LATE HOLOCENE AGGRADATION AND INCISION IN THE NAAS RIVER, AUSTRALIAN CAPITAL TERRITORY – PRELIMINARY FINDINGS

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INTRODUCTION

European settlement triggered a major phase of incision and gully development in most upper catchments in south-eastern Australia (e.g. Wasson *et al.* 1998, Scott 2001). These changes brought unwelcome results such as loss of farmland, increased sedimentation and turbidity in downstream reaches as well as dramatic changes in stream ecology. In many areas these incised channels continue to be a major source of sediment. However, channel incision is not just a recent phenomenon. Many rivers in southeastern Australia have undergone numerous changes between aggradational and incisional phases during the Holocene (Prosser *et al.* 1994, Prosser 1996). Although many studies attempt to quantify the magnitude of the post-European incision phase, its extent in comparison to equivalent periods in the past is not known. Historic changes need to be viewed in the context of past changes in order to better understand how these river systems recover from incision events. In this study we examine periods of aggradation and incision in the Naas River valley during the late Holocene.

THE NAAS RIVER VALLEY

The Naas River is located within the Australian Capital Territory (ACT) in south-eastern Australia. It descends from a height of ca. 1,360 m ASL, through open *Eucalypt* woodland for ca 40 km before entering more open pasture land for the remaining ca. 20 km until its junction with the Gudgenby River at about 600 m ASL. The catchment (ca. 283 km^2) is underlain primarily by granodiorite. In the upper reaches it is characterized by steep (up to 30º) rocky hill slopes supporting thin regolith with shallow soils. In the lower parts alluvial deposits are increasingly dominant and occur in a 50-300 m wide 'corridor' along the river.

The climate is semi-arid but with no pronounced dry period during the year. Annual average rainfall is 500-700 mm with a mean monthly rainfall of 40-60 mm. Mean daily winter temperatures ranges from -4 to 9 ºC and mean daily summer temperatures from 9 to 25 ºC.

METHODS

Following a reconnaissance survey of the catchment and the surrounding region a ten kilometer reach immediately downstream of the Namadgi National Park boundary was selected for detailed studies of sediment stratigraphy and fluvial morphology.

Stream gradients of the river were measured using a Trimble 4800 differential GPS. This equipment was also used for mapping the heights and lengths of all terraces along the 10 km study reach (Figure 1). Mapping of 'hanging' gullies, abandoned channels and prominent stratigraphical boundaries was also undertaken.

Two major exposures in the alluvial deposits were selected for a detailed description of the sediment stratigraphy and soil analyses. The stratigraphical descriptions were complemented by augering and the digging of a trench through two bench terraces. Samples were collected for particle size analysis and dating, using Optically Stimulated Luminescence (OSL). Altogether 20 samples have been collected for OSL-dating; in this paper the results from seven are presented.

TERRACES AND ALLUVIAL SEDIMENTS

In the study reach the channel consists mainly of a sequence of shallow pools and riffles. In the upper section the riffles consist mainly of cobbles and large boulders, in the lower reaches they are predominantly cobbles. The stream gradient varies significantly from 0.72% in the upper third part of the study reach to 0.30% in the lower part (Figure 1).

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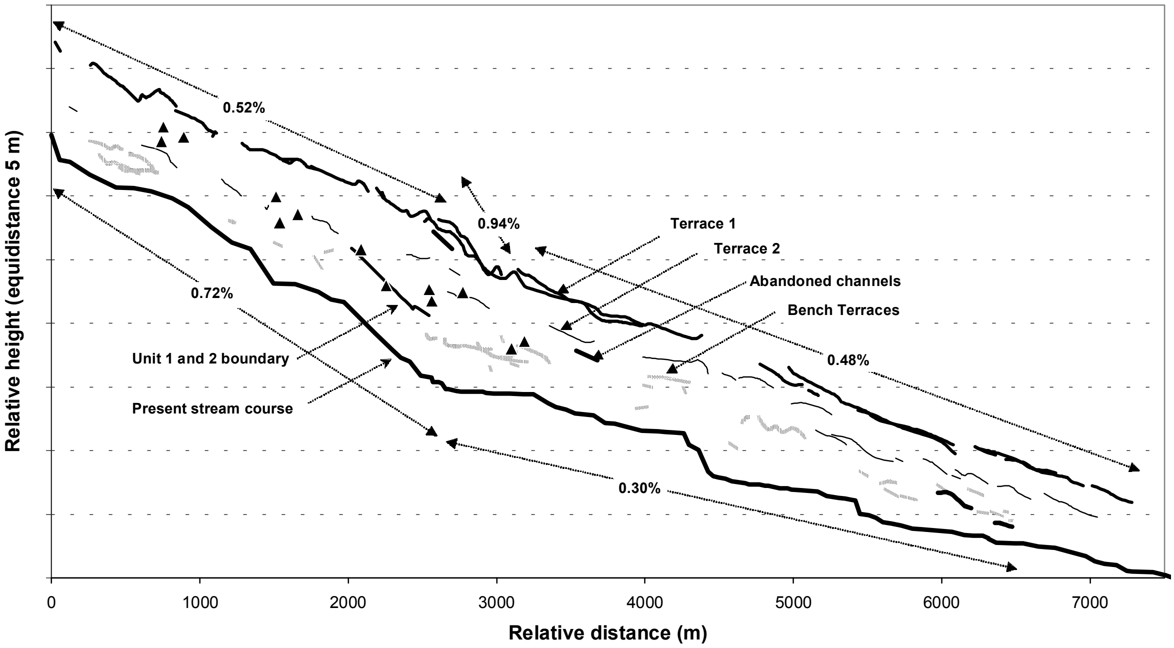

