Thinhope Burn

[NY 645 535]

Thinhope Burn, a west-bank tributary of the River South Tyne, is a steep (< 1% to ~ 10%) and deeply entrenched stream that drains a small (12 km^2) moorland catchment on the north-west flank of the Northern Pennines, Northumberland (Figure 5.1). During the past 1600 years or so, the vertical tendency of this stream has been one of the marked incision, locally as much as 8 m, punctuated by extended periods of lateral channel migration and valley floor sedimentation (Rumsby, 1991; Macklin *et al.,* 1992b). Phases of accelerated incision have been shown to coincide with abrupt changes in hydroclimate (Macklin *et al.,* 1994b; Rumbsy and Macklin, 1994), registered by changes in peat stratigraphy evident within raised lowland mires in the region (Barber *et al.,* 1994). Indeed, until early historical times, Thinhope Burn appears to have been a vertically stable channel with fine-grained sediment accretion in overbank environments.

Geomorphological and sedimentological studies in Thinhope Burn constitute the most detailed investigation of late Holocene river alluviation and erosion hitherto undertaken in the British uplands. The wider regional and national significance of this research lies in the fact that this was the first site in Britain at which valley floor entrenchment, and the temporal clustering of major flood events, was related to abrupt, yet relatively modest variations in climate. In addition, episodic channel aggradation and braiding downstream in the River South Tyne during the Holocene has been shown to be broadly synchronous with phases of accelerated erosion identified in Thinhope Burn (Passmore *et al.,* 1993; Macklin *et al.,* in press), highlighting the important influence that headwater tributaries have on sediment supply, and the sedimentation histories, of river systems fringing the British uplands.

Holocene river sequences are most clearly developed in the upper part of Thinhope, immediately downstream of the Faugh and Mardy's Cleugh confluence (NY 645 535, (Figure 5.28)(a)) where four paired terraces are evident at *c.* 7.5, 6, 5 and 4 m above the present stream bed (Figure 5.29). The highest fill-terrace comprises cobble gravels overlain by 2 m of sands and silts which, in the upper part of the unit and towards the valley side, interdigitate with peat. ^{14}C dates of 7910 ± 30 (7060–6500 cal BC) and 1670 ± 50 (240–530 cal AD) from wood within the basal gravels and at the junction between silt and peat (0.5 m below the terrace surface), respectively, indicate relatively slow alluviation over most of the Holocene.

At some time after 250–530 cal AD, the first major phase of Holocene valley entrenchment occurred, resulting in nearly 4 m of channel-bed erosion (Figure 5.28)(b). ^{14}C dates of 1160 ± 50 and 1230 ± 60 from peat at the top and bottom, respectively, of the 6 m terrace show that the stream incision had slowed, or ceased, before 660–980 cal AD.

The oldest Holocene age coarse-grained, flood deposit so far recognized in Thinhope is a boulder berm (*sensu* Macklin *et al.,* 1992b) emplaced on the 6 m terrace and located on the north bank of the burn, 50 m downstream of the Faugh and Mardy's Cleugh confluence ((Figure 5.28)(a)). This flood unit consists of open-work, clast-supported boulders (with *b* axes up to 1.5 m) that are moderately well imbricated with steeply dipping A–B planes (mean dip 60°). It has a convex cross-section with steep sides which in places are curved, streamlined and aligned parallel to inferred flow direction. Deposits, the morphological form and sedimentary sequence of which resemble this and younger boulder berms in Thinhope, have been attributed to flows with high sediment loads, variously termed debris torrents, bedload and hyperconcentrated flood flows (see Macklin *et al.,* 1992b for a review). These, with respect to bulk density and shear strength, are intermediate between stream and debris flows, and may be Newtonian or transitional in character depending on sediment concentration. Relatively well-developed imbrication, moderate sorting and open-work texture of boulder berms in Thinhope, however, are sedimentary properties more consistent with Newtonian flows.

