

A Dynamic Record of Late-Holocene Environmental Change Recorded in Banded Colluvium from the Northern Great Plains: Preliminary Data and Implications for Long-Term Drought Cycles since the Late Pleistocene

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We report here on a late-Holocene colluvial record of environmental change from the Little Badlands, 13 km south of South Heart, Stark County, North Dakota (103° 00' 39" W, 46° 45' 20" N). Gully erosion of a pediment has exposed more than 3 m of poorly consolidated, color-banded clayey silts. At least 11 distinct couplets of dark carbon-rich and light carbon-poor bands (Figure 1) record multiple episodes of sediment accumulation and soil formation. Banded colluvium of late-Pleistocene to Holocene age occurs throughout the unglaciated regions of southwestern North Dakota. Here we demonstrate the potential value of these deposits as proxy paleoclimatic indicators, especially for determining longer-term drought cycles (ca. 200 yr). Drought cycles have been reported from studies of late-Holocene lacustrine deposits in eastern and central North Dakota (Laird et al. 1996a, 1996b; Yu and Ito 1999), but their occurrence in the late Pleistocene and early Holocene is less well known, having been reported from only a single site on the Missouri Coteau (Newbrey and Ashworth 2004).

The colluvium was deposited by sheet wash following erosion of Oligocene Brule Formation mudstones and sandstones exposed in a 30-m-high escarpment about 300 m east of the section. Although modern soil development has overprinted the upper part of the profile, banding is present from a depth of

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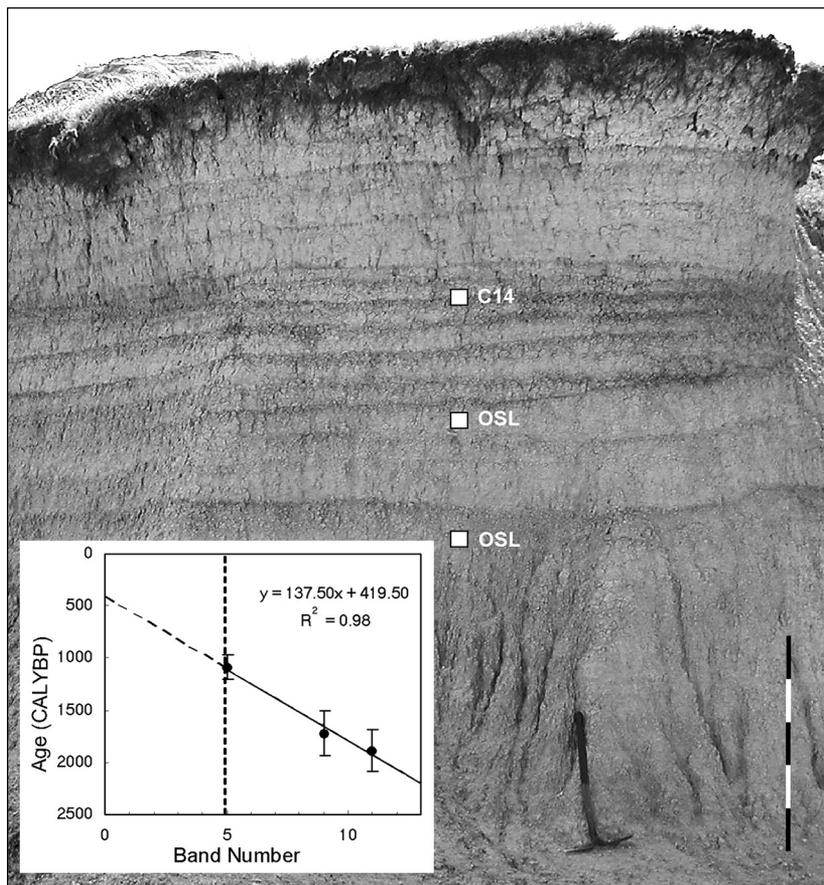


Figure 1. Banded colluvial deposits in the Little Badlands, Stark County, North Dakota. ^{14}C and OSL sample horizons are indicated. The ^{14}C sample was collected from a hearth at the equivalent stratigraphic position exposed in the opposite wall of the gully. The vertical scale on the photograph is 1 m. The inset shows the dating results and an analysis of banding periodicity (slope). The vertical dashed line in the inset represents the discontinuity surface.

about 50 cm from the surface to the base of the colluvium. The bands range in thickness from 18 to 33 cm. Each couplet consists of a 1- to 2-cm brown to dark grayish brown (10YR 4/2, 10YR 4/3, 10YR 5/2), carbon-rich horizon, including finely disseminated charcoal, with soil structures and textures ranging from granular loam to platy loamy clay overlying light gray to pale brown (10YR 7/3, 10YR 7/2, 10YR 6/3, 10YR 5/3), carbon-poor, angular blocky to prismatic friable loams (Munsell colors and organic carbon analysis from Foss, written comm., 1992). Induration of the sediments increases downward from weakly to well indurated due to the presence of the carbonate.

