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Floodplain morphology, sedimentology, and development processes of a partially alluvial channel

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ABSTRACT

The floodplain morphology, sediment deposits, and development mechanisms of a partially alluvial, low-moderate energy channel flowing over a mixed gravel/cobble-till bed are investigated and compared to existing ideas of floodplain development. The findings partially support the idea of a floodplain developed through lateral accretion capped with vertically accreted sediments as predicted by the energy-based classification scheme of Nanson and Croke (1992), though oblique accretion and partial channel avulsion are also important. Channel migration consists of limited cross-valley migration and downstream meander translation. Because of low channel sinuosity, well-formed neck cutoffs are rare, and instead the channel cuts headward along the insides of confined or underdeveloped meander bends forming a localized anabranching pattern. The floodplain architecture can be divided into gravel bar and bed deposits (GB), lateral accretion deposits (LA), overbank deposits (FF), and abandoned channel deposits (FF(CH)), which are described with four alluvial facies. Owing to the limited supply of coarse and fine sediment, none of the architectural elements are particularly thick, with total floodplain thickness being <3 m. Floodplain development for partially alluvial channels is compared within a new floodplain discrimination framework. Comparisons with common facies models of single-thread, coarse-grained channels show important differences that suggest that the floodplain deposits and formative processes described herein represent a subset of single-thread systems that may be common in partially alluvial channels, particularly in slightly sinuous, coarse-grained channels of low-moderate energy with partly confined floodplains.

1. Introduction

Floodplains preserve alluvial deposits previously laid down by river channels and are essential archives in understanding depositional processes and channel dynamics. Floodplain development and composition are largely determined by the energy in the system, the calibre and quantity of sediment delivered to the channel from valley sides and tributaries, and the degree to which the floodplain is confined (Nanson and Croke, 1992). Since the pioneering work of Wolman and Leopold (1957), many floodplain types have been identified for alluvial channels, broadly segregated by their planforms and migratory styles, energy levels, and bedload characteristics (Nanson and Croke, 1992; Miall, 1996). Nanson and Croke (1992) devised a qualitative classification scheme describing nine genetic, or geomorphic, floodplain types for predominantly alluvial channels that can be loosely differentiated based on specific stream power. Each of these floodplain types has a characteristic channel planform, sediment character, and floodplain morphology produced by a combination of various floodplain formative processes. From a strictly sedimentological perspective, Miall (1996) developed facies models that describe the underlying alluvial architecture of major alluvial channel types. These two classification schemes inform scientists and river management practitioners of how a 'typical' alluvial river of a given planform and sediment type should develop its floodplain. However, these schemes are largely biased toward unconfined channels with fully alluvial boundaries and tend to neglect channels with partially alluvial boundaries that form in supply-limited watersheds.

Partially alluvial channels have beds composed of a mix of alluvium and bedrock (Turowski et al., 2008), indurated Pleistocene sediments (Nittrouer et al., 2011), or fine-grained glacial sediments, the latter of which are prevalent in low-relief regions that were covered by continental ice sheets during the last glaciation (Nanson, 1980; Macklin and Lewin, 1986; Croke, 1994; Brooks, 2003; Arbogast et al., 2008; Foster et al., 2009; Gran et al., 2009, 2013; Belmont et al., 2011; Day et al., 2013; Phillips and Desloges, 2014). Channels in these glacially conditioned watersheds have beds composed of fine to coarse alluvium, thinly and/or discontinuously overlying fine-grained, cohesive till or glaciolacustrine clay that behave like erodible bedrock and constrain the vertical adjustment of the channel (Meshkova et al., 2012). In some reaches, the channel is also partly confined by glaciogenic sediment along one or both banks, where the lower bank is glaciogenic

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and the upper bank is alluvial. In these cases, the channels do not fit existing models of partially alluvial channel morphology (Meshkova et al., 2012).

Detailed studies on floodplain development and stratigraphy in low relief, glacially conditioned watersheds are not well documented and have focused primarily on large, low gradient reaches (A_d > 5000 km^2; Nanson, 1980; Walker et al., 1997; Brooks, 2003; Stewart and Desloges, 2014), while little information is available for smaller watersheds. The available information typically shows thin gravel deposits overlain by structureless or weakly graded sand and silt (Phillips and Robert, 2005; Foster et al., 2009; Thayer, 2012; Gran et al., 2013; Phillips and Desloges, 2015b), which is more rudimentary than existing facies models for single-thread channels (Miall, 1996) but seems to be comparable to floodplain descriptions from some mixed alluvium-bedrock channels, although information regarding floodplain sedimentology and genesis in many of these cases has not been clearly documented (Brakenridge, 1984; Nanson, 1986; Tooth et al., 2002, 2004, 2007; Marren et al., 2006; Cohen and Nanson, 2008; Kermode et al., 2012, 2015; Keen-Zebert et al., 2013). Further, existing classifications of floodplain development in alluvial channels (e.g., Nanson and Croke, 1992) may not necessarily apply to glacially conditioned watersheds (Phillips and Desloges, 2015a) where channels, particularly in mid-watershed and downstream reaches, are often partly confined forming floodplains as narrow, discontinuous surfaces, similar to the partly confined, mixed alluvium-bedrock settings of Fryirs and Brierley (2010). Existing floodplain models suggest that floodplains in such partly confined reaches are 'strip and fill' where the channel erodes the floodplain down to a coarse basal lag and rebuilds the floodplain through gradual vertical accretion (Nanson and Croke, 1992; Fryirs and Brierley, 2013), though the energy necessary to achieve floodplain stripping is seldom, if ever, reached in low-relief watersheds (Phillips and Desloges, 2015a).