Peat immediately below the boulder berm dated to 1160 ± 50 provides a *terminus post quem* for its emplacement, while a most probable *terminus ante quem* is likely to have been around 980 ± 60 on the basis of a ^{14}C date from a buried peaty soil within the younger 5 m terrace ((Figure 5.28)(a)). This flood event, which appears to have no precedent in the earlier Holocene alluvial record of Thinhope, can be dated reasonably precisely to between 720–1000 and 960–1180 cal AD. Its most probable age is around 890–1020 cal AD. It should be noted, however, that though the 6 and 5 m terraces are morphologically and sedimentologically separate units, they do have overlapping ^{14}C age ranges. It seems likely that incision to form the 6 m terrace and partial refilling of the valley floor, to a level 5 m above the present stream bed, could have occurred over a period of 100–200 years or less. Indeed, studies of stream planform and cross-section change following recent severe flooding in the Yorkshire Dales (Newson and Macklin, 1990), and in the Howgill Fells (Harvey, 1991), have shown that in some upland basins several metres of channel 'fill and cut' can be accomplished during one large flood. In practice, however, dating resolution constraints make it very difficult to establish unequivocally that 6 and 5 m terraces are the result of a single event.

A second period of major river-bed erosion occurred after 960–1180 cal AD, resulting in Thinhope Burn trenching through Pleistocene till and soliflucted material and, in the study reach, coming to rest directly on Carboniferous sandstone and shale bedrock. Subsequently, the valley floor was refilled, predominantly with fine-grained sediment, to a level *c.* 4 m above the present stream bed (Figure 5.28) (a). This fill-terrace is the most extensive Holocene alluvial unit in Thinhope. It has a number of well-developed palaeochannels on its surface that have generally higher sinuosities and lower width : depth ratios than the present channel. Pollen analysis (Heap, unpublished) of organic-rich silts that infill one of these palaeochan-nels (Figure 5.28)(a) showed a vegetation sequence very similar to that recorded by Roberts *et al.* (1973) in nearby upper Weardale, which has been ^{14}C dated to 1700–1780 cal AD. No ^{14}C dates are presently available for the pollen sequence at Thinhope, but comparison with Roberts' and other sites in the Northern Pennines suggests it accumulated in the post-Medieval period. It therefore provides a tentative *terminus ante quem* for the deposition of the 4 m fill-terrace.

