, natriic, salic, and duripan horizons (Buol et al. 1997, Southard 2000).
**Surface Crusts**

Desert soils commonly display the presence of thin (10–20 mm) crusts on surfaces largely devoid of vegetation and gravel cover. The crusts are typically massive but may possess a platy structure in their upper part. The lower portion of the crusts is commonly vesicular where it is in contact with the underlying vesicular horizon. Crusts typically display low permeability and accompanying enhanced runoff (Buol et al. 1997, Schaetzl and Anderson 2005), however some studies have suggested that some crusts (especially organic-rich crusts) may in fact enhance infiltration (Gifford 1972, Blackburn 1975, Dunkerley and Brown 1997). Crusting is widely believed to be the result of repeated wetting and drying of predominantly loamy soils (Buol et al. 1997). These authors believe that during wetting, soil plasma moves to contact points between skeletal grains where upon drying it acts as a weak reversible cement. The source of the binding agents (the plasma) has long been elusive (Sharon 1962, Schaetzl and Anderson 2005). For a long time it was widely believed that crusting was the result of raindrop impact (McIntyre 1958a, b, Schaetzl and Anderson 2005) which both compacted soil particles and produced and transported clay size particles into voids. However crusting probably includes both inorganic and organic processes and components. Inorganic components include clays (Frenkel et al. 1978, Benhur et al. 1985, Dunkerley and Brown 1997) which serve as binding agents, exchangeable sodium (Painuli and Abrol 1986) which results in soil dispersion, and the presence of small quantities of salts and calcium carbonate (Sharon 1962, Benhur et al. 1985).

Desert soil crusts are now generally attributed to biological processes resulting in the production of thin microphytic layers on the soil surfaces (Dunkerley and Brown 1997, Schaetzl and Anderson 2005). Microphytic crusts are dominated by assemblages of algae, mold, cyanobacteria, (Schaetzl and Anderson 2005) as well as mosses, liverworts, lichen, bacteria, and fungi (Dunkerley and Brown 1997). These organisms grow in the upper few millimeters of the soil surface after rain events, and form biomantles in which their mycelia bind soil particles together. The soil mantles are commonly enriched in C and N as well as silt and clay (Fletcher and Martin 1948).

**Vesicular Horizons**

Immediately beneath the gravel surface layer of many aridic soils a vesicular Av horizon (Fig. 5.1) commonly occurs and is often associated with a surface crust. Formation of the vesicular horizon has been widely attributed to the saturation of the fine grained soil surface horizon (Miller 1971). Nettleton and Peterson (1983) argued that in the saturated state the soil plasma of this upper horizon is free to move and in so doing traps air. With repeated episodes of saturation and air entrapment, the vesicles in the surface horizon increase in size. Repeated destruction of the vesicular horizon is thought to be caused by wetting and drying cycles (Springer 1958, Miller 1971). Nettleton and Peterson (1983) alternatively suggested that vesicular horizon destruction is primarily the result of soil trampling by animals. Upon destruction, the formation of the vesicular horizon begins anew as soil saturation episodes begin and air entrapment resumes.

A substantially different explanation for the origin of the vesicular horizon has been proposed by Wells et al. (1985), McFadden et al. (1986, 1987, 1998) and Blank et al. (1996). These workers attributed the origin of the fine-grained surface horizon and accompanying vesicular structure to aeolian addition of fine grained materials and associated soluble salts, carbonates, and iron oxides. The development of vesicles is attributed to entrapment of air by aeolian infall with subsequent expansion due to heating following summer rainfall events. This model follows that of Evenari et al. (1974) for vesicular horizons developed in soils in Israel.

![Fig. 5.1 Soil developed beneath desert pavement showing vesicular A horizon (Av) and carbonate and gypsum enriched B horizon (Btky). Bedrock rubble is designated (R) (photo courtesy of L.D. McFadden)](image-url)