River Tyne at Low Prudhoe, Northumberland

[NZ 088 637]

Highlights

Exposures of floodplain sediments at Low Prudhoe provide a record of flooding in the lower Tyne valley over the past 100 years. This site illustrates the value of documentary sources and chemostratigraphic studies for dating major floods, and also the use of fine-grained alluvial deposits for extending the flood series.

Introduction

A 2.5 m sequence of fine-grained overbank sediments at Low Prudhoe in the lower Tyne valley, 1 km west of Newcastle-upon-Tyne, provides a unique record of floods in the River Tyne over the past century (Macklin *et al.,* 1992c). Stratigraphic variations in sediment trace metal concentrations have been related to mining production figures and used to date overbank flood units. This also enables floodplain sedimentation rates to be calculated over annual and decadal length time periods, as well as helping to identify sediment sources. be colonized by vegetation. These sites subsequently became the focus of fine sediment deposition, resulting in the infilling of side channels and attachment of bars to the former river bank. Rates of incision and bed erosion increased considerably in the late 1950s and 1960s following gravel extraction from the river bed, and is still continuing today, necessitating regular upgrading of the footings of Ovingham Bridge.

Description

Following a major flood on 26 August 1986, bank erosion at Low Prudhoe [NZ 088 637] (Figure 5.1) in the lower Tyne valley, 15 km west of Newcastle upon Tyne, revealed extensive sections (up to 5 m in height and several hundred metres long) in the historical floodplain of the River Tyne. Floodplain sediments were found to be composed of 2–3 m of finely laminated soils and silty sands overlying 2 m of sandy gravels. Beneath these gravels an *in situ* tree stump was exposed and ^{14}C dated to *c.* 1460 cal AD, providing a *terminus post quem* for the sequence. Granulometric analysis (Rumsby, 1991) of prominent coarser sand layers in the upper fine-grained alluvial unit showed them to be similar to sands deposited overbank on the Tyne floodplain during the August 1986 flood (Macklin and Dowsett, 1989), suggesting that sediments at this site could provide a valuable record of recent major floods in the lower Tyne valley. Although unusually good exposure of alluvium at Low Prudhoe initially prompted sedimentological and stratigraphic-based studies of recent floods in the lower Tyne valley, flood stones on the Rectory steps at Ovingham (Figure 5.18), marking the heights of the great floods of 1771 (the largest on record) and 1815, together with good archive records (newspapers, local books and journals and meteorological publications) of major floods in the Tyne catchment since 1699 (Rumsby, 1991; Archer, 1992), make Low Prudhoe an excellent site at which to compare documentary and sedimentary flood records.

Over the past 130 years or so, the thalweg of the Tyne at Low Prudhoe has moved very little (Figure 5.18)(a), but since the early 1950s its channel has narrowed appreciably, most notably in a 500 m reach downstream of Ovingham Bridge, within which the study section is located. Channel narrowing has been primarily the result of incision which elevated former lateral gravel bars above the level of the low-flow channel and enabled them to

Interpretation

The well-bedded sands and silty sands exposed in the river bank at Low Prudhoe are believed to have been formed by vertical accretion (Figure 5.19). This deposit has a similar surface morphology (asymmetric in cross-section with its highest point located adjacent to the channel; see (Figure 5.18)(b)) and stratigraphy to shrub- and herb-covered alluvial benches located within the present Tyne channel which accrete fine sediment to the level of the contemporary floodplain. Initial sedimentation at the study section was therefore under sub-bankfull flow conditions, with fine sediment deposition confined within the channel banks. Later sediments, as the result of progressive vertical accretion, would tend to be deposited under flow conditions close to bankfull and also by overbank floods. Thus a considerable proportion of fine-grained alluvium at Low Prudhoe is believed to represent the vertical component of within-channel sedimentation, and is of a somewhat different origin from overbank fines (usually of silt and clay size and deposited some distance from the channel) more frequently described on British floodplains (e.g. Lambert and Walling, 1987).