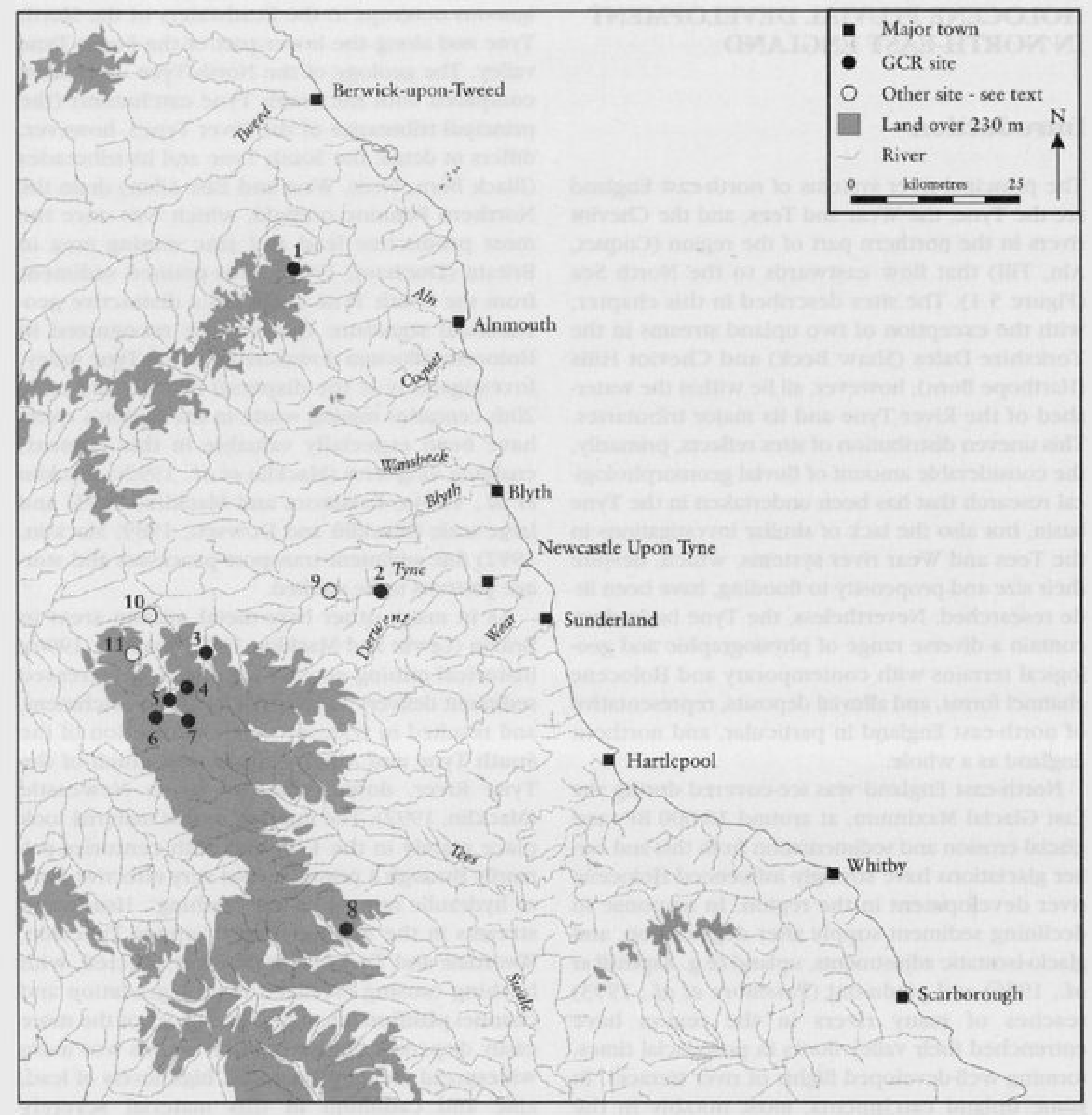
The third phase of major stream entrenchment began possibly as early as the late 17th century and continues, on a more limited scale, to the present day. Over this period there has been up to 4 m of channel incision, locally through bedrock, that has produced a series of unpaired, terraced coarse flood units (Figure 5.30). The deposits of 21 large floods have been identified in Thinhope, and lichenometric analysis shows that all but one of these (discussed above) date from the mid-18th century. Over this period, there is evidence that large floods were more frequent from 1780 to 1820, 1840 to 1880 and 1920 to 1950, corresponding with secular hydroclimate change recorded in both northern Britain and north-west Europe (Rumsby and Macklin, 1994). Lichenometric dating of levelled flood deposits has also enabled the timing and pattern of channel incision in the Thinhope catchment since 1766 to be examined in detail. This shows that incision ended earlier in downstream (*c.* 1780) than in upstream (*c.* 1820) reaches of Thinhope (Macklin *et al.,* 1992b). In the 19th century valley floor sedimentation took place (with particularly high rates during the 1820s and 1830s) until *c.* 1870 when channel trenching was renewed. During the 1920s and 1930s significant coarse flood sediment deposition is evident, followed by further valley floor incision after 1940. Rates of incision over the past 200–250 years have varied along the channel. They have been highest in the upper part of Thinhope, in reaches with relatively high gradients underlain by fissile and mechanically weak shales. This has resulted in an uneven pattern of channel degradation, very similar to the development of discontinuous gullies reported by Schumm and his co-workers in the USA (Schumm and Hadley, 1957; Schumm *et* at., 1984).

