Fluvial Geomorphology of England (FLU-GME-EG)

Block Description

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Introduction

The subject of this GCR Block is fluvial geomorphology, the branch of Earth science that is particularly concerned with rivers and with their present behaviour, the effects that they have in contemporary scenery, the landforms rivers produce and the ways in which they have developed in the past. Scenery in Britain is closely associated with rivers. Because no area is very far from the sea there are no very large rivers, but since the country includes areas with more than 1000 mm of precipitation annually, there are large numbers of rivers and streams. An understanding of rivers past and present can provide an indication of how rivers might change further in the future. This GCR Block aims to encompass sites important for understanding river processes and how British river history has been deciphered.

River processes

The network of river channels that makes up the fluvial system is really a series of linked 'conveyor belts' because water and sediments do not progress continuously through the system. Storage of water in lakes or in the deeper pools of river channels occurs for relatively short periods of time, but sediment and solutes can be stored in or adjacent to river channels for much longer periods of time.

The 'conveyor belt' also transports solid material, which is rolled or jumped along the bed of the channel as bedload, or carried as sediment suspended in the stream flow. Some materials dissolve in the water and are transported in solution. The bedload is obtained largely by erosion of the river bed and the banks of the river channel. The size (calibre) of the bed material available to the river may reflect the legacy of glaciation, if glacial deposits provide a source of bedload for the river. During downstream transport of the bedload, considerable differences exist in the size of the material, which decreases downstream; in the roundness of the material, which rapidly increases to a particular level and is then maintained; and in the composition of the bed sediments because some survive longer than others. Intermediate in character is the suspended sediment, which can be derived from channel bed and banks, but also from slopes, pipes and cultivated areas.

Sediment and solutes do not continue uninterrupted on the 'conveyor belt' throughout any drainage basin. It is the interaction between storage and transport of sediment and water which gives rise to characteristic forms of scenery, or 'landforms', associated with rivers and their channels. For example, along the course of a river channel there is an alternation between shallow areas, called riffles, and deeper pools, sediment may accumulate in bars and these are the temporary locations for material; longer-term storage of sediment can occur in the floodplain; river channels gradually shift by erosion of one bank and deposition on the other, and in this way meanders can gradually be translated. The 'conveyor belt' in the river basin is made up of streams and rivers which collectively make the drainage pattern. The river channel planform is usually divided into two major types, those that are single-thread and composed of a single river channel, which may be either meandering or for short distances may be straight; and those which have more than one channel, are multi-thread, and are described as 'braided' river channels.

The history of fluvial processes

Reconstruction of the way in which scenery was fashioned can use evidence from morphology and landforms, from sediments and from deductions about the way in which processes operated in the past.Particularly dramatic landforms created under past conditions are large meandering valleys, now occupied by small underfit streams, which were produced when river discharges were much larger than those of the present time. In some cases river valleys that received water from glacial drainage channels, which were created by meltwater from melting glacier ice, or draining from lakes impounded by ice, were a feature of the Quaternary environments of northern and western Britain. In the headwaters of drainage basins, particularly on limestone and sandstone rocks, there are extensive networks of dry valleys, and examples are included in the Quaternary GCR Blocks. These valleys, without any trace of stream channels at the present time, were also produced when the hydrological cycle of the past involved greater amounts of surface runoff.

Some features were produced by changes in sediment distribution and, for example, along some small rivers in upland Britain, there are sequences of deposits laid down as alluvial fans which have now been abandoned and dissected by present streams. Abandoned channels survive along many rivers as remnants that may be dated from the organic deposits which infill the old channels. Many of the river systems of Britain are still endeavouring to recover from the most recent glacial and cold phases, which produced vast quantities of sediment. Materials from glacial deposits are still being released into the fluvial system. In many parts of Britain, such as Scotland and north-east England, the present fluvial system clearly records the legacy of recent and of earlier glaciations. We therefore have a landscape today in which river systems are still recovering from the impact of different processes in the past.