A buried hearth with charcoal, bison-bone fragments, and chert was exposed in the profile at a distinctive discontinuity surface marked by a thin lag

of gravel (Figure 1). The occurrence of several hearths in nearby sections of colluvium, abundant bison bones, chert and quartzite tools, and debitage indicates that the area was inhabited by Plains Indians taking advantage of potable water from springs and fuel from an ash woodland located at the base of the Brule escarpment. Within the banded deposits in an adjacent gully, at a depth of 122 cm, Ashworth recovered the skull of an adult gray wolf (*Canis lupus*) with worn teeth. The blunting of the canines appears too extreme for natural wear and may be the result of intentional human modification, in which case the skull could represent that of a domesticated animal.

A ^{14}C sample was obtained from charcoal extracted from the hearth at 200-cm depth. Sediment samples for OSL dating were collected at a depth of 255 cm and 295 cm below the modern surface (Figure 1). OSL dating was conducted in the Optical Dating and Dosimetry (ODD) Lab at North Dakota State University. Experimental methods included single-aliquot regeneration (SAR) data collection procedures (adapted from Murray and Wintle 2000, 2006) and the "leading edge" data-analysis approach (Lepper and McKeever 2002; Lepper et al. 2007). These methods make it possible to determine hundreds of age estimations per sample and to select a representative age for the deposit based on the shape of the data distribution. Dosimetric data were obtained via instrument neutron activation analysis (INAA; Ohio State University Research Reactor). The OSL ages obtained were 1720 ± 220 (255 cm; $n = 45$; $M/m = 1.85$) and 1890 ± 200 (295 cm; $n = 93$; $M/m = 1.43$) CALYBP. The radiocarbon age of the hearth was 1170 ± 100 (Beta-23335) RCYBP or 1086 ± 114 CALYBP (Fairbanks et al. 2005).

The dates represent a stratigraphically coherent chronology suggesting rapid but episodic deposition of the thick colluvial pediment in the late Holocene; subsequent gully incision occurred in the latest Holocene, perhaps even in historic times. We interpret the banded structure of the colluvium to be related to long-term wet-dry cycles, with increased rates of erosion and colluvial mobilization alternating with phases of landscape stability and incipient soil development. We recognize that fire, through natural and possibly anthropogenic activities, may have played a role in the accumulation of carbon but consider it secondary to climate in couplet formation.

In one of the few continuous paleoclimatological records from western North Dakota, Yu and Ito (1999), using spectral analysis of geochemical data, show cyclical drought periodicities at 400, 200, 130, and 100 years. They consider the most likely cause to be long-term variation in solar output. Based on our chronology, an average length for the formation of a couplet below the distinctive discontinuity surface is 137 yr (Figure 1, inset). The discontinuous nature of deposition and low resolution of the chronological control make it impossible to know if deposition of the colluvium is cyclically controlled by centennial scale drought cycles, but the average age of couplets places them in the correct time framework for that to be a possibility. Another lacustrine record from central North Dakota suggests that drought cycling in the region was not limited to the late Holocene, but occurred in the early Holocene and late Pleistocene (Newbrey and Ashworth 2004). The colluvial archives of unglaciated southwestern North Dakota, such as the one examined in this report, have the potential to hold a complete Quaternary drought record.

Our preliminary data indicate that ^{14}C and OSL dating can be used together to yield a coherent chronology for these deposits. Continued work in this area may reveal a longer Quaternary record assembled from similar colluvial deposits and may answer such outstanding questions as: How are local colluvial records linked to regional climate factors such as drought and fire history? How have humans influenced the development of these colluvial records? When was pediment incision initiated, and was it influenced by changes in modern land-use practices, especially in introducing upland farming of small grains, corn, and sunflowers?

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