Valley-floor erosion in Thinhope Burn coincides with a shift to wetter conditions around 550–690 cal AD, recorded at this time by humification changes in both upland blanket peats (Blackford and Chambers, 1991) and lowland raised mires (Barber, 1981) in western and northern Britain. However, climate change cannot have been the sole cause of valley destabilization, given that climatic fluctuations of a similar magnitude had occurred earlier in the Holocene (e.g. 1350–550 cal BC) without resulting in significant erosion in the Tyne basin uplands (Macklin *et al.,* 1992b). Coming shortly after extensive deforestation in Iron Age and Roman times (Turner, 1979), it is quite possible that vegetation degradation and destruction triggered gulleying by lowering the threshold for erosion. Thus, during the mid-first millennium AD, climatic deterioration, recently cleared upland catchments such as Thinhope (with runoff augmented by decreased interception, infiltration and evaporation) would have been particularly vulnerable to erosion. Once streams became entrenched, positive feedback would have operated, with greater flood depths producing higher bed shear stresses resulting in increased rates of channel incision.

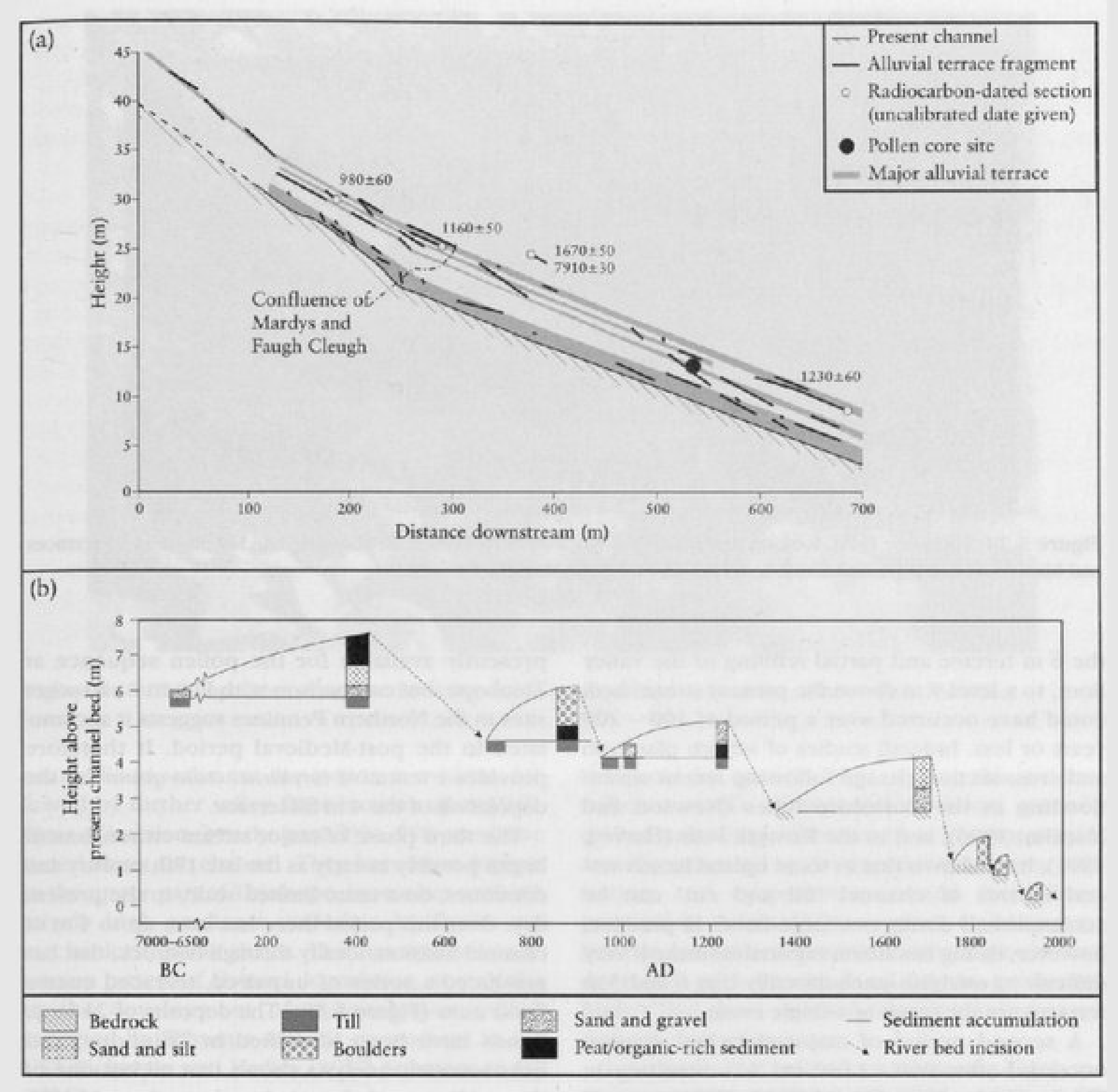
Later periods of valley-floor incision in Thinhope at around 890–1020 cal AD, 1200–1400 cal AD and in the 18th century also appear to have occurred during periods of cooler, wetter climate as shown by stratigraphic analysis of peat profiles in north-west England (Barber, 1981; Barber *et al.,* 1994). The most recent phase of channel and flood-plain metamorphosis in Thinhope, which started at some time in the latter part of the 17th century, however, witnessed many more dramatic changes than those that occurred in earlier periods of river instability. It saw the replacement of a relatively stable meandering stream and floodplain accreting fine-grained sediment by a vertically and laterally unstable low-sinuosity boulder-bed channel with a high coarse sediment load. This transformation appears to have followed widespread entrenchment and extension of the drainage network in the Thinhope catchment. Major erosion of bedrock by the main channel, together with dissection of bouldery till by tributaries on adjacent slopes, resulted in a significant increase in both the supply and calibre of coarse sediment to the system (Macklin *et al.,* 1992b). A sharp rise in effective precipitation during the Little Ice Age, shown clearly by widespread evidence of exceptional flooding in northeast England in the late 17th and 18th centuries (Rumsby, 1991), appears to have been the principal cause of channel incision and river transformation. Land drainage and agricultural enclosure in the South Tyne valley during the mid-and late 18th century, as noted by local commentators (Palmer, 1882), also augmented runoff, resulting in shorter times to peak flow and greater flood magnitudes. The main impact of human disturbance, however, is considered to have been one of increasing the sensitivity of channels, floodplains and drainage basin networks to climatically induced changes in flood frequency and magnitude (Rumsby and Macklin, 1994).