Flood events in fine-grained alluvial deposits at Low Prudhoe are represented by layers of generally flat-bedded sands and silty sands (Figure 5.20), which on the basis of grain size can be assigned to one of three sedimentary categories; medium-fine sand, fine-very fine sand or silty fine sand. Following Knox (1987), textural discontinuities formed by layers of medium-fine (type 1 flood unit) and fine-very fine sand (type 2 flood unit) which reverse the overall fining upward sequence are interpreted as the deposits of large floods. Finer-grained silty sands (type 3 flood unit) are believed to represent lower magnitude floods or sediment deposited on the falling stage of a large flood event. Twenty-five large flood events would appear to be represented in the alluvial profile at Low Prudhoe, and these have been dated by relating sediment trace metal concentrations to lead and zinc production in the Northern Pennine orefield (Macklin *et al.,* 1992c).

As has been shown in mining-age alluvium elsewhere in the Tyne basin (Macklin and Lewin, 1989; Macklin *et al.,* 1994a), especially high zinc levels mark the peak of zinc extraction in the Allendale and Alston Moor orefields between 1897 and 1915. At Low Prudhoe this is evident in sediments between 196 and 118 cm in the section. Above 118 cm zinc concentrations decline, corresponding with the demise of zinc mining in the region after 1915. Comparatively low lead levels (<1000 $mgkg^{-1}$) between 118 and 90 cm indicate that sedimentation at Low Prudhoe post-dates the main phase of lead production in the Tyne basin, which ended in 1880, confirming age estimates provided by sediment zinc concentrations. Above 90 cm, lead concentrations rise in response to the revival of lead mining in the 1920s and 1930s. Peaks in lead production in 1927, 1933 and 1937 are reflected by increased lead concentrations in flood sediments and decreased zinc : lead ratios at 56, 28 and 24 cm. Trace metal dating of fine-grained alluvial sediments at Low Prudhoe therefore indicates that the major part of the sequence was deposited over a comparatively short period of time (*c.* 50 years) between 1890 and 1937.

On the basis of dating control provided by sediment heavy metal analyses, and in the knowledge that archive sources tend to record larger spatially extensive floods (Archer, 1992), flood units evident in the Low Prudhoe section were assigned as far as possible to documented floods since 1890 in the Tyne valley. However, not all flood units could be related to recorded flood events, and in these cases chemostratigraphic dating control provided general bounded time limits. In (Figure 5.21) floods documented in the Tyne basin between 1890 and 1989 are plotted with the sedimentary flood record (where present) over the same period. The documentary flood record of the River Tyne between 1890 and 1949 shows an increase in flood frequency between 1890–1909 and 1920–1939 with relatively few floods in the decades 1910–19 and 1940–49. Flooding over this period (1890–1949) follows changing hydrometeorological conditions in north-east England, with increases in flood frequency corresponding with rainfall maxima recorded in the region during the late 19th century and again between 1920 and 1939 (Harris, 1985).

Most flood units deposited before 1900 appear to have resulted from sub-bankfull flows, many of which would not have been reported by local commentators or newspapers. The similar number of floods between 1900 and 1929 evident in both the stratigraphic and documented flood record, however, suggests that type 1 and 2 flood units were deposited during overbank events that inundated both the depositional bench at Low Prudhoe and the Tyne valley floor. Since 1930 an increase in the relative height of this surface above the river bed (resulting initially from sediment accretion and later by channel incision) has effected a 'censoring' of the alluvial stratigraphic record to reflect progressively less frequent and larger floods. Today, continuing river bed incision has enlarged the Tyne channel at Low Prudhoe to a size that can accommodate floodwaters in all but the very largest floods.