Three main reasons explain the differences between the past and present conditions. The most obvious is the impact of changes of climate. Not only did the Quaternary bring a series of glaciations that affected much of the northern parts of Britain, but to the south of such glacier ice were climatic conditions that resembled the contemporary Arctic climates of northern Canada or Russia. This meant that the regimes of rivers were typically very seasonal, with little or no flows during the winter months and very large floods before and immediately after the spring thaw, followed by lower flows for much of the summer. Under such conditions, when the ground was frozen so that infiltration was not possible, extensive networks of valleys were produced, later to become dry valleys, and larger river discharges characteristically occurred along river valleys compared to those of the present time. Secondly, there have been changes along river valleys instigated by sea-level change. Such sea-level changes have affected the levels to which river activity could work and so allowed the destruction of original valley floors, remnants of which now remain as river terraces. In some cases the development of incised meanders occurred after significant lowering of river levels. A third difference between the present and the past is that the influence of human activity today is very substantial, whereas in the past it was often less significant. Many rivers and river channels have been modified as a consequence of deliberate changes by human action so that streams have been channelized for flood control, for drainage, to prevent erosion and for improvement of navigation. A particularly dramatic way in which fluvial systems of the past were changed was when deforestation between 2000 and 4000 years ago released quantities of fine sediment which were transferred into the river systems and which are very evident in the floodplain sediments of major rivers. In the upper Thames basin it has been shown how flooding and alluviation were largely restricted to the past 3000 years.

For the purposes of the GCR fluvial geomorphology sites were selected according to regional ‘Blocks’. Within the ‘Fluvial Geomorphology of England’ GCR Block, sites were selected to represent three prinicpal regions: North-west England; North-east England; and central and southern England, which form distinct fluvial geomorphological areas.

Holocene fluvial development in North-west England

The river systems of north-west England fall into five main groups, the Mersey, Ribble, Lune and Eden drainage basins, and the radial drainage of the Lake District. Almost all have undergone a similar sequence of Late Pleistocene and Holocene development. With the exception of a small part of the Dane headwaters in the Mersey system, the whole area lies within the Devensian glacial limits and therefore was under glacial ice at the Devensian maximum (i.e. c. 18 000 BP). The Loch Lomond Readvance (c. 10 000 BP) affected only small parts of the Lake District mountain catchments. The modern river systems were therefore initiated during the Devensian deglaciation between c. 18 000 BP and c. 14 500 BP, by which, approximately, the margins of the Lake District had become ice-free, and by implication when the regional ice sheet had melted from outside the Lake District, leaving still under ice only the Lake District valleys, and possibly the far north of the region within the limits of the disputed Scottish readvance.

There then followed a period of periglacial activity, interrupted by warmer conditions during the Windermere interstadial, culminating in the intensely cold phase of the Loch Lomond stadial, before hillslope stabilization under an increasing vegetation cover took place in Early Holocene times. A relatively stable early Holocene landscape under an almost complete woodland cover is envisaged, providing little sediment to what were presumably relatively stable rivers. However, for the later part of the Holocene, there is considerable evidence for fluvial change resulting from increased hillslope erosion as the woodland cover decreased, perhaps in part as the result of climatic deterioration, but increasingly under direct human impact.

Holocene fluvial development in North-east England

The principal river systems of north-east England are the Tyne, the Wear and Tees, and the Cheviot rivers in the northern part of the region (Coquet, Aln, Till) that flow eastwards to the North Sea. The sites, with the exception of two upland streams in the Yorkshire Dales (Shaw Beck) and Cheviot Hills (Harthope Burn), however, all lie within the watershed of the River Tyne and its major tributaries. The Tyne basin contains a diverse range of physiographic and geological terrains with contemporary and Holocene channel forms, and alluvial deposits, representative of north-east England in particular, and northern England as a whole.