Figure 1: Longitudinal section along the study reach in the Naas River valley showing the present stream surface, terraces, abandoned channels and hanging gully mouths (triangles). Gradients for the present stream and Terrace 1 are also displayed. Note the steeper part of Terrace 1 in the middle of the diagram.

Numerous terraces are visible along the Naas River. In the study reach, the uppermost terrace (Terrace 1) is the only one that is nearly continuous and present along both sides of the valley. Terrace 1 is a depositional terrace with a gradient of 0.50% except for a steeper ca. 500 m long section with a gradient of 0.94%. This steep section occurs at the break of the stream gradient described above. In nearly all cases the remaining terraces are erosional features classified as bench terraces formed as isolated features as the river moved laterally during its progressive incision through the sediments. The second highest group of terraces (below Terrace 1) are more prominent than the rest. These terraces (Terrace 2) may have formed simultaneously as erosion terraces during a period when incision by the stream came to a temporary halt.

Three major sedimentary units have been mapped along the study reach. The basal unit (Unit 1) sits directly on top of bedrock and/or saprolite and consists of up to nearly 4 m of very hard loam, sandy loam and fine to medium sands in 20-100 cm thick units. Unit 2, which overlays Unit 1, is made up of a number of sediment couplets, each consisting of a massive, very loose layer of mixed sands and gravels overlain by a more fine-grained very hard clay loam or fine sand. The loose sandy gravel layer in each couplet is normally 30-90 cm thick while the fine grained top is seldom thicker than 30 cm. The boundary between the two is clear and occurs gradually over a few centimetres, while the boundary between different couplets is abrupt. This boundary sometimes truncate root channels within the fine grained layer. Unit 2 is about 5 m thick and consists of ~10 of these couplets. Unit 3 is an infilled stream channel that was incised within the Unit 2 sediments until the top of the more resistant Unit 1 was reached, which at that time formed the base of the incised channel. Unit 3 consists mainly of very loose mixed sands and gravels with minor finer-grained clay-rich layers. It is characterized by extensive layers showing cross bedding, graded bedding and planar bedding. The unit display more fine grained layers towards the surface.

FLUVIAL HISTORY OF THE NAAS RIVER

Based on geomorphological-stratigraphical evidence and the optical dates a preliminary reconstruction of the environmental history for the Naas River can be made. The oldest date is from the bottom of Unit 1, collected at a depth of 6.9 m below the surface of Terrace 1, and provides an age of 2,900-3,500 BP for that layer. This date gives an age of the oldest sediments found along the study reach and suggest that the Naas River valley was stripped to the bedrock, and/or the saprolite and associated core boulders, prior to ca 3,500 years BP. Numerous scour holes in the bedrock and large boulders that make up the present river bed support this and further indicate that the stream bed have been exposed for lengthy periods in the past. The date marks the commencement of a major depositional period that lasted for at least 1,000 years up to at least 1,730 ± 300 years BP, which is a date for a layer 1.15 m below the Terrace 1 surface. This deposition phase accounted for the formation of Unit 1 and 2.

Subsequent to the deposition of Unit 1 and 2 an incision of the Unit 2 sediments (Terrace 1) took place. A meandering stream formed an incised channel up to ca. 4 m deep within the Unit 2 sediments, but came to a halt as the more resistant unit 1 sediments were reached. The period of incision is bracketed by the uppermost date of the Terrace 1 sediment (1,730 ± 300 years BP) and a sample of the infilled material (Unit 3) at a depth of 3 m, giving an age of 1,120 ± 150 years BP.

