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Particle-Size, $CaCO_3$, Chemical, Magnetic, and Age Data from Surficial Deposits in and around Canyonlands National Park, Utah

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Open-File Report 2005-1186

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey, Reston, Virginia: 2005

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Introduction

This report presents data and describes the methodology for magnetic, geochemical, and textural measurements of sediment and soil, as well as age determinations of sites located in and around Canyonlands National Park, on the Colorado Plateau, southeastern Utah (fig. 1).

The data presented in this report are results of ongoing studies of American drylands, where numerous sites have been investigated to assess how climate change and land use affect the landscape, largely through geomorphic processes. In particular, the influence of eolian and fluvial processes on ecosystem dynamics, ranging from nutrient inputs to landscape evolution, is a central focus of these studies (Neff and others, in press; Reheis and others, in press; Reynolds and others, 2001; Reynolds and others, in press).

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Methods

Site Selection

Many sites in and around Canyonlands National Park, Utah, were selected to include different geomorphic settings that contain sand sheets/dunes, playas, and fluvial/alluvial deposits (table 1; fig.1). Site selection was determined by strategies to examine a variety of plant communities, ecotones, occurrences of plant invasion, especially by cheat grass (*Bromus tectorum*), as well as different land-use histories and local bedrock.

Virginia Park

Virginia Park is located in Canyonlands National Park (figs. 1 and 2). It is a sheltered basin of vegetated, stabilized sand dunes surrounded on three sides by walls of the Cedar Mesa Sandstone and bounded on the southwest by a canyon. This site was sampled from the fall of 1998 through the spring of 2000. The deposits sampled at this site consist of multiple sequences of locally derived sand separated by poorly to moderately developed soil that formed in the sand layers. The shallowest samples (0–10 cm) represent the most recent episode of significant eolian modification of the landscape, including dune formation, which likely ceased about 2 ka. Difficult access and lack of water have precluded livestock grazing at this site (Kleiner and Harper, 1972). It is the only such ungrazed site in this study.

Squaw Flat

The Squaw Flat site is located in Canyonlands National Park (figs. 1 and 3). The transect sampling and the soil pit sampling at this site occurred during the spring of 2000 and the fall of 2001, respectively. The upper sampling sites in the transect are in a low-angle (1–3°) sand-sheet that slopes away from the Cedar Mesa Sandstone. The lower sampling sites are from mixed alluvial-eolian deposits in a poorly drained area near the middle of a meadow. This site was grazed until 1974 (M.E. Miller, U.S. Geological Survey, oral commun., 2004).

Needles

The Needles area is located in Canyonlands National Park (figs. 1, 4a, and 4b). The sites in this area are in playa deposits interbedded with eolian sand sheets and were sampled in the fall of 1998. These sites were auger sampled to about 4 meters in depth. The bedrock in this area is the Cedar Mesa Sandstone. This site was grazed until 1974 (M.E. Miller, U.S. Geological Survey, oral commun., 2004).

Mustard Patch

The Mustard Patch site (figs. 1 and 5) is near the eastern boundary of Canyonlands National Park and consists of eolian sand on a surface sloping away from Cedar Mesa Sandstone. This site was sampled during the spring of 2000. The upper part of this transect occupies a surface characterized by small coppice dunes representing recent eolian activity. The surface over the middle part of the transect generally is featureless, thereby representing a sand-sheet environment. The lowest sampling sites are in a mixed eolian sand-alluvial setting at the margin of a poorly drained valley oriented nearly 90° to the trend of the sampling transect. Grazing by domestic livestock ceased at this site in 1974 (M.E. Miller, U.S. Geological Survey, oral commun., 2004).

Gray's Pasture

Gray's Pasture (figs. 1 and 6) is located in the Island in the Sky area of Canyonlands National Park. Samples were collected in the spring of 2003 along a shallow-gradient slope away from the Navajo Sandstone. The sampled deposits consist mainly of eolian sand in small dune-forms in the upper half of the transect and in a mostly featureless surface in the lower half. The site previously was grazed until 1974 (M.E. Miller, U.S. Geological Survey, oral commun., 2004).

