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Permian dust in Oklahoma: Source and origin for Middle Permian (Flowerpot-Blaine) redbeds in Western Tropical Pangaea

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ABSTRACT

Analogous to many Permian units globally, the Middle Permian of Oklahoma (Flowerpot Shale and Blaine Formation) contains voluminous fine-grained redbeds. These units have long been interpreted to record marine to marginal-marine deposition owing to minor evaporite/dolomite strata; this interpretation, however, disregards the predominant siliciclastic material. Siltstone predominates, and all siliciclastic material is of inferred aeolian origin owing to the fine and remarkably uniform grain size, internally massive structure, blanket-like geometry, and common palaeosols, especially in the Flowerpot Shale. Previously suggested alternative environments for such abundant fine-grained material, such as distal deltaic deposition, are inconsistent with the absence of key sedimentary structures (e.g., graded beds), associated facies (e.g., channelised units), and vertical or lateral trends (e.g., upward coarsening). The minor claystone and associated evaporite and dolomite facies of the Blaine Formation exhibit evidence for subaqueous deposition, but with aeolian delivery of the siliciclastic component. An aeolian dust origin for the siliciclastic material reinforces the interpretation of generally semiarid conditions for this equatorial region of western Pangaea. Whole-rock geochemical and detrital-zircon geochronological data on the siliciclastic units indicate a mixed provenance that includes a mafic component exhibiting a composition similar to reference populations from the Ouachita orogen. The dominant zircon populations reflect transport from easterly/southeasterly directions, with fewer grains likely derived from basement located to the west. Combining an aeolian delivery with the provenance signal indicates predominant equatorial easterlies during deposition of the study units, and subordinate westerlies, consistent with Pangaean monsoonal circulation. Permian redbeds preserved in many parts of former low-latitude Pangaea bear attributes similar to those of the units documented here, suggesting a possible greater role for dust deposition during this time than previously appreciated.

1. Introduction

Mud-rich redbeds, commonly intercalated with evaporite and carbonate strata, form a common facies succession within many Permian and Triassic clastic strata throughout the world (e.g. Waugh, 1971; Dubiel and Smoot, 1994; Zhang et al., 1998; Benison and Goldstein, 2001; Schneider et al., 2006; Tabor et al., 2011). These redbeds archive the transition from late Palaeozoic icehouse to Mesozoic greenhouse conditions. Furthermore, Middle Permian redbeds that characterise the North American Midcontinent accumulated in the wake of the Appalachian–Ouachita orogeny, which records a part of the Gondwanan–Laurentian collision (Slingerland and Furlong, 1989). Thus, understanding these systems provides data for interpreting climatic and tectonic aspects of western equatorial Pangaea.

Permian strata of Oklahoma comprise voluminous redbeds long interpreted to record tidal flat and/or marginal marine conditions primarily on the basis of intercalated evaporite and carbonate strata (Muir, 1933; Hills, 1942; Everett, 1962; Fay, 1964; Johnson, 1967), which were long associated primarily with marine conditions. Evaporite and carbonate strata, however, are now well recognised components of continental settings as well (i.e., Lowenstein and Hardie, 1985). Nevertheless, palaeogeographic reconstructions for the Permian of Midcontinent North America continue to reflect an overall marine interpretation, which largely ignores the siliciclastic component forming the majority of these strata. For units in northwestern Oklahoma, Totten (1979) followed the marine interpretation, but noted that evidence for fluvial–deltaic delivery of the clastics, such as channels, is oddly absent. For the correlative Permian Nippewalla Group (Kansas), some have suggested aeolian and palaeosol interpretations reflecting arid continental environments, including acid saline lakes (Holdoway, 1978; Benison et al., 1998; Benison and Goldstein, 2000, 2001). These discrepancies in environmental interpretations highlight the need for re-evaluation of Permian redbeds in Oklahoma, and the greater North American Midcontinent, with potential application to analogous units elsewhere.

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Additionally, provenance for this large volume of Permian redbeds remains unclear, with proposed derivation from (in modern coordinates) the Wichita and/or Ouachita uplifts (Oklahoma) to the south and southeast (Muir, 1933; Everett, 1962; Fay, 1964; Johnson, 1967; Totten, 1979; Kocurek and Kirkland, 1998), the uplifts of the ancestral Rocky Mountains to the west and northwest (Muir, 1933; Kocurek and Kirkland, 1998), and the Ozark dome (Fay, 1964; Totten, 1979) and Appalachian Mountains to the east (Soreghan et al., 2002a, 2002b; Soreghan and Soreghan, 2007; Gehrels et al., 2011).

Here, we present new data and analyses on sedimentology, geochemistry, and detrital zircon geochronology of fine-grained siliciclastic strata of the Middle Permian (Flowerpot Shale and Blaine Formation) of Oklahoma that suggests a prominent role for aeolian processes. Recognition of widespread accumulation of aeolian dust here, and its provenance, bear on palaeogeographic and palaeoclimatic reconstruction for this time and region, including reconstruction of atmospheric circulation and dust loading, and have potential application for interpretations of analogous fine-grained redbed strata elsewhere in greater equatorial Pangaea.