Given the paucity of information regarding floodplain formation in partially alluvial watersheds, where a wide range of energy levels and degrees of confinement exist, it seems necessary to better characterize the floodplain genesis of these rivers and contextualize them in the broader scheme of floodplain development and classification. To this end, this study describes a floodplain facies model for a partially alluvial

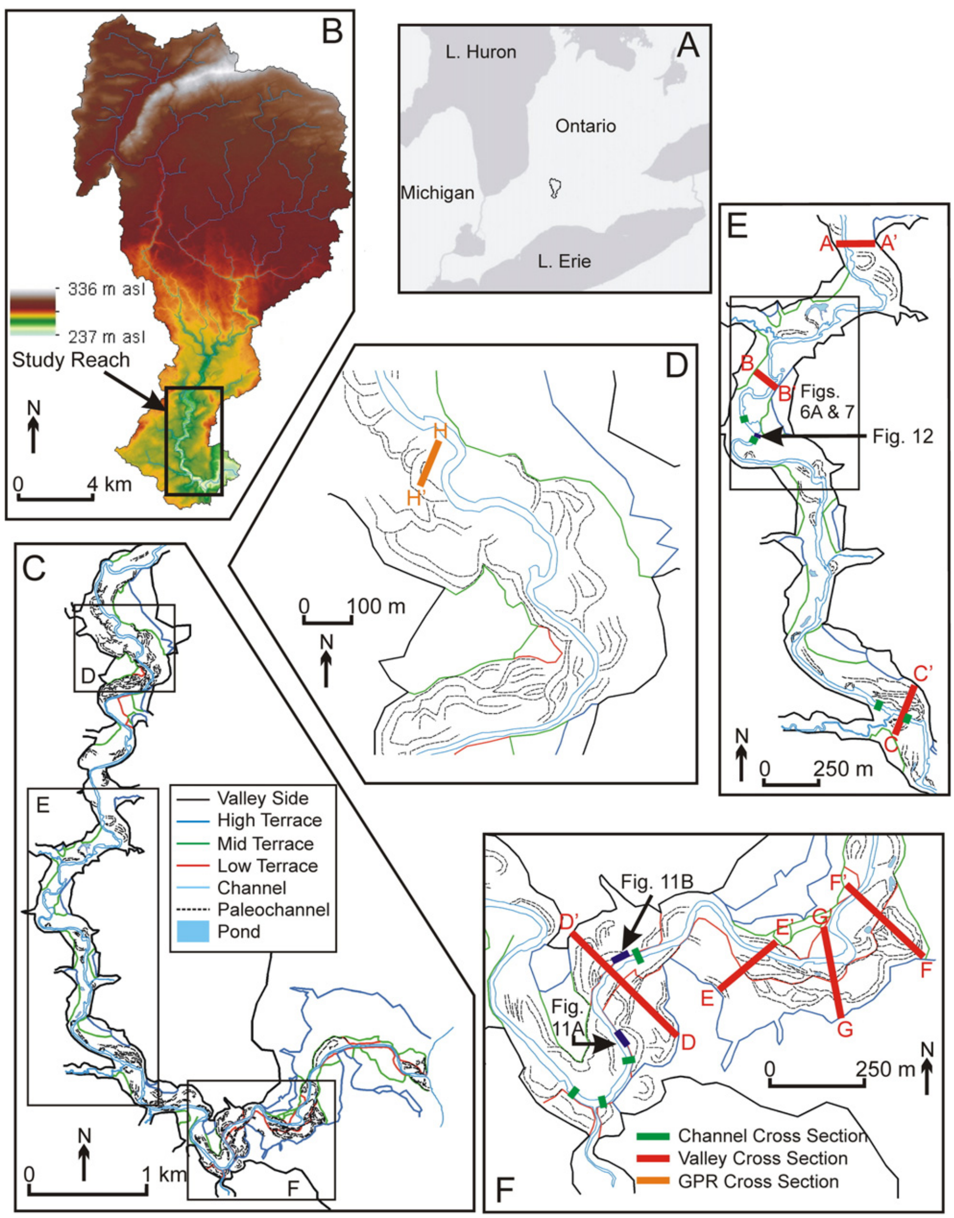

Fig. 1. Inset map of the Medway River watershed within southern Ontario (A). A 10-m digital elevation model of the watershed delineating the study reach (B). Morphological map of the study reach showing various terraces, paleochannels, and cross section locations referenced in the study (C—F).