The Grabens

The Grabens sites (figs. 1 and 7) are located in Canyonlands National Park and consist of alluvium, colluvium, and eolian sediment deposited within closed, fault-related depressions formed in the Cedar Mesa Sandstone. The auger hole samples were taken during the fall of 1998. The arroyo exposure was sampled during the fall of 1999, and the optically stimulated luminescence samples were collected during the fall of 2002. Grazing practices for the Grabens area are not directly known; however, nearby Chesler Park was previously grazed until 1964, and the Grabens area grazing practices likely followed those at Chesler Park (M.E. Miller, U.S. Geological Survey, oral commun., 2004).

Dugout Ranch

The Dugout Ranch site (figs. 1 and 8) is located approximately 7 km east of the Canyonlands National Park boundary. This site consists mainly of eolian sand deposited on a nearly flat surface. The bedrock in this area is the Chinle Formation, the Wingate Sandstone, and the Kayenta Formation. This site initially was sampled during the fall of 2001 and was resampled in the spring 2004 to assess the influence of documented wind erosion between sampling times. This site and the surrounding areas have been grazed by domestic livestock since the arrival of Anglo-American settlers in the 1880s (Loope, 1977) and is currently grazed, mostly in the spring.

Corral Pocket

The Corral Pocket site (figs. 1 and 9) is located approximately 4 km east of the Canyonlands National Park boundary and consists of a sand-sheet and alluvial fan complex. The local bedrock consists of small exposures of Cedar Mesa Sandstone and overlying cliffs of Organ Rock Shale. The Organ Rock Shale contributes nearly all of the locally derived sediment to the sampled slope. This transect was sampled during the fall of 2000. The site is on Bureau of Land Management land and is currently grazed (M.E. Miller, U.S. Geological Survey, oral commun., 2004).

Meteorological Stations

The majority of sites presented in this report are in close proximity to climate monitoring equipment. Virginia Park, Corral Pocket, and Dugout Ranch sampling sites have Climate Impact Meteorological Stations (CLIM-MET) on site that are operated and maintained by the Central Region Earth Surface Processes team of the U.S. Geological Survey (USGS) (*http://climchange.cr.usgs.gov/info/sw/clim-met/*). Another USGS CLIM-MET station is located in the Needles district of Canyonlands National Park near the staff residence area, approximately 1–2 km from the Needles sampling sites (*http://climchange.cr.usgs.gov/info/sw/clim-met/needles.html*). The closest CLIM-MET station to the Squaw Flat and Mustard Patch sampling sites is located in Needles; however, the Mustard Patch sampling site also is in close proximity (~6 km) to the Corral Pocket CLIM-MET station (*http://climchange.cr.usgs.gov/info/sw/clim-met/corral.html*). The Virginia Park CLIM-MET station (*http://climchange.cr.usgs.gov/info/sw/clim-met/virgpark.html*) is closest to the Grabens sampling sites. The nearest weather monitoring station to the Gray's Pasture sampling site is located in the Island in the Sky area of Canyonlands National Park and is operated and maintained by the National Park Service (*http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?utcank*).

Sampling

Three sampling strategies were employed throughout the study area: (1) isolated deep auger holes, (2) transects that consist of several shallow (50 cm), small soil pits anchored by deep auger holes, and (3) soil pits (table 1). In addition, when possible, arroyo exposures were utilized for stratigraphic relations and sampling.

