Cryptobiotic Soils: Holding the Place in Place

Jayne Belnap
Soil Ecologist
U.S. Geological Survey

Cryptobiotic soil crusts, consisting of soil cyanobacteria, lichens and mosses, play an important ecological roles in the arid Southwest. In the cold deserts of the Colorado Plateau region (parts of Utah, Arizona Colorado, and New Mexico), these crusts are extraordinarily well-developed, often representing over 70 percent of the living ground cover. Cryptobiotic crusts increase the stability of otherwise easily eroded soils, increase water infiltration in regions that receive little precipitation, and increase fertility in soils often limited in essential nutrients such as nitrogen and carbon (Harper and Marble, 1988; Johansen, 1993; Metting, 1991; Belnap and Gardner, 1993; Belnap, 1994; Williams et al., 1995).

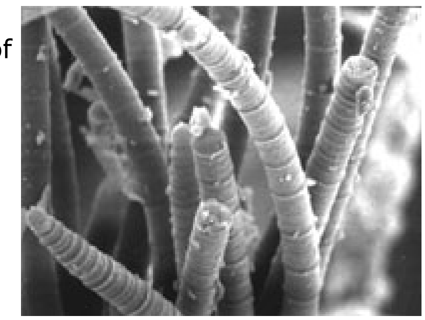


Figure 1. *Filaments of Microcoleus vaginatus (x 3000), the dominant organism in the crust. Individual cells abut each other to form the filaments. Click on image for full size.*

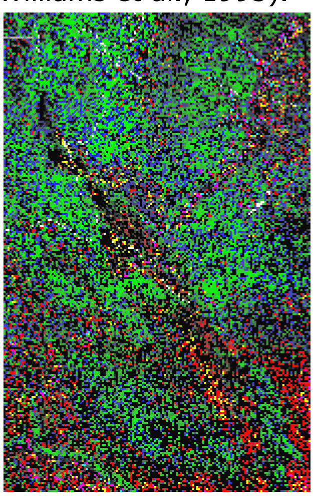
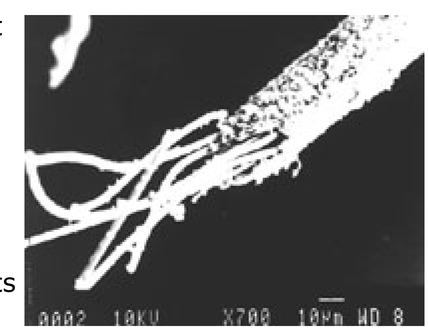


Figure 2. *Arches Microbiotic Soils Map (Kokaly, Clark, and Swayze, 1993). Click on this image for full size and explanation.*

Cyanobacteria occur as single cells or as filaments. The most common type found in desert soils is the filamentous type. The cells or filaments are surrounded by sheaths that are extremely persistent in these soils. When moistened, the cyanobacterial filaments become active, moving through the soils and leaving a trail of the sticky, mucilaginous sheath material behind. This sheath material sticks to surfaces such as rock or soil particles, forming an intricate webbing of fibers in the soil. In this way, loose soil particles are joined together, and otherwise unstable and highly erosion-prone surfaces become resistant to both wind and water erosion. The soil-binding action is not dependent on the presence of living filaments. Layers of abandoned sheaths, built up over long periods of time, can still be found clinging tenaciously to soil particles at depths greater than 15 cm in sandy soils. This provides cohesion and stability in these loose sandy soils even at depth.

Cyanobacteria and cyanolichen components of these soil crusts are important contributors of fixed nitrogen (Mayland and McIntosh, 1966; Rychert and Skujins, 1974). These crusts appear to be the dominant source of nitrogen in cold-desert pinyon-juniper and grassland ecosystems over much of the Colorado Plateau (Evans and Ehleringer, 1993; Evans and Belnap, unpub. data). Biological soil crusts are also important sources of fixed carbon on sparsely vegetated areas common throughout the arid West (Beymer and Klopatek, 1991). Plants growing on crusted soil often show higher concentrations and/or greater total accumulation of various essential nutrients



when compared to plants growing in adjacent, uncrusted soils (Belnap and Harper, 1995; Harper and Pendleton, 1993).

