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Forces driving late Pleistocene (ca. 77–12 ka) landscape evolution in the Cimarron River valley, southwestern Kansas

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ABSTRACT

This study presents stratigraphic, geomorphic, and paleoenvironmental ($\delta^{13}C$) data that provide insight into the late Pleistocene landscape evolution of the Cimarron River valley in the High Plains of southwestern Kansas. Two distinct valley fills (T-1 and T-2) were investigated. Three soils occur in the T-2 fill and five in the T-1 fill, all indicating periods of landscape stability or slow sedimentation. Of particular interest are two cumulic soils dating to ca. 48–28 and 13–12.5 ka. $\delta^{13}C$ values are consistent with regional paleoenvironmental proxy data that indicate the prevalence of warm, dry conditions at these times. The Cimarron River is interpreted to have responded to these climatic changes and to local base level control. Specifically, aggradation occurred during cool, wet periods and slow sedimentation with cumulic soil formation occurred under warmer, drier climates. Significant valley incision (~25 m) by ca. 28 ka likely resulted from a lowering of local base level caused by deep-seated dissolution of Permian evaporite deposits.

Introduction

Despite long-term interest in the late-Pleistocene stratigraphy and paleoenvironments of the High Plains (e.g., Antevs, 1935; Frye and Leonard, 1952; Haynes and Agogino, 1966; Holliday et al., 1994, 1996, 2011; Holliday, 1995, 2000), significant knowledge gaps still exist. Previous studies in the central High Plains (western Kansas, southwestern Nebraska and eastern Colorado) have typically focused on late-Quaternary eolian sands and loess (e.g., Forman et al., 1995; Maat and Johnson, 1996; Olson et al., 1997; Porter, 1997; Muhs et al., 1999, 2008; Olson and Porter, 2002; Johnson et al., 2007) whereas research on alluvial deposits has primarily been directed toward Holocene-aged fills (e.g., Johnson and Martin, 1987; Mandel, 1994; Bettis and Mandel, 2002). In contrast, with the exception of studies during the mid-twentieth century that focused on basic lithostratigraphic and paleontological relationships (e.g., Smith, 1940; Frye and Hibbard, 1941; Frye and Leonard, 1952; Gutentag, 1963), little work has been undertaken on the Pleistocene alluvium in this region. Our study expands upon this early work by assessing stratigraphic, geomorphic, and pedologic data from late-Pleistocene (Marine Oxygen Isotope Stage (MIS) 4–2, ca. 77–12 ka) alluvial fills stored in the Cimarron River valley, southwestern Kansas. Also, stable carbon isotope ($\delta^{13}C$) data from buried soils provide insight into late Pleistocene paleoenvironmental change and subsequent alluvial response. While $\delta^{13}C$ analyses have been successfully employed in Holocene alluvial environments (e.g., Nordt et al., 1994; Baker et al., 2000; Cordova et al., 2011; Mandel, 2013), here we report data from the late Pleistocene, a time interval for which such records are scarce in the Great Plains.

Study area

Physiography and geology

The study area is located in southwestern Kansas, which is part of the High Plains region of the Great Plains physiographic province (Fig. 1A; Fenneman, 1931). The High Plains covers ~450,000 km^2 and represents the remnant of an extensive alluvial apron formed by sediment shed from the Rocky Mountains. The High Plains is predominantly underlain by the Miocene and early Pliocene-aged sediments of the Ogallala Formation together with Quaternary alluvial and eolian deposits. Topographic relief is largely confined to stream valleys in which the Ogallala Formation crops out and Quaternary alluvium is stored.

Interfluves and alluvial terraces in the High Plains are mantled by at least three late-Quaternary loesses: the Loveland, Gilman Canyon, and Peoria (e.g., Muhs et al., 1999; Bettis et al., 2003). The Loveland loess is typically the oldest loess unit exposed and dates to the

