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Quaternary river terraces in England: Forms, sediments and processes

J. Lewin [a], P.L. Gibbard [b,*]

[a] Institute of Geography and Earth Sciences, University of Aberystwyth, Aberystwyth SY23 3DB, Wales, UK
[b] Cambridge Quaternary, Department of Geography, University of Cambridge, Downing Street, Cambridge CB2 3EN, England, UK

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ABSTRACT

Flights of Quaternary river terraces in south and east England have common characteristics involving low-gradient planed or irregular bedrock surfaces and single or multi-storey gravel deposits. Rather than depending on warm–cold or cold–warm transitions, it is suggested that bedrock planation, "working depths" of gravel and later-stage (relatively shallow) aggradations are all dominantly of cold-climate origin. Basal sediments show active incorporation of plucked and periglacially-shattered materials, whilst super-incumbent units incorporating up-catchment and slope-derived materials demonstrate later cold-stage sediment influx and consequent cessation of active bedrock erosion. Channel activity effecting both planation and deposition are reviewed, together with the detailed sedimentology of gravelly sediments which show evidence of both autogenic processes (bar migration, channel switching and infilling, and truncation of upper sedimentation units), cold-climate indicators (turbation, ice-wedge casts, and frozen block transport), and (specifically for the last glacial–interglacial cycle) varying sediment flux as climates changed. Both interglacial and "transitional" activities are believed to be of lesser morphological significance, whilst prior uplift is taken as enabling rather than being a generator of terrace within the timescale of a glacial–interglacial cycle. Variations within cold-stage climates, varying sediment influx and channel-belt bedrock erosion are stressed as dominating mid-catchment and mid-latitude Quaternary terracing at the glacial–interglacial scale.

1. Introduction

This paper addresses the problem of extra-glacial Quaternary river terrace formation in mid-latitudes as a geomorphological process: how and under what conditions were laterally extensive bedrock platforms cut, what do the sediments on them indicate, and was there a prototype sequencing of events within a glacial–interglacial cycle? We examine specifically middle-course catchment locations in lowland England where there are elevated flights of valley-side Pleistocene terrraces, rather than the multi-unit, cut-and-fill aggradation environments of depocentres and coastal prisms downstream (as in the Thames estuary and East Anglia), or the fill–cut sequences of smaller valleys and upland environments which are dominated by post-glacial incision into prior fills, including glacial and solifluction deposits. We survey river behaviour during a glacial cycle as it affected bedrock erosion, deposition and terracing in a region of moderate relief in north-west Europe, using evidence from any particular cycle that has been well-researched and is relevant, most being available for the last glacial–interglacial cycle (post-Ipswichian–Eemian–*c.* MIS 5e). The preserved evidence from cold-stage sediments does not have the interpretative richness of interglacial biological diversity (Gibbard and Lewin, 2002), and there are buried erosional features to consider, so this is not so straight forward.

2. Terraces and their deposits

Flights of terraces can develop in alternative ways as was appreciated by Bryan and Ray (1940), Leopold and Miller (1954) and Bull (1991), to mention only a few. Basic concepts are illustrated in Fig. 1. Leopold et al. (1964) usefully distinguished between strath (bedrock-cut) and fill terraces (where terrace surface height is essentially that produced at the end of aggradation episodes). Fig. 1 (a) and (b) shows terrace sequences representing stages of incision into prior fills (fill–cut), and aggradations within fomerly incised fills (cut–fill). These are recorded in numerous studies of post-glacial terraces in upland Britain incised into Pleistocene valley fills (for a listing of studies, see Macklin et al., 2009, Table 1). Up to six terracing episodes have been distinguished in the later Holocene alone (Passmore and Macklin, 2000). The focus in this paper is on older Pleistocene terraces cut in bedrock and overlain with a thin covering of sediment. These are essentially of type 1(c). In recent years, they have been viewed predominantly as recording MIS stages and uplift (Bridgland and Westaway, 2008), whilst there have been numerous studies of site stratigraphy (e.g., Collins et al., 1996; Coope et al., 1997, 2002; Maddy et al., 1998; Lewis et al., 2001; Gao et al., 1998, 2007; Briant et al., 2004, 2005, 2008; Langford et al., 2007; Rose et al., 2000).

* Corresponding author. Tel.: +44 1223 352946.
E-mail address: plg1@cam.ac.uk (P.L. Gibbard).

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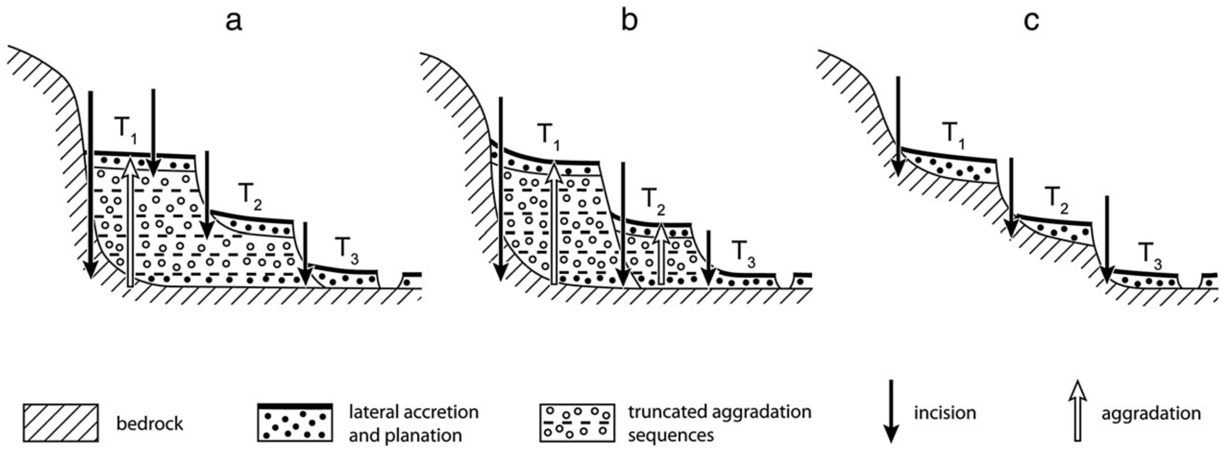