North-east England was ice-covered during the Last Glacial Maximum, at around 18 000 BP, and glacial erosion and sedimentation from this and earlier glaciations have strongly influenced Holocene river development in the region. In response to declining sediment supply after deglaciation, and glacio-isostatic adjustments, upland and piedmont reaches of many rivers in the region have entrenched their valley floors in postglacial times, forming well-developed flights of river terraces. In some upland catchments, most notably in the Cheviot Hills, partial refilling of valley floors has occurred more recently, following major deforestation in the prehistoric and early historical periods. In contrast, the vertical tendency of channels in the lower Tyne, Wear and Tees valleys during the Holocene has been one of episodic, progressive alluviation. This was in response, principally, to rapid sea-level rise in the early Holocene and anthropogenically induced accelerated catchment erosion in more recent times.

The Tyne catchment is developed predominantly on Carboniferous sandstone, limestone and shale, with igneous outcrops in the headwaters of the North Tyne and along the lower part of the South Tyne valley. The geology of the North Tyne catchment compared to the South Tyne catchments (the principal tributaries of the River Tyne), however, differs in detail; the South Tyne and its tributaries (Black Burn, Nent, West and East Allen) drain the Northern Pennine orefield, which was once the most productive lead and zinc mining area in Britain. Fine-grained sediment from the South Tyne basin has a distinctive geochemical signature that can be recognized in Holocene alluvium downstream in the Tyne valley. Investigations of the dispersal of 19th and early 20th centuries mining waste in the region's rivers have been especially valuable in this context, enabling long-term and large-scale fine sediment transport processes and storage patterns to be studied.

As in many other base-metal mining areas in Britain historical mining activity significantly increased sediment delivery to rivers in the Tyne catchment, and resulted in widespread contamination of the South Tyne and Allen systems, and much of the Tyne River, downstream as far as Newcastle. The input of coarse material took place mainly in the 17th and 18th centuries primarily through a primitive, but very effective form of hydraulic mining called 'hushing'. Headwater streams in the mining areas of upper Tynedale, Weardale and Teesdale were most affected, with hushing causing localized river aggradation and channel planform change. The impact of the more easily dispersed finer metal-rich wastes was more widespread. Being phytotoxic, high levels of lead, zinc and cadmium in this material severely impaired vegetation growth, reducing bank stability and colonization rates of gravel bars, promoting river instability and braiding.

Present river channels in the Tyne basin are inset either within Pleistocene glacial and glaciofluvial deposits, Holocene alluvium or bedrock. Holocene river sediments range from coarse gravels in the Northern Pennine uplands and piedmont, deposited by laterally and vertically active near-braided channels, to sandy and silty alluvium in the lower parts of the basin, characterized by vertical accretion and relatively low rates of channel migration. Local differences in valley slope, degree and nature of channel confinement and the calibre of bed and bank sediment have, however, engendered considerable diversity in both Holocene sedimentation styles in the Tyne basin and present-day river channel patterns and bar development.

Fluvial landforms and processes in central and southern England

The boundary between the 'Highland Zone', of the north and west of Britain, and the 'Lowland Zone', of the south and east, is usually taken as a line running approximately from the mouth of the River Exe to the mouth of the River Tees. The area defined here as central and southern England includes some portions of the Highland Zone. These are principally found in south-west England, where three upland plateau areas of western Cornwall rise above a landscape that is dominated by coastal low plateaux cut across resistant Palaeozoic rocks. Also representing the upland scenery and resistant rock theme of the Highland Zone are the Mendips and the Quantocks, although the limestone features of such areas as the Mendips are included in another volume in this series. The central and southern Pennines also have the relief, scenery and resistant rock outcrops characteristic of the Highland Zone. Such areas have features similar to those already described for Wales and for north-west and north-east England.

Much of the remainder of the area is made up of two types of landscape which are scarplands or lowlands. A cuesta is an asymmetrical feature made up of a steeper scarp slope and a comparatively gentle dip slope that leads into a vale which is usually underlain by clay. This scarpland pattern of alternating scarp, dip slope and vale is a recurrent theme across much of central and southern England and makes up the scarpland landscape of much of southern Britain. The scale of cuestas varies very considerably from one area to another. Overlooking the lower Severn valley, the scarpland of Jurassic rocks at Birdlip Hill is up to 250 m above the Vale of Gloucester. The Cretaceous Chalk outcrops of southