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Sedimentological effects and stratigraphic implications of a rare, high-stage flow in an evolving, braided to anabranching stream with riparian woodland

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ABSTRACT

Low-frequency (1 in 25 years) high-stage flows on the South Platte and upper Platte rivers in Nebraska (USA) during September–October 2013 produced sedimentary effects that are unaccounted for in depositional models of that fluvial system. Being superimposed on a historically recent trend of channel-belt abandonment and encroachment of woody vegetation, these outcomes are even more useful for comparison with the wider sedimentary record. Rooted vegetation, particularly riparian trees, played a major role in determining where erosion and sedimentation occurred outside of the main (perennially flowing) channels. Effects of the 2013 event include: (1) small pebble to cobble-sized gravel in various bar-top and flood-channel settings; (2) common current or sediment shadows, including streamlined sediment shadow bars, several meters or more in length, which formed downstream from rooted trees and logjams; (3) sand lobes that prograded into densely wooded abandoned parts of the historical channel belt at angles of as much as 85° from average downstream flow; (4) large scours, some approaching 2 m in depth, many of which formed behind trees near the diffluences of flood channels and the main channel; (5) deposits of sand that were baffled by nonwoody or shrubby vegetation in the abandoned channel belt; and (6) local accumulations of large woody debris in front of rooted trees, as cross-flood-channel dams, and rarely as walls alongside flood channels. In an aggrading system, these features should be preserved as a distinctive set of sedimentary structures, which may be interpretable as evidence for episodic major flows in a system in which woody vegetation has encroached widely onto the channel belt.

1. Introduction

During September 9–15 2013, the heaviest rainfall recorded in 116 years fell over a 300 km-wide area on the flanks of the Colorado Front Range, USA. Extraordinary floods on the South Platte River and its tributaries in the Denver metroplex and Colorado Piedmont received worldwide media exposure. The progression of these floodwaters downstream into sparsely populated western Nebraska presented the first opportunity in four decades to document the effects of abnormally large flows on the normally low-discharge South Platte River and downstream on the upper Platte River (Figs. 1, 2A). The September 2013 flows in the South Platte and upper Platte rivers extended well beyond the limits of the one or two narrow channels that normally carry permanent flow. Parts of the channel belt abandoned for decades to more than a century were inundated by flow at least 2.0–2.5 m above normal flow level. Channels, bars, and vegetated islands underwent reworking; many abandoned or generally inactive channels were reoccupied; and characteristic sedimentary structures were produced as sediment-bearing flows interacted with woody vegetation in riparian zones alongside channels.

The opportunity to witness the effects of overbank flows on the South Platte River only manifests itself an average of once every 25 years; only four other events having peak discharges exceeding >600 m^3/s have occurred on the South Platte River in northeastern Colorado and southwestern Nebraska (Fig. 2B, C) during the period of modern stream gaging (National Weather Service, undated; United States Geological Survey, undated). Unquantified high-stage flows also occurred in 1844 and 1894 (Follansbee and Sawyer, 1948). Such events are attributed to heavy rainfall upstream (as in 1973 and 2013), particularly intense montane snowmelt, or a combination of those two factors (Engel and Fischer, 1991). The earliest models for braided-stream deposition in the Platte system (e.g., Smith, 1970, 1971) were published during the same period as the two preceding high-discharge events of June 21–22 1965 and

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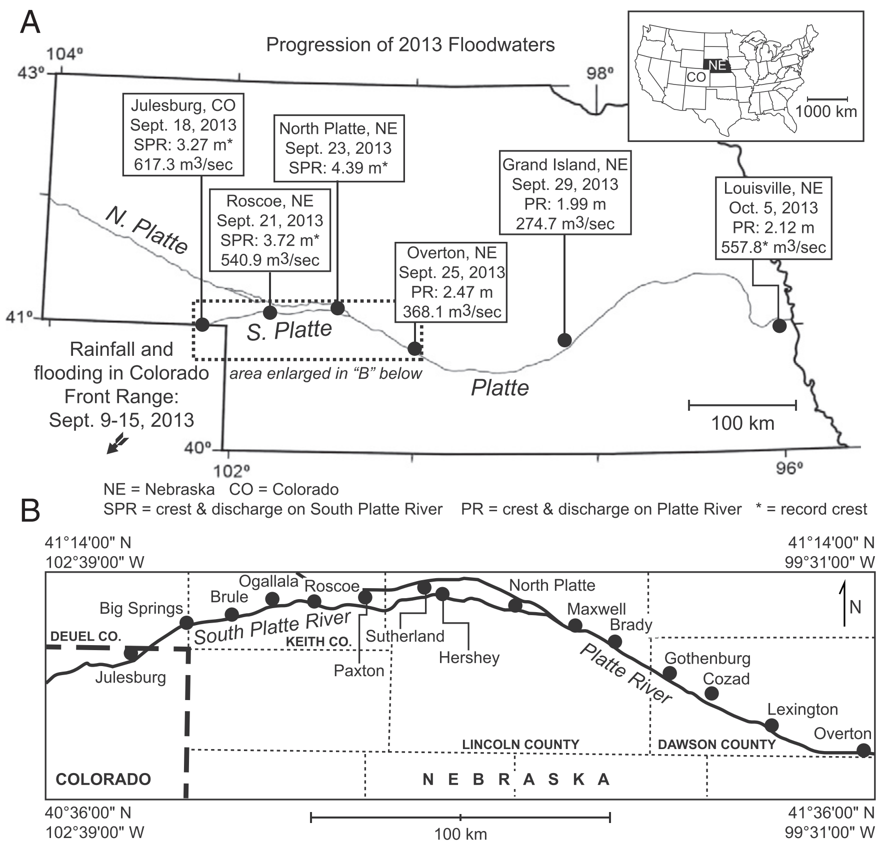

