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Headwater peatland channels in south-eastern Australia; the attainment of equilibrium

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ABSTRACT

Many small headwater catchments (<50 km^2) in temperate south-eastern Australia store sediment in valley fills. While accumulation in some of these systems commenced up to 30,000 years ago, most did not commence filling with peat or clastic material until at least the mid Holocene. In such headwater settings, many clastic valley fills develop cut-and-fill channels, which contrast to some peatland settings where sinuous equilibrium channels have evolved. Four peatland systems within this dataset demonstrate stable channel systems which span nearly the full spectrum of observed valley-floor slopes. We assess new and published longitudinal data from these four channels and demonstrate that each of these channels has achieved equilibrium profiles. New and published flow and survey data are synthesised to demonstrate how these peatland systems have attained equilibrium. Low rates of sediment supply and exceptionally high bank strengths have resulted in low width to depth ratios which accommodate rapid changes in flow velocity and depth with changes in discharge. In small peatland channels, planform adjustments have been sufficient to counter the energy provided by these hydraulically efficient cross-sections and have enabled the achievement of regime energy-slopes. In larger and higher energy peatland channels, large, armoured, stable, bedforms have developed. These bedforms integrate with planform adjustments to maintain a condition of minimum variance in energy losses as represented by the slope profiles and, therefore, a uniform increase in downstream entropy.

1. Introduction

Flows from small catchments are often confined by narrow valleys and, because of commonly steep headwater slopes, tend to maximise their relatively small discharges into high specific stream powers (Knighton, 1998; Reinfelds et al., 2004). Valley fills in such settings have previously been described as cut-and-fill systems which cycle through periods of stability, during which valley floors accumulate sediment and organic material, and instability, when reinvigorated channels incise into the fill and cause the evacuation of material down-valley (e.g. Young, 1986a,b; Prosser, 1988; Nanson and Croke, 1992). In humid settings, such systems encompass a range of sub-categories of alluvial-organic accumulations (Brierley and Fryirs, 2005): valley fills (Brierley and Fryirs, 1998; Eriksson et al., 2006; Johnston and Brierley, 2006), chains-of ponds (Eyles, 1977), swamp (Nanson, 2009), dells (Young, 1986a,b); and swampy meadows (e.g. Prosser, 1988; Erskine and Melville, 2008; Mactaggart et al., 2008). The dominant controls on the accumulation of sediment or the initiation of cutting or channel development in such systems have been attributed to both extrinsic factors, such as Holocene climate (e.g. Dodson, 1987; Cohen and Nanson, 2007), and intrinsic controls such as threshold valley slopes (e.g. Prosser et al., 1994; Erskine and Melville, 2008; Cheetham et al., 2010).

Given the broad range of morphologies, processes and catalysts for the progression of sediment accumulation in small humid-catchments, we collate a dataset to investigate controls on the timing of the onset of accumulation in small (<50 km^2) south-eastern Australian catchments in valleys with small depths of fill (generally 1–10 m). We then focus on channelized peatlands, a subset of these systems, where we investigate how they have achieved stability.

2. Valley fills

The extent to which organics dominate sediments in alluvial fills of small catchments is a function of climate and biophysical parameters (e.g. sediment supply, vegetation extent and type, topographic setting). Organic and clastic-dominated systems can operate in very different ways. Most alluvial cut-and-fill systems have high specific stream powers during the channel-dominant part of their cycle (Nanson and Croke, 1992) and respond to channel incision through positive feedback mechanisms which cause unarrested incision and expansion. Large, disequilibrium ephemeral channel (or gully) networks result. These networks can refill over 10^2 to 10^3 year timescales (e.g. Young, 1986a; Brierley and Fryirs, 1998; Eriksson et al., 2006). Valley fills also occur on lower gradients in small upland catchments and some such systems have