Late Holocene patterns and rates of valley-floor development in Thinhope Burn, Northumberland, are shown to have been exceptional when viewed in the context of earlier postglacial river activity. Accelerated rates of channel entrenchment appear to have been caused by an increase in flood magnitude, associated with periods of wetter and cooler climate, with flow augmented by early historical woodland clearance and drainage of the catchment in more recent times. The deposits of 21 large floods have been identified, and lichenometric analysis shows that all but one of these events date from the mid-18th century. Over this period there is evidence for the clustering of major floods, particularly in the periods 1780–1820, 1840–80 and 1920–50. They also correspond with phases of increased flow in a number of European rivers (Probst, 1989) and suggest that the timing of floods in the upper South Tyne between *c.* 1766 and 1960 follows major hydroclimatic fluctuations over the same period in western Europe.

References



(Figure 5.1) The major river systems and relief of north-east England. GCR Sites: 1 Harthope Bum; 2 Low Prudhoe; 3 Blackett Bridge; 4 Blagill; 5 The Islands, (Alston Shingles); 6 Black Burn; 7 Garrigill; 8 Shaw Beck. Other sites descibed in the text: 9 Farnley Haughs; 10 Lambley; 11 Thinhope Burn.



(Figure 5.28) (a) A surveyed longitudinal profile of the study reach in Thinhope Burn, showing the positions, heights and sequence of dated Holocene alluvial fills and river terraces in relation to the present stream bed. (b) A time-level diagram for Holocene alluvial units in the Thinhope Burn study reach. (After Macklin et al., 1994b.)

(Figure 5.29) Thinhope Burn, looking upstream in a southwesterly direction, showing late Holocene river terraces and historical coarse-grained flood deposits. (Photo: M.G. Macklin.)

(Figure 5.30) Thinhope Burn: historical flood deposits overlying a bedrock terrace. (Photo: M.G. Macklin.)