Fig. 1. The 2013 flood event on Platte River system in Nebraska. (A) Progression of high-stage flows across state during September 18–October 5 2013 (National Weather Service, undated; United States Geological Survey, undated); inset map in upper right shows location of Colorado (CO) and Nebraska (NE) in contiguous USA. (B) Enlargement of area most affected by high-stage flows in South Platte and Platte rivers in Nebraska; see text for further discussion.

May 13–June 1 1973 (Engel and Fischer, 1991). Unfortunately, those previous floods on the South Platte and Platte rivers went undocumented from a comprehensive sedimentologic and stratigraphic perspective, although some sedimentary effects of 1965 and 1973 floods on a tributary of the South Platte in Colorado were documented by Osterkamp and Costa (1987). Moreover, the sedimentary implications of such floods on the Platte system were not incorporated in either the fundamental (Smith, 1970, 1971; Miall, 1978) or most recent models of "Platte-type" braided-stream deposition (e.g., Horn et al., 2012a). The 2013 event was superimposed on decades-long trends of partial channel-belt abandonment, planform change and woodland encroachment in the Platte system overall (Joeckel and Henebry, 2008; Horn et al., 2012a).

The chief purpose of this study is to document the sedimentary effects of the 2013 event on the Platte system, considering that prior events were not at all well-documented from this perspective, and to compare them with similar effects described from the small number of comparable accounts of other rivers elsewhere. Its secondary purpose is to place the erosional and depositional effects of the 2013 event into context relative to the recent evolution of the Platte system by examining overall changes in channel belts, planforms, and riparian vegetation in a series of historical serial images taken at intervals during the period 1938 to 2014. The resultant case study of a single, major flow event, placed within an historical background of recent fluvial-system change, should be useful in the interpretation of flow dynamics and sedimentation patterns in modern and ancient fluvial systems undergoing longer-term changes driven by climate shifts, the encroachment of woody vegetation, and channel abandonment. The critical scientific assessment of long-term sedimentary effects is beyond the scope of the present study, but we suggest that our observations should be considered in the interpretation of deposits laid down by ancient braided, sandy to gravelly streams under changing environmental conditions.

2. Setting

The South Platte River, one of the two principal tributaries of the Platte River, drains nearly 63,000 km^2. It originates in the montane valley known as South Park and flows thence across the eastern slopes of the Colorado Rockies, the Colorado Piedmont, and onto the Great Plains to converge with the North Platte River and form the Platte River east of North Platte, Nebraska, USA (Fig. 2). A fluvial system with headwaters in the Rockies and a strong eastward component of flow has existed in the same general area since at least the Oligocene (e.g., Swinehart et al., 1985), and possibly since the late Paleocene (Galloway et al., 2011). The South Platte River has been known since at least the 1850s as having comparatively unimpressive or unreliable flows. Samuel Clemens (Twain, 1873, p. 60), for example, summarized his experience with the river in 1864 thusly:

> We came to the shallow, yellow, muddy South Platte, with its low banks and its scattering flat sand-bars and pygmy islands — a melancholy stream straggling through the center of the enormous flat plain, and only saved from being impossible to find with the naked eye by its sentinel rank of scattering trees standing on either bank. The Platte was "up," they said — which made me wish I could see it when it was down, if it could look any sicker and sorrier.

Stream-gaging data (U.S. Geological Survey, undated) generally support the observation expressed by Clemens. During the period 1902–2013 at Julesburg, Colorado, 61% of all peak annual flows were less than 100 m^3/s, or less than one-sixth the size of September, 2013 flows, and 82% were less than 300 m^3/s, or less than one-half of the same (Fig. 2B).