Fig. 1. Terrace formation sequences producing the same surface appearance: (a) by a set of incisions into prior valley fill, (b) by coupled cut-and-fill episodes, and (c) by progressive incision into bedrock to produce strath terraces.

These have included analyses of lithofacies, palaeontology and chronology.

In broad terms, these terrace sediments are mobile channel-belt gravels (Gibling, 2006), with incursions of slope material. Understanding is obviously restricted unless the actual nature of erosion and sedimentation has been established through subsurface investigation. As Fig. 1 suggests, virtually identical surface features can be produced by different combinations, and numbers, of aggradation and incision–planation episodes. The use of surface height data from ground survey can be adequate for lateral correlations between terrace fragments at the basin scale, but this reveals only limited aspects of the geomorphological processes involved. In addition to surface exposures and core information, ground penetrating radar is beginning to provide much greater understanding of subsurface sediments and bedrock surface forms (Davis and Annan, 1989; Vandenberghe and van Overmeeren, 1999; Bridge and Lunt, 2006; Howard et al., 2007; Gibbard et al., 2008). Sediments may constitute alloformations, or alluvial architectures, styles or ensembles (Autin, 1992; Miall, 1996) which are commonly subdivided into facies associations. Together with biostratigraphy and dating control this allows identification of formations and members and their interpretation in terms of environmental change, whilst geomorphological processes may be deduced from the sedimentology and erosional forms.

Even within the simple model provided by Fig. 1, multi-phase activity leads to unit insetting, overlapping and intra-terrace sediment truncations (that is, within the sediment packages beneath the levels shown in Fig. 1) — both autogenically as channels relocate laterally or vertically, and allogenically as external factors (such as changes in river discharge or sediment supply) remove at least some of the primary-phase materials related to terrace-cutting, and then deposit others. The point to emphasise is that a sedimentological record of much geomorphological activity is likely to be missing. Fig. 2 represents three possible situations affecting preservation. The process of vertical stacking (Fig. 2a) quite commonly also eliminates upper facies in older alluvial materials. This is the autogenic norm for braided rivers where migrating channels operate at different depths and energies within an active alluvial system even without any necessary vertical system tendency, and there is continous overprinting of the total sediment package as channels shift. Stepped incision (Fig. 2b) may preferentially preserve (and in a sense over-represent in the lithostratigraphic record) valley-margin colluvial materials and deeper, confined scour-pool fills in the stratigraphic sequence (Lewin and Macklin, 2003). Preserved terrace remnants can be broad or narrow, with alluvial units overlapping bedrock benches where incision amounts are small (e.g., Antoine et al., 2000). Unidirectional shifting without pronounced incision (Fig. 2c) may

Table 1
Alluvial plains, channels and channel patterns for contemporary Arctic and British gravel-bed rivers.

River		Plain width (km)	Channel width (m)	Slope (m/km)	Pattern style and sequence
Cold-climate					
Colville	69°18′N 152°24′W	1.48	250	0.88	mWbmd
Toolik	69°47′N 149°36′W	3.19	130	0.74	Ma
Sagavanirkok (Lunt and Bridge 2004)	69°50′N 148°43′W	2.4	260	2.12	m/bB
Babbage (Forbes 1983)	69°09′N 138°20′W	2	110	1.25	mM
Albany (Martini et al., 1993)	52°11′N 81°53′W	3.91	1160	0.55	aA
Tana	69°26′N 25°41′E	0.79	90	1.12	M
Mongocheyakha	72°06′N 79°01′E	4.34	110	0.05	mM
Lenivaya	75°05′N 89°38′E	1.3	160	0.35	mW
Yana	70°21′N 133°00′E	3.94	230	0.98	mAm
Khroma	70°27′W 147°34′E	11.46	750	0.03	mAm
Regtymel'	69°25′N 174°48′E	1.48	290	1.2	bBb
United Kingdom (historical change sites)					
Spey (Lewin and Weir 1977)	57°39′N 3°05′W	1.4	50	4	B/W
Feshie (Werritty and Ferguson 1980)	57°39′N 3°54′W	0.2	40	11.56	W/B
South Tyne (Macklin and Lewin 1989)	54°56′N 2°31′W	0.18	30	3.84	W/B
Severn (Brewer and Lewin 1998)	52°28′N 3°26′W	0.14	30	2.5	M/B
Ystwyth (Lewin et al. 1977)	52°20′N 3°54′W	0.18	20	8.47	B/W

Pattern styles: m, meandering; b, braiding; w, wandering; a, anastomosing; and d, deltaic. Pattern at data site in capitals.