The isolated deep auger holes were sampled approximately every 10 to 20 cm and ranged from 2.5 to 4.0 meters deep. The shallow, small soil pits and deep auger hole transects are the most common sampling arrangement. The shallow, small soil pits and the top of the deep auger holes were sampled fairly consistently at 0–10 cm, 10–30 cm, and 30–50 cm. The deep auger holes that anchor the transects are as much as 2.29 meters deep and below 50 cm were sampled approximately every 10 cm. Five larger soil pits (VP-1, VP-2, JN-1, JN-2, JN-3) were excavated at selected sites within the study area. The soil pits are all approximately 1 meter deep and were channel sampled based on soil horizon designations. Arroyo exposures also were sampled based on soil horizon designations.

The arroyo and graben exposures and the VP-soil pits were described (table 2) following Birkeland (1999). In some cases, the soil auger sequences were described similarly, but with less precision due to the lack of visible exposure and to mixing when the auger was reinserted into the hole. Approximate soil horizon boundaries were identified during the augering using changes in soil color, carbonate morphology, effervescence in HCl, and sediment texture.

Laboratory Analysis

Samples were analyzed at the USGS Earth Surface Processes soils and magnetics laboratories (Denver, Colo., United States of America) for hygroscopic moisture factor, calcium carbonate percent, particle size, and magnetic properties (table 3). The soil analyses followed the protocols outlined in Singer and Janitzky, (1986). Geochemical analysis was performed by the USGS Geologic Division geochemistry lab (Denver, Colo., United States of

America). All samples were analyzed at <2-mm size fraction and in some cases magnetic properties were measured on the <63-µm size fraction (silt + clay).

Age determinations were made by optically stimulated luminescence (OSL) and Carbon-14 (^{14}C) methods. Optically stimulated luminescence ages were determined at the Aberystwyth Luminescence Research Laboratory (Wales, United Kingdom). Radiocarbon samples were prepped at the ^{14}C laboratory of the U.S. Geological Survey (Reston, Va.), and ages were determined by accelerator mass spectrometry (AMS) at the NSF-University of Arizona AMS laboratory (Tucson, Ariz.). Age data presented in this report, as well as other age data from the area, have been placed in stratigraphic and geomorphic context and can be found in Reheis and others, (in press).

Hygroscopic Moisture Factor

The hygroscopic moisture factor (table 3) is a measure of the moisture content of a sample at or near field conditions and is calculated by:

H = OD/AD, where

H = Hydroscopic Moisture Factor

OD = Oven-dry sample weight (105°C; 16 hrs)

AD = Air-dry sample weight

Calcium Carbonate Percent

Calcium carbonate percent (table 3) was measured using a Chittick apparatus (Dreimanis, 1962) as described by Machette (1986) whereby 6*N* HCl is applied to the sample and the gas evolved from the reaction displaces fluid within the Chittick apparatus. The volume of liquid displaced is used to calculate the percent of calcium carbonate in the sample.

$CaCO_3$ % = (V_{CO2} * C)/W_S, where

$CaCO_3$ % = Calcium carbonate percent

V_{CO2} = The volume of liquid displaced during reaction in presence of HCl

C = Constant; (P_B/T_K)*0.16, where

P_B = Barometric Pressure in Hg mm

T_K = Temperature in degrees Kelvin

W_S = Oven-dry sample weight (105°C; 16 hrs)

Particle-Size Analysis

Particle-size analysis was performed on the <2-mm size fraction using a Malvern laser analyzer (tables 3 and 4). Prior to analysis, all samples were prepared by digesting organic matter and $CaCO_3$ using 30% H_2O_2 and 15% HCl, respectively. Prior to analysis, sodium hexametaphosphate was added to each sample to deflocculate clays.

Geochemical Analysis

Samples were analyzed for chemical properties by inductively coupled plasma-atomic emission spectrometry (ICP-AES) and inductively coupled plasma-mass spectrometry (ICP-MS) techniques (tables 3 and 5) (Lichte and others, 1987). All samples were analyzed on the <2-mm size fraction and were finely ground using a shatterbox.