Backfilling of the incised stream channel commenced not long before 1,120 ± 150 years BP and was probably rapid in the beginning, as seen from the coarse-grained cross bedded sediments in the bottom of Unit 3. The numerous cross bedded and interlayered clay-rich sediments further up in the stratigraphy, some finely laminated, indicate that the aggrading stream forming Unit 3 was an active meandering stream which over time changed its course laterally, thereby causing temporary inactive pools, or billabongs, in which fine sediments were trapped. The surface morphology of Terrace 1 and upper part of the stratigraphy of Unit 3 suggest that the stream may have been of the 'chain of ponds' type (Eyles 1977) towards the end of its life time.

The last major incision period that cut through the entire alluvial sequence and gave rise to the present river channel, commenced sometimes after 1,120 ± 150 years BP. Most of the bench terraces occurring throughout the study reach derive from this period of incision. From the trenches which were dug through two bench terraces, four OSL samples were retrieved. They provide ages between 335 ± 100 years BP and 730 ± 80 years BP. These dates indicate: a) that incision started before ca. 700 years BP and; b) that the incision has not been a straight forward process, but involved shorter periods of aggradation at ca. 700, 500 and 350 years BP. Moreover, the group of erosion terraces (Terrace 2) indicate a period of standstill in the incision process. Evidence from aerial photo interpretation as well as information from local farmers show that the incision continues to be active in present day in the lower part of the study reach where bedrock has not yet been exposed in the stream bed, apart from in a few places.

DISCUSSION

Based on OSL dated alluvial material and geomorphological-stratigraphical studies, the present study discloses two periods of aggradation and two periods of incision in the Naas River during the last 3,500 years. There are several preview studies of aggradational and incisional history of rivers in southeastern Australia before European settlement (e.g. Prosser *et al.* 1994, Prosser 1996). However, they are mostly based entirely on ^{14}C dating of various organic material transported by the stream. Interpretation of these results has therefore been ambiguous as it is difficult to know whether the obtained dates actually represent the time for deposition or not. It may be older material that has been dated, or the dates may have been obscured by contamination from younger carbon. Prosser *et al.* (1994) stress the need for research on fluvial history using improved dating methods, e.g. AMS dating as described by Gillespie *et al.* (1992). However, by dating the sediment deposition using OSL, a more accurate record of past fluvial activities will be obtained.

The causes behind aggradation and incision of rivers in southeastern Australia remain unsolved despite several studies in the past. Prosser (1996) inferred that a period of increased sensitivity to gully incision occurred between 4,000 and 2,000 years BP. However, data from several catchments shows discernible lags between erosion of individual valleys and long periods of stability between erosion periods. Based on these results, Prosser argued that large scale climatic variations have been less important than extreme events and intrinsic factors for triggering aggradation and incision. The results from the fluvial record of the Naas River do not clarify the question of whether incision have occurred synchronously in different catchments or not. On the contrary, the record from Naas shows two periods of incision where most catchments visited by Prosser indicate uninterrupted aggradation. The answer to the question of what triggered changes in the fluvial system in Naas may lie in catchment-specific changes as well as shifts in the regional climate. There are indications that the climate in southeastern Australia became cooler and drier around 3,000 years BP (Costin 1971, Wasson & Donnelly 1991) after a period of relatively wet and warm climate between ca 9,000 and 3,000 years BP. Such a change could mean that surface material on hillslopes became more erodable as a result of vegetation becoming more scarce. Extreme high energy climatic events may also have been more common. This climatic period continued probably intermittently until ca. 1,500-2,000 years ago and could have contributed to the period of aggradation detected in Naas between ca. 3,000 and 1,500 years ago. A rebound to wetter conditions ca. 2,000 years ago (Wasson & Donnelly 1991) could have encouraged the incision detected to have commenced between ca. 1,700 and 1,100 years ago.

It is difficult to determine when aborigines first took possession of the area covered by the Namadgi National Park. However, dated artefacts from a neighbouring catchment to Naas suggest increased activity around 3,700 years BP (Flood 1996). This could imply increased fire and vegetation disturbance, triggering increased soil erosion and subsequent downstream aggradation at this time period.

Finally, the results from the survey of terraces along the Naas River disclose a steep section (0.94%) in Terrace 1 which otherwise show an even slope of 0.5%. Steepening of valley slopes is a frequently invoked mechanism of autonomous change leading to channel incision (Patton & Schumm 1975, Nanson & Erskine 1988). Terrace 1 was built up during the aggradation between ca. 3,000 and 1,500 years ago. The incision that followed may have been triggered by the increased slope steepness during aggradation of Terrace 1.

We have given examples of environmental changes of both extrinsic and intrinsic character that may have been of importance for the Naas River system to change between aggradational and incisional behaviour. At present it is not possible to determine which process has been more important in triggering the changes detected. It is likely that a combination of the above factors have accounted for the aggradational and incisional history in the Naas River.

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