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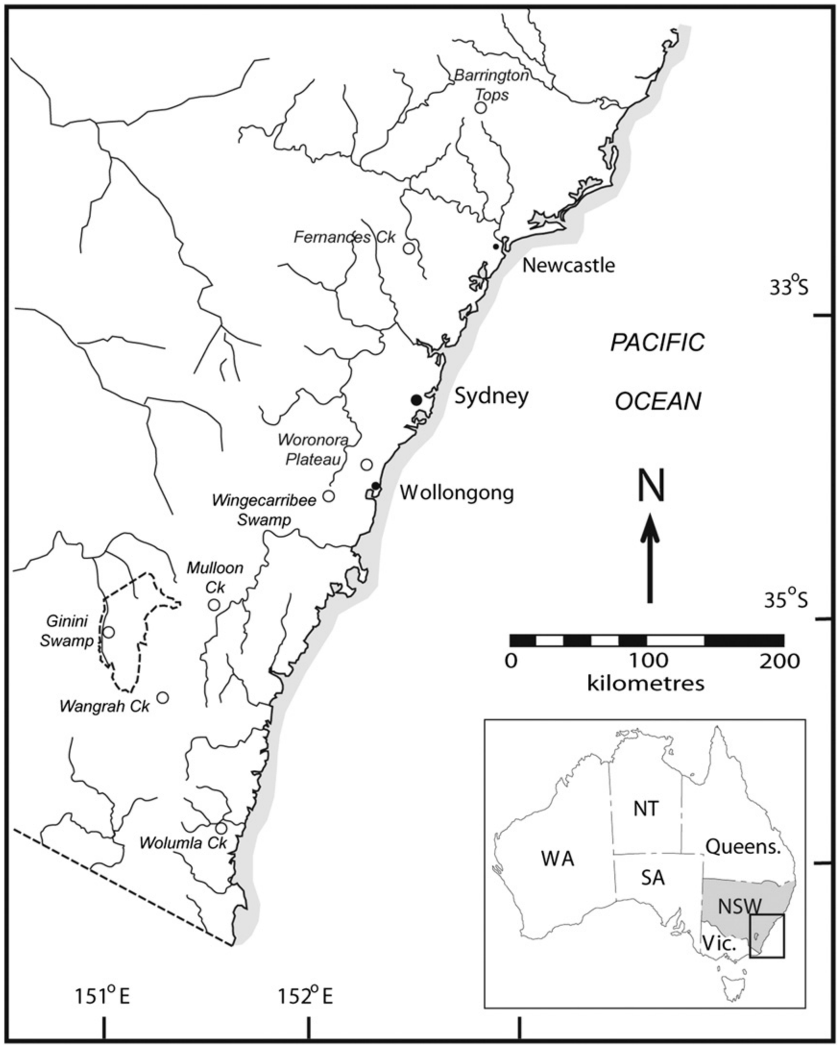

Fig. 1. Locality map with sites utilised within the study shown as open circles.

enhanced boundary strength supplied by vegetation and fibrous peat. Unlike their sandier clastic counterparts, however, highly organic low-gradient systems have the potential to withstand erosive flow forces and some are able to develop and maintain stable channels (e.g. Zimmerman et al., 1967; Jurmu and Andrle, 1997; Watters and Stanley, 2007; Nanson, 2009).

Globally, a range of terms has been used to classify organic terrains, most of which are country or discipline-specific (for international reviews see: Gore, 1983; Mitsch and Gosselink, 1986; Mactaggart et al., 2008). This paper uses the term *peatlands* to describe organic valley fills in which organic matter comprises >20% dry weight of the fill (Hope et al., 2012). As such, peatland systems include bogs, fens, moors and mires (Hope et al., 2012), but exclude most clastic cut-and-fill systems. A recent definition of swampy meadow terminology in Australia excluded channelled peatland systems (Mactaggart et al., 2008); such channelled conditions challenge conventional definitions of these environments and require further investigation.

2.1. Peatlands: with or without a channel?

Certainly, peatlands are sensitive to watertable height (Price et al., 2003) and can become compacted and dewatered in response to drainage, with consequent impacts on peatland hydrology, floristics and sedimentology (Southern, 1982; Young, 1983, Hope, 2003; Ramchunder et al., 2009). The effect of drainage ditches on peatlands and their catchments has been the focus of much research (e.g. Conway and Millar, 1960; Stewart and Lance, 1991; Holden et al., 2004, 2006) and historically, open-cut drains in UK blanket peatlands were spaced to maximise peat dewatering (typically at 5–50 m spacing; Holden et al., 2011). The effectiveness of such drains, however, is impeded by the low hydraulic conductivity of the basal (catotelm) peat horizon; the impact of individual drainage lines on peatland water tables may be limited to only 1–2 m laterally (Stewart and Lance, 1991; Holden and Burt, 2003; Holden et al., 2006). In peatlands with intact catotelms, a single drainage line may have only minimal impact on the hydrological function of the majority of the peatland system.

The post-European catchment disturbance in southern Australia has resulted in the development of gullies and watercourses through *Sphagnum* peatlands, causing many to convert, probably irreversibly, to grasslands or sedgelands (Good, 1992; Hope et al., 2012). Observations of many of the channels adjacent to such degraded systems in the Australian Alps demonstrate dewatered peat profiles, bank erosion and overwidened channels (Hope et al., 2012). Such channels have little opportunity for contraction for two reasons: 1. they are located in the headwaters of catchments where they receive only limited (clastic) sediment loads and 2. Australian peatlands have formed under marginal conditions for peat development such that accumulation rates are generally slow (Whinam et al., 2003). While global examples of pre-anthropogenic disturbance, equilibrium channelled peatlands are relatively rare, some systems have been described. Jurmu and Andrle (1997) examined a peatland channel in a small catchment (25 km^2) in Connecticut (USA) that had adopted unusually low width–depth