Methods

Sampling. We sampled 9 sites (7U and UES sites) in the mantle of surficial sediment that is covered by biological soil crust (BSC) in three settings: (*i*) potholes developed in the slickrock of aeolian sandstone; (*ii*) surfaces of mesas; and (*iii*) grassland surfaces at varying distances from outcrop (Table 1). The sampling encompassed elevations of about 1,510-1,900 m, mainly in shrub and grassland zones. Some sampled potholes support shrubs and probably all harbor insects.

Most sampling sites are in sediment that fill potholes developed in sandstone of the Entrada, Navajo, Kayenta, and Cedar Mesa (Cutler Group) formations (Table 1). Where sampled, the Entrada and Navajo sandstones are composed of aeolian sand. The Kayenta Sandstone is a redbed, the color of which is imparted by fine-grained interstitial hematite, deposited in mixed fluvial and aeolian environments. In the study area, the Cedar Mesa Sandstone consists largely of beds of red silty sandstone and siltstone alternating with white sandstone. The redbeds represent arkosic fluvial and aeolian sediments, and the white beds represent aeolian sand reworked from the marine shoreline; we sampled the sediment mantle on each sandstone facies (Table 1). One site lies on a mesa capped by both sandstone and a thin limestone bed near the top of the lower Cutler beds (Table 1).

At most sites, samples were taken by boring with a soil sampling tube, 3 cm in diameter. The depth of sediment in the tube was measured in increments (from the surface to 0.5 cm, 0.5-2 cm, and 2-5 cm), and each increment was stored as a separate sample. Multiple borings were taken from each pothole to obtain bulk samples weighing 50-100 g. At most sites, multiple samples were taken to represent each depth interval. At one site (UES-3; Table 1), only two sediment samples were taken that represent the BSC (0-0.5 cm) and the underlying sediment (1-10 cm). At each sampling site, we collected nearby rock either in outcrop (pothole sites) or float (other sites) for comparison of the magnetic, chemical, and mineralogic properties of the sediments and bedrock. In the laboratory, we separated from most BSC samples the uppermost filamentous layer (representing the top [dsim]0.25 cm) and prepared it separately for magnetic property measurements. For this operation, the remaining sample from the upper 0.5 cm was assigned a depth of 0.25-0.5 cm to represent the data. Magnetic data are presented in the manuscript (Fig. 1), using averaged results from the BSC intervals and from the two sampled layers in the underlying sediment. Chemical results were obtained on the 0-0.5-cm samples and separately on the two deeper layers. Results from these deeper layers were averaged to produce Fig. 3 in the manuscript.

Magnetic Methods. The types, amounts, and grain sizes of magnetic minerals were determined from a combination of petrographic and magnetic methods. The identification of magnetic minerals was done primarily by using reflected-light microscopy. In this way, reliable identification of different Fe--Ti oxide minerals can be made on grains larger than about 3 µm in diameter, and the presence of iron oxide can be discerned from

grains as small as about 1 µm. The grains were prepared in polished grain mounts after isolation from the bulk sediment in a pumped-slurry magnetic separator.

The common magnetic minerals can be placed in two groups---low coercivity ferrimagnetic minerals (e.g., magnetite, titanomagnetite, and maghemite) and high-coercivity ferric oxide minerals (e.g., hematite and goethite). On the basis of the petrographic examinations, it is appropriate to use simply the terms "magnetite" and "hematite" to designate the two groups. Information on the abundance of these different magnetic minerals, as well as on magnetic grain size of magnetite (magnetic domain state), is provided by magnetic-property measurements (Table 2). For this study, the measurements were made on dried bulk sediment packed into 3.2-cm^3 plastic cubes and normalized for sample mass. Magnetic susceptibility (MS) is a measure of all magnetic material but mainly ferrimagnetic minerals such as magnetite when it is present. MS was determined in a 0.1-mT induction at frequencies of 600 Hz and 6,000 Hz, using a susceptometer with a sensitivity better than 2×10^{-10} m^3 kg^{-1}. A measure of the quantity of magnetite sufficiently large enough (magnetic grain size greater than about 30 nm) to carry remanence (permanent magnetization) is isothermal remanent magnetization (IRM), the magnetization acquired by a sample after exposure to a strong magnetic field (either 0.3 or 1.2 T). In this study, remanent magnetization was measured by using a 90-Hz spinner magnetometer with a sensitivity of about 10^{-5} A m^{-1}. Hard isothermal remanent magnetization (HIRM), a measure of high-coercivity ferric oxide minerals such as hematite, is calculated as $(IRM_{1.2T}-IRM_{0.3T})/2$. Magnetic grain size, which may not be a proxy for sediment particle size, reflects the magnetic domain structure of magnetic minerals that provides information about origins of these minerals. We determined frequency-dependent MS (FDMS) to test for the presence of ultrafine (<30 nm) superparamagnetic (SP) magnetite or maghemite grains near the SP single domain boundary. Higher MS at low frequency than at high frequency (expressed as a positive difference in magnitude or as a percentage, FDMS% = $[(MS_{600\,Hz}-MS_{6000\,Hz})/MS_{600\,Hz}) \times 100]$ provides an estimate for concentrations of SP grains. Such ultrafine particles have intrinsically high MS and may form *in situ* in soils, as in Chinese loess-paleosol sequences.

Chemical Methods. Major, minor, and trace elements were determined by using a combination of energy-dispersive x-ray fluorescence (XRF; Tables 3 and 4) and inductively coupled plasma-atomic emission spectroscopy (ICP-AES; Table 5) analyses on pulverized bulk samples. Analytical precision from repeated runs of two standard reference materials are presented with the data (Table 3). XRF also provided analysis for V, Cr, Mn, Ni, Cu, Zn, Rb, Sr, Y, Nb, Mo, Sn, Sb, Cs, Ba, La, and Ce. The ICP-AES method yielded detectable values for 27 elements, some of which are shown in Table 5.