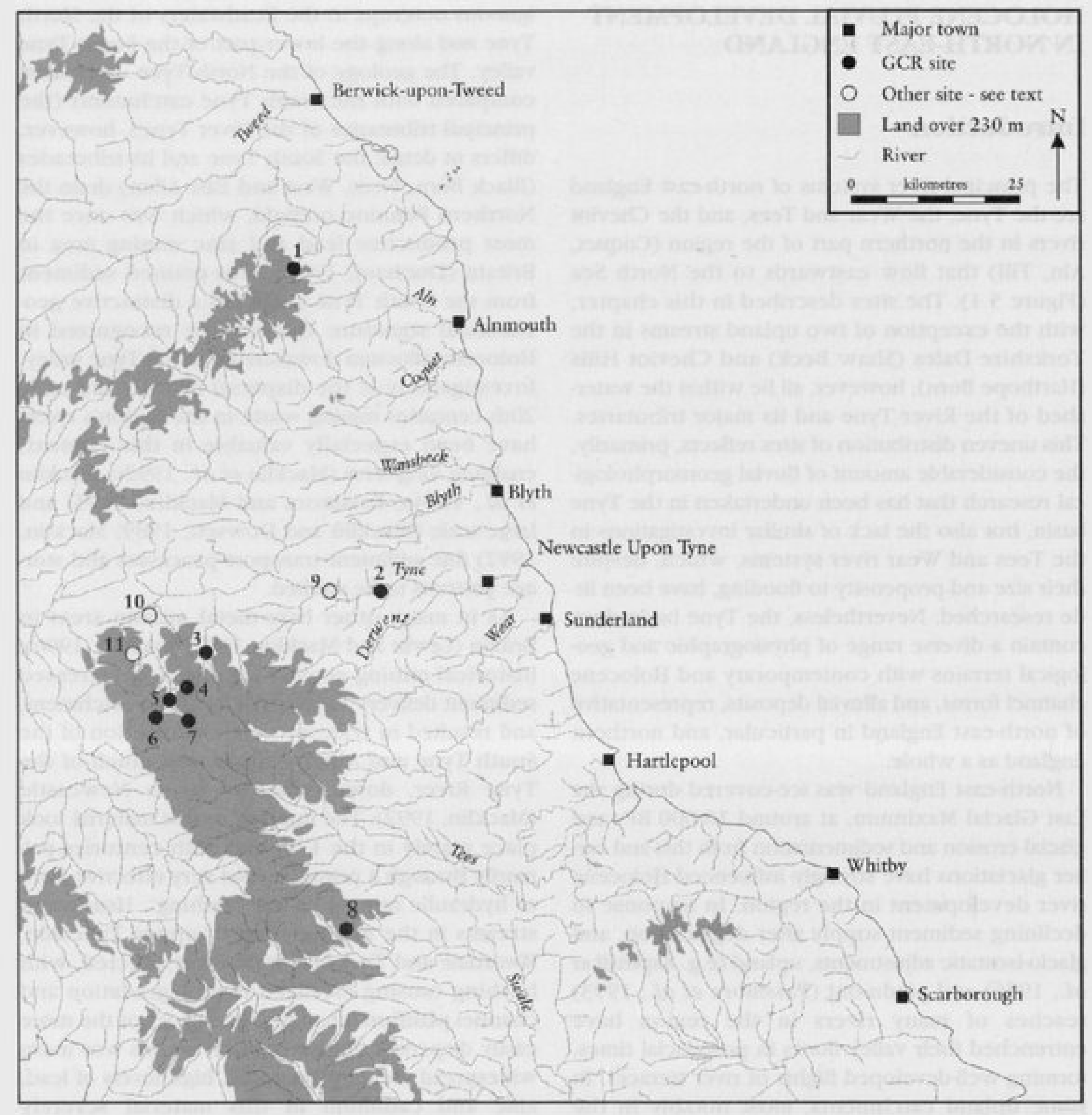
The disparity between the stratigraphic and documentary flood records at Low Prudhoe over the past 100 years probably reflects the latter's bias towards recording large overbank floods. Archive sources will therefore inevitably under represent the actual number of flood events recorded in the stratigraphic record when a depositional surface is of low elevation and subject to inundation by low-magnitude floods. Deposition of fine-grained flood sediment within the Tyne channel (which in this particular study forms the basis of the palaeoflood record), although reflecting in a systematic way changes in flood flow magnitude and frequency (controlled primarily by climate), has also been strongly influenced by variations in sediment supply (associated with upstream bank erosion rates and input of mining waste) and entrenchment of the channel over the period of investigation. It is therefore imperative that sediment availability and the vertical tendency of a channel reach are evaluated, and quantified, before stratigraphic evidence at a site is used to extend the flood series in a river basin.