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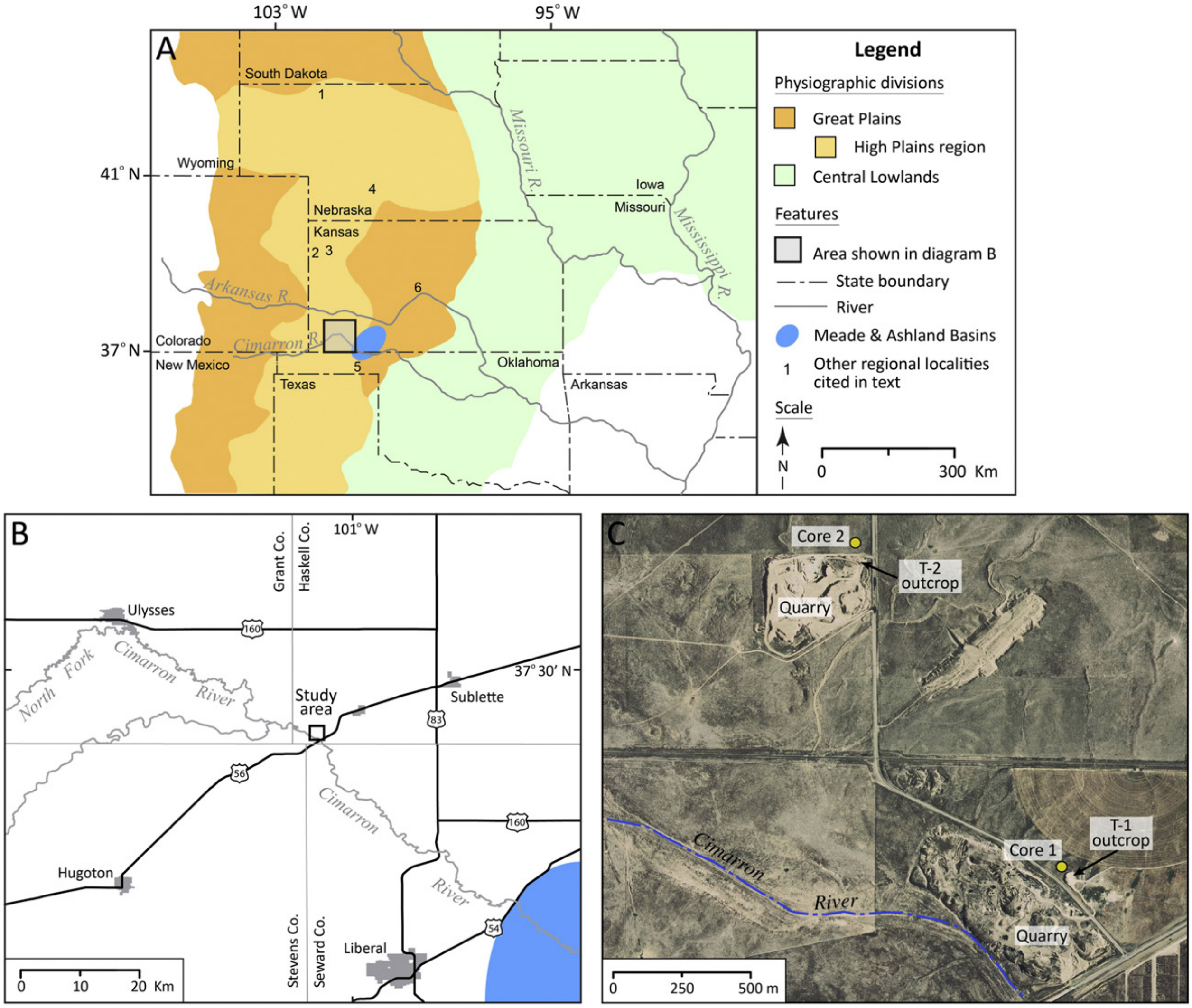

Figure 1. (A) Regional map showing the central High Plains and paleoenvironmental localities mentioned in text: 1) Cobb Basin, 2) Kanorado, 3) Willem Ranch, 4) Eustis Ash Pit, 5) Bull Creek, 6) Cheyenne Bottoms. (B) Study area location in the central High Plains, southwestern Kansas. (C) Aerial photograph of study area with quarry outcrop and core locations.

penultimate glaciation (MIS 6). The Gilman Canyon Formation overlies the Loveland Loess and is usually < 2 m thick (Bettis et al., 2003). The Gilman Canyon Formation typically consists of a dark noncalareous silt loam that has been modified by pedogenesis, commonly with two or more soils forming a pedocomplex (e.g., Reed and Dreeszen, 1965; Mandel and Bettis, 1995; Johnson et al., 2007). Radiocarbon ages from sites in the Great Plains indicate that the Gilman Canyon Formation dates between ca. 40,000 and 20,000 ^{14}C yr BP (Muhs et al., 1999; Johnson et al., 2007). The Peoria Loess mantles the Gilman Canyon Formation and is the thickest and most areally extensive loess deposit in the Great Plains (Bettis et al., 2003). Radiocarbon ages indicate that Peoria Loess deposition began ca. 30,000–20,000 ^{14}C yr BP and continued to accumulate until ca. 10,000 ^{14}C yr BP (e.g., Bettis et al., 2003; Muhs et al., 2008).

We investigated late-Quaternary alluvium stored in the Cimarron River valley of southwestern Kansas. Valley fills underlying two terraces (T-1 and T-2) were investigated in two sand and gravel quarries in the southwest corner of Haskell County (Fig. 1C). The T-1 and T-2 terrace treads stand 9 and 24 m above the modern river channel, respectively (Fig. 2A). The Cimarron River, a tributary of the Arkansas River, originates on the High Plains in northeastern New Mexico and drains ~49,000 km^2 (Fig. 1A). In the study area, the valley width is ~3 km, with ~45 m of elevation change between the uplands and the valley floor.

Climate and vegetation

The climate of southwestern Kansas is a semiarid steppe (Peel et al., 2007). Mean July and January temperatures for the period of record (AD 1918–2014) at Sublette, Kansas are 26°C and 0°C, respectively, and mean annual precipitation is 47.3 cm (High Plains Regional Climate Center, 2014). Approximately 75% of the precipitation falls during the months of April through September, largely as a result of frontal activity. The collision of Pacific and polar air masses with warm, moist maritime-tropical air from the Gulf of Mexico often produces intense rainfall of short duration along the zone of convergence. Periodic intensification of westerly (zonal) airflow, however, prevents moist Gulf air from penetrating into the High Plains and tends to cause drought in the region.

The natural vegetation of southwestern Kansas is short grass prairie (see Küchler, 1974). Uplands are dominated by C_4 plant communities, including blue gramma (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*). C_3 broadleaf deciduous trees,