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Freshwater megaflood sedimentation: What can we learn about generic processes?

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ABSTRACT

There is growing recognition that sedimentary deposits related to high-energy, large-scale, freshwater floods are widespread across the continents and, in the main, can be related to Quaternary outbreak flows from ice-dammed lakes. Such deposits may also occur in the Neogene and earlier. Recognition of these 'megaflood' deposits is hindered by the lack of well-conditioned stratigraphic models of depositional successions. However, descriptions of successions from many locations often exhibit commonalities when compared carefully. Thus the primary purpose of this paper is to examine and condense the published stratigraphic and sedimentological evidence so as to identify the key signatures of megaflood successions. The deposits often are the only record of a flood and so the secondary purpose is to interpret the sedimentary sequences in order to recreate the behaviour of floods through single and multiple events. Finally, some pointers are provided as to those areas of sedimentological research that might be profitably explored in more depth to improve understanding of megaflood dynamics.

A key characteristic of megaflood deposits is the apparent massive appearance of single units, which on closer inspection usually are amalgamated layers of similar grain-size distribution. Individual beds and sets of beds are commonly near-horizontal, planar and laterally extensive. Successions evidently are not channelized and extensivity is indicative of simultaneous and coherent deposition over large areas. Localised large-scale clinoforms, or smaller-scale cross-beds are common, associated with bar-front or dune progradation respectively, but otherwise extensivity implies that cross-cutting erosional contacts, notably steeply inclined examples, and small-scale scours are not common except immediately around large isolated clasts, such as dropstones and ice-blocks.

A common vertical stack of sequences in any one succession consists of: (1) basal, thick, coarse parallel-bedded units, (2) large-scale clinoforms, (3) horizontally-bedded thin laminated units, (4) ripple and dune cross-beds, (5) silt-beds, and (6) succession-capping debris flow deposits (in some cases). Such a succession usually is indicative of a single cycle of waxing and waning flood flow, generally dominated by high-concentration suspension deposition onto plane beds. The high power allows the transport of fine gravel and coarse sand in suspension leading, upon deposition, to relatively coarse beds from suspension fall-out. Clay and silt is generally sparse or absent, being transported further down the system. At the scale of the hydrograph, the successions indicate that flows initially accelerate and then decelerate, with significant shorter period flow pulses also evident in the sedimentary signatures. In parallel-bedded sequences (primarily during waxing flows), bedload transport often was ineffective in sorting sediment due to the high-rates of deposition from the highly sediment-charged waters, resulting in diffuse accretion surfaces. At each location, similar sequence stacks are common, leading to the impression of rhythmic deposition from pulsing flow, including from repetitive series of floods. Although often composed of coarse grains, many sequence stacks (excluding any debris flows) are not dissimilar to turbidity flow sequences; the Bouma sequence in particular. Although there is limited experimental evidence for turbidity currents associated with high energy freshwater flows, theory does not preclude the deposition of similar sedimentary motifs from high concentration flows, such that an analogy between some megaflood sedimentary beds and turbidites is not unreasonable. Despite considerable variation in megaflood sedimentary successions, commonalities occur which are indicative of similar processes of deposition from high energy floods at geographically different locations. The changes in style of deposition throughout a succession provide clues as to the nature of the flood flows and this information could be used to improve estimates of flood hydrograph behaviour. However, hypotheses linking deposit characteristics to flow dynamics are currently ill-conditioned and often poorly tested.

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The majority of published studies describe the coarser-scale stratigraphy, with only passing reference to the fine-scale structure of individual beds. Closer attention to lamination styles, particle orientation and syn-depositional deformation structures, for example, should provide information on the flow mechanics at the time of bed deposition. Thus, better consideration of the sedimentology of megaflood deposit beds will lead to better understanding of the controlling hydraulics and should result in better models of flood deposition.

Contents

1. Introduction

Although possible examples of catastrophic freshwater flooding have been known for decades (Andrews, 1869), it is only in recent years that it has become evident that such spectacular events were circumpolar; associated with the termination of the Pleistocene Epoch and the decay of polar and continental ice sheets, which process also extended into the Holocene. Not only was flooding a global phenomenon (Fig. 1; Baker, 2009), with extraordinary spatial extent and repeated frequency, but significantly the runoff contributed to continental-scale drainage systems that are now defunct or residual (Baker, 1997; Mangerud et al., 2004; Baker, 2007, 2013). Further there is speculation