Studies of floodplain development at the Low Prudhoe site in the lower Tyne valley represent one of the most detailed investigations of longer-term vertical accretion yet undertaken in a major British river. From a methodological viewpoint it confirms the utility of trace metals for dating fine-grained alluvial sequences in large mineralized catchments. The identification of systematic differences between sedimentary and documentary-based estimates of flood frequency in the lower Tyne highlights the important contribution that fluvial geomorphologists can make to developing and refining historical flood information. Low Prudhoe is also of special significance with respect to the historical flood record of the Tyne, for it is one of only five sites in the catchment at which levels of major floods (marked by flood stones) in the past 200 years or so have been recorded (Archer, 1992). Comparison of documented floods in the lower Tyne valley with the sedimentary sequence at Low Prudhoe, however, demonstrates the inherent partiality of both types of historical flood record. Nevertheless, in combination, these records reveal a non-stationarity in the flood series which has been attributed, primarily, to recent climate change (Rumsby and Macklin, 1994).

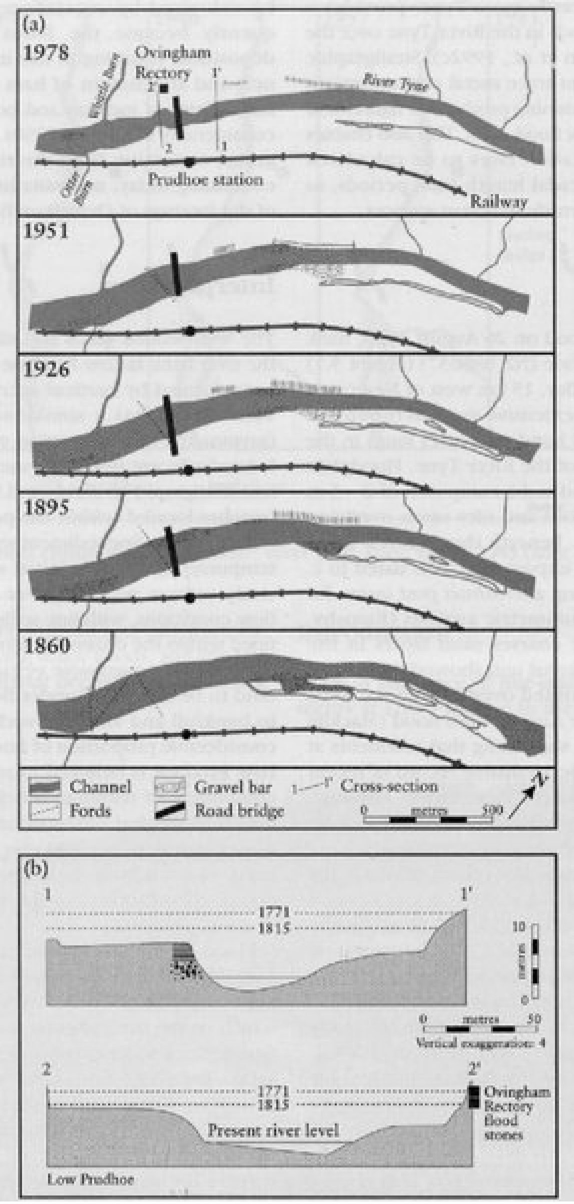
Conclusion

Historical documentation of floods, together with sedimentological and trace metal analysis of fine-grained flood sediments, have been used to construct a flood record for the River Tyne over the past 100 years. Changes of trace metal concentrations in vertically accreted alluvium have been related to lead- and zinc-ore production in the Tyne basin and used to date flood events. Significant differences between documentary- and sedimentary-based estimates of the frequency of inundation emerge, but are shown to be the result of bias in archive sources towards recording large overbank events and the censoring of the alluvial stratigraphic record, as the result of variations in sediment supply and channel entrenchment, to reflect progressively less frequent and larger floods. Climate change, however, appears to be the underlying control of non-stationarity in the incidence of major floods in recent times.