Figure 3. *Microcoleus filaments (lower left) emerging from mucilagenous sheath (upper right). Scale bar is 10 micrometers. Click on image for full size.*

Cryptobiotic soil crusts are highly susceptible to soil-surface disturbance such as trampling by hooves or feet, or driving of off-road vehicles, especially in soils with low aggregate stability such as areas of sand dunes and sheets in the Southwest, in particular over much of the Colorado Plateau (Belnap and Gardner, 1993; Gillette et al., 1980; Webb and Wilshire, 1983). When crusts in sandy areas are broken in dry periods, previously stable areas can become moving sand dunes in a matter of only a few years.

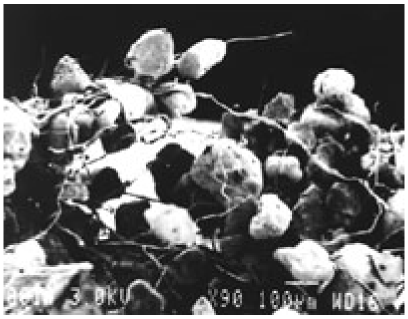


Figure 4. *Crust in sandy soils. The visible fibers are Microcoleus vaginatus. Note how Microcoleus connects the otherwise loose sand grains together, thus preventing wind and water erosion. Microcoleus is important in enhancing water and nutrient relations within the soil, as well. Scale bar is 100 micrometers. Click on image for full size.*

Cyanobacterial filaments, lichens, and mosses are brittle when dry, and crush easily when subjected to compressional or shear forces by activities such as trampling or vehicular traffic. Many soils in these areas are thin and are easily removed without crust protection. As most crustal biomass is concentrated in the top 3 mm of the soil, very little erosion can have profound consequences for ecosystem dynamics. Because crustal organisms are only metabolically active when wet, re-establishment time is slow in arid systems. While cyanobacteria are mobile, and can often move up through disturbed sediments to reach needed light levels for photosynthesis, lichens and mosses are incapable of such movement, and often die as a result. On newly disturbed surfaces, mosses and lichens often have extremely slow colonization and growth rates. Assuming adjoining soils are stable and rainfall is average, recovery rates for lichen cover in southern Utah have been most recently estimated at a minimum of 45 years, while recovery of moss cover was estimated at 250 years (Belnap, 1993).

Because of such slow recolonization of soil surfaces by the different crustal components, underlying soils are left vulnerable to both wind and water erosion for at least 20 years after disturbance (Belnap and Gillette, 1997). Because soils take 5,000 to 10,000 years to form in arid areas such as in southern Utah (Webb, 1983), accelerated soil loss may be considered an irreversible loss. Loss of soil also means loss of site fertility through loss of organic matter, fine soil particles, nutrients, and microbial populations in soils (Harper and Marble, 1988; Schimel et al., 1985). Moving sediments further destabilize adjoining areas by burying adjacent crusts, leading to their death, or by providing material for "sandblasting" nearby surfaces, thus increasing wind erosion rates (Belnap, 1995; McKenna-Neumann et al., 1996).

Soil erosion in arid lands is a global problem. Beasley et al. (1984) estimated that in rangeland of the United States alone, 3.6 million ha has undergone some degree of accelerated wind erosion. Relatively undisturbed biological soil crusts can contribute a great deal of stability to otherwise highly erodible soils. Unlike vascular plant cover, crustal cover is not reduced in drought, and unlike rain crusts, these organic crusts are present year-round. Consequently, they offer stability over time and under adverse conditions that is often lacking in other soil surface protectors. However, disturbed crusts now cover vast areas in the western United States as a result of ever-increasing recreational and commercial uses of these semi-arid and arid areas. Based on the results of several studies (McKenna-Neumann et al., 1996; Williams et al., 1995; Belnap and Gillette, 1997), the tremendous land area currently affected by human activity may lead to significant increases in regional and global wind erosion rates.

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