Magnetic Properties

Magnetic properties were determined on a majority of samples, both <2-mm and, in some cases, <63-µm size fractions (tables 3 and 6). Magnetic properties determined included low frequency and high frequency magnetic susceptibility (MS_{lf}, MS_{hf}), anhysteretic remanent magnetization (ARM), and isothermal remanent magnetization (IRM).

Magnetic Susceptibility

Magnetic susceptibility (MS) was measured by using a susceptometer with a sensitivity better than about 4×10^{-7} m^3/kg. Samples were measured in a 0.1 mT induction at a low frequency of 600 Hz (MS_{lf}) and high frequency of 6000 Hz (MS_{hf}). For each sample, the MS value was determined as the mean of four measurements. Frequency dependent susceptibility was calculated as:

$$FDMS = (MS_{lf} – MS_{hf})/MS_{lf}.$$

Laboratory Induced Magnetization

Measurements of anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) experiments were made by using a high-speed spinner magnetometer. Anhysteretic remanent magnetization was imparted in a decreasing alternating field from a peak induction of 100 mT and a DC bias of 0.1 mT. IRM magnetizations were generated at room temperature by using an impulse magnetizer. First, IRM was imparted in a 1.2T induction ($IRM_{1.2T}$). The samples then were magnetized in the opposite direction by using an induction of 0.3T ($IRM_{-0.3T}$). Hard isothermal remanent magnetization (HIRM) and the S-parameter were calculated as follows (King and Channel, 1991):

$HIRM = (IRM_{1.2T} + IRM_{-0.3T})/2;$

$S = IRM_{-0.3T}/IRM_{1.2T}$

Age Determinations

C-14

Charcoal within the alluvial deposits at the Virginia Park site was sampled and placed into plastic bags using metal trowels. The charcoal received a standard acid-alkali-acid pretreatment to remove post-depositional contamination. One milligram of carbon was collected from the charcoal by converting it to graphite over an iron catalyst. The graphite was pressed into a target and ^{14}C dated using accelerator mass spectrometry. The raw ^{14}C ages later were converted to calibrated years B.P. (cal yr B.P.) by using the CALIB program of Stuiver and others (2003) (table 7). Calibration of raw ^{14}C ages corrects for known time intervals when atmospheric carbon concentrations deviated from modern values causing the appearance of an age that was too old or too young.

Optically Stimulated Luminescence

For OSL dating, samples were taken from outcrops and pits using PVC pipe hammered horizontally into freshly cleaned faces. Laboratory OSL measurements were performed using an automated Risø TL/OSL reader, equipped with blue LEDs (470 nm) providing about 17 mW cm^{-2} power density and a beta source for irradiations. Three 3mm Hoya U-340 filters were used to detect the OSL signal. To determine the equivalent dose (D_e) of each sample, a minimum of 24 aliquots were examined for a range of preheat temperatures between 160–300°C using the single-aliquot regenerative-dose (SAR) measurement procedure of Murray and Wintle (2000), which corrects for changes in the luminescence sensitivity. All OSL measurements were made at 125ºC. Each aliquot yields an independent estimate of D_e; the mean D_e of between 13–23 aliquots was used to determine each 90–125-µm coarse-grained OSL age, and the 4–11-µm fine-grained OSL ages were calculated using the mean D_e of between 19-22 aliquots (table 7). The uncertainty on D_e was calculated as the standard error of the mean for all samples. For further discussion of OSL methods, see Reheis and others, (in press).

Acknowledgments

Many people have contributed to the compilation of data presented in this report. We thank Rich Tigges, Marie Bernatchez, and the Bobby's Hole crew for field assistance; Eric Fisher, Jiang Xiao, Isla Castaneda, Yarrow Axford, and Ken Takagi for sediment analyses; Darren "Paco" Van Sistine for GIS work; and Jeremy Havens and Lisa Rukstales for their stellar formatting and editorial assistance. Thanks to Gary Skipp and Jossh Beann for review of this report and helpful suggestions for improvement.

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