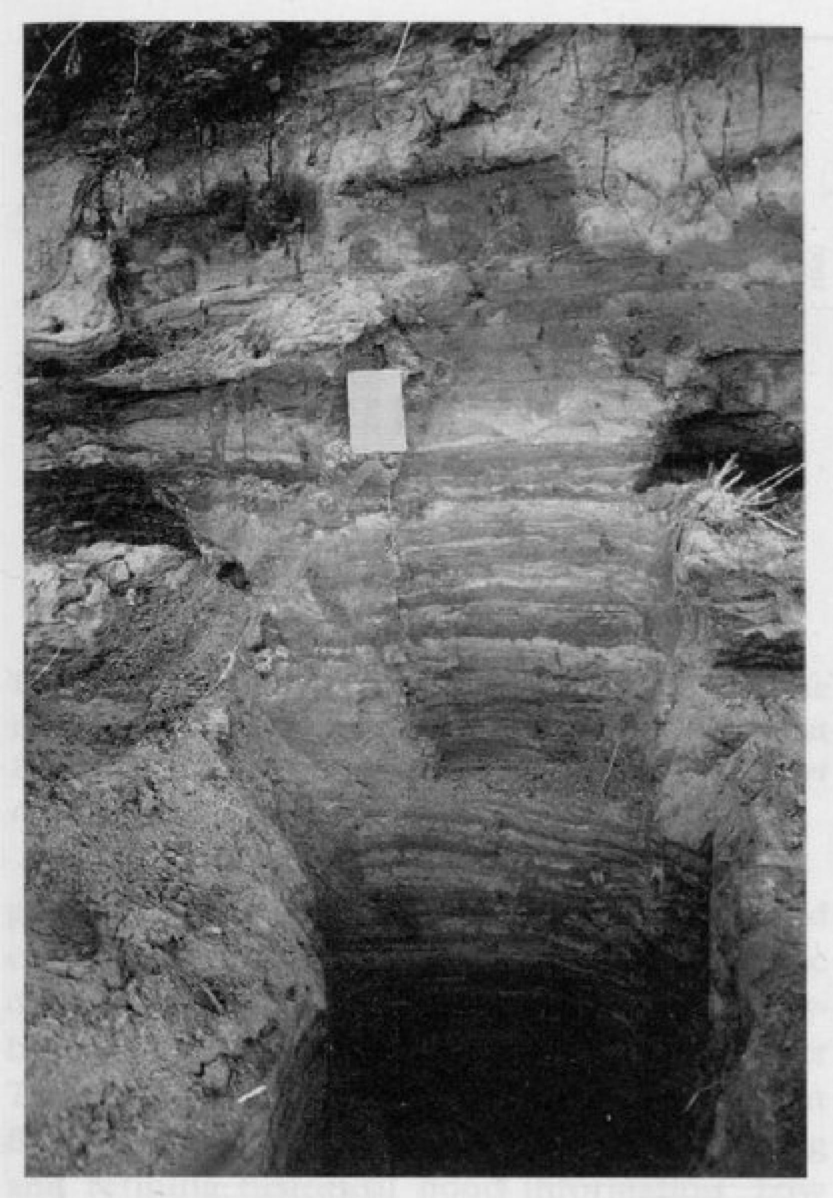
References



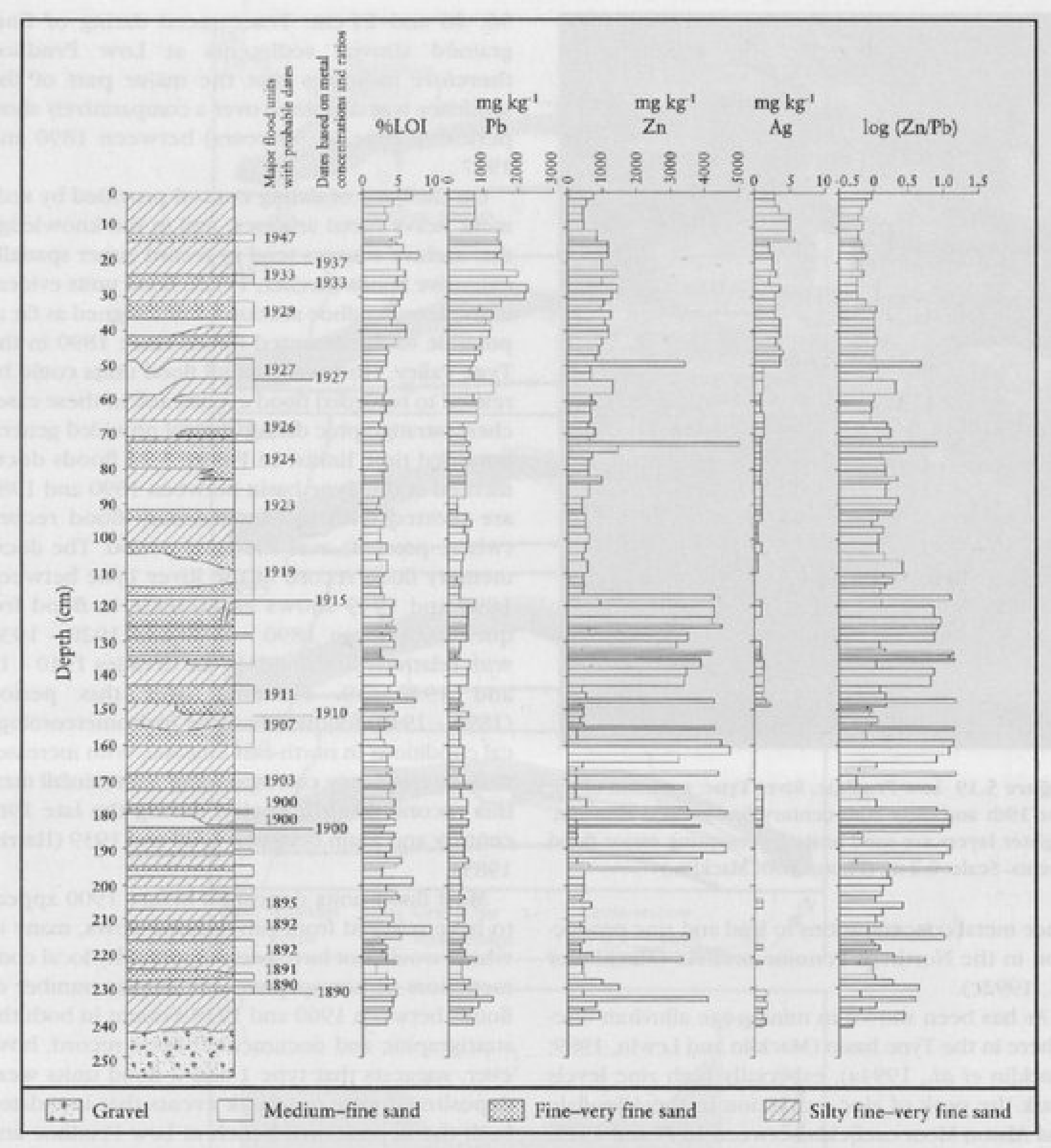
(Figure 5.1) The major river systems and relief of north-east England. GCR Sites: 1 Harthope Bum; 2 Low Prudhoe; 3 Blackett Bridge; 4 Blagill; 5 The Islands, (Alston Shingles); 6 Black Burn; 7 Garrigill; 8 Shaw Beck. Other sites descibed in the text: 9 Farnley Haughs; 10 Lambley; 11 Thinhope Burn.



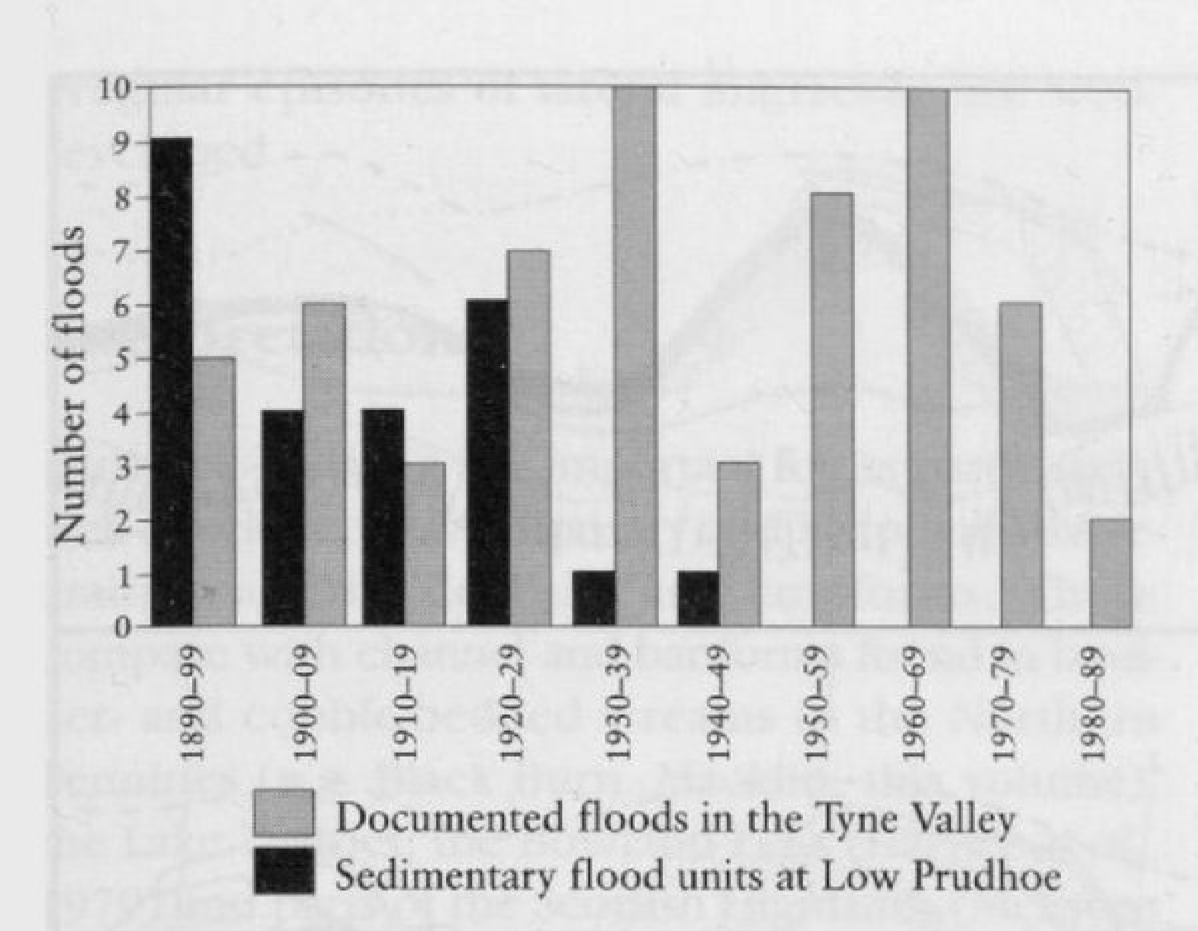
(Figure 5.18) (a) Maps showing channel change at Low Prudhoe between 1860 and 1978, and the location of the sections. (b) Valley floor and channel cross-sections upstream and downstream of Ovingham bridge: the relative heights of the 1771 and 1815 floods are indicated. (After Macklin et al., 1992c.)



(Figure 5.19) Low Prudhoe, River Tyne: a section of the late 19th and early 20th century fine-grained alluvium. Lighter layers are sand units representing major flood events. Scale: 0.2 m. (Photo: M.G. Macklin.)



(Figure 5.20) Metal concentrations and organic matter content in vertically accreted alluvium at Low Prudhoe, showing major flood units with their probable dates. (After Macklin et al., 1992c.)



(Figure 5.21) A comparison of floods documented in the lower Tyne valley and the sedimentary flood record at Low Prudhoe between 1890 and 1989. (After Macklin et al., 1992c.)