2. Tectonic and depositional setting

The late Palaeozoic was characterised by global mountain building resulting from the assembly of Pangaea. Within the North American craton, western equatorial Pangaea experienced Late Carboniferous orogenesis resulting in the Ancestral Rocky Mountains (ARM), a series of Precambrian-cored uplifts and basins formed in the distal foreland of the Ouachita–Marathon orogen of westernmost equatorial Pangaea (Kluth and Coney, 1981; Kluth, 1986; Dickinson and Lawton, 2003). In the study region, regional compression resulted in formation of the Wichita Uplift and adjacent Anadarko foreland, separated by a series of thrust faults (Fig. 1; Kluth and Coney, 1981; Kluth, 1986). However, Permian strata onlapping the Wichita Uplift record incipient subsidence and ultimate burial of the uplift by the Middle Permian (Ham and Wilson, 1967; Johnson, 1971; Johnson, 1978; Gilbert, 1986; Soreghan et al., in press), with the Anadarko Basin continuing to subside into the Late Permian (Fay, 1964). Regionally, structural elements of the Midcontinent such as the Nemaha Uplift, Ozark Dome, and Hugoton Embayment may have remained prominent into the Middle Permian

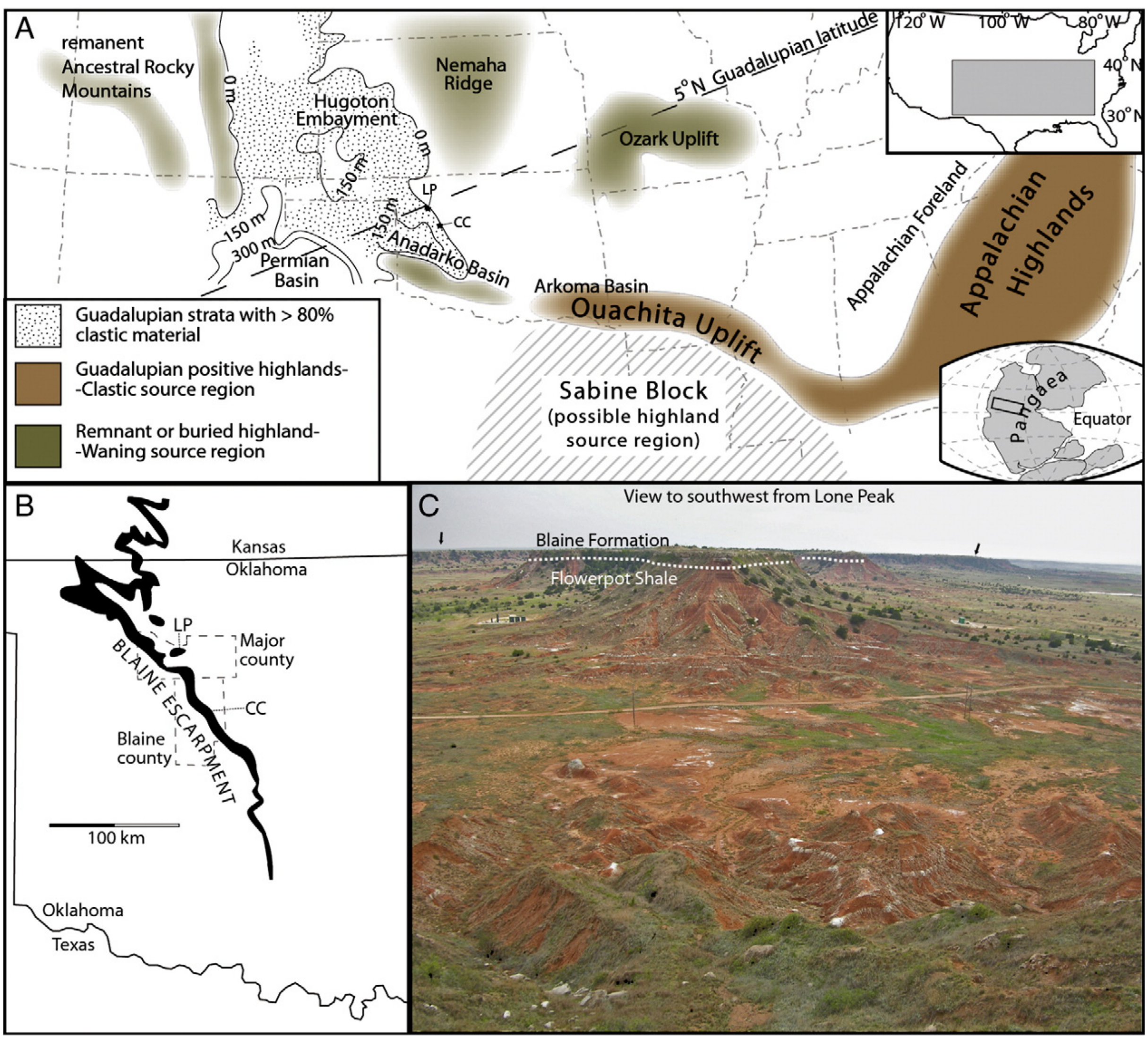

Fig. 1. A) Guadalupian palaeogeography of the central United States showing highlands and depocenters. Colour of positive regions reflects relative elevations such that the brown regions indicate the topographically highest and the green reflect remnant or buried highlands. Note that emerging evidence varies on the amount of positive elevation for the (late Carboniferous-aged uplifts of the) Ancestral Rocky Mountains, Nemaha Ridge and Ozark Uplift for this time interval (Soreghan et al., in press). Isopachs of >80% clastic-rich strata are from Adler et al. (1971). The Sabine Block includes the Yucatan Block, Sabine Uplift and Texarkana Platform (Sharrah, 2006). Guadalupian 5° N latitude is estimated from Scotese (1999). LP = Lone Peak study area. CC = Cat Canyon study area. Inset (upper Right): Grey box outlines approximate region of map within the United States. B) Regional extent of the Blaine Escarpment shown in black (Modified from Fay, 1964). C) View from top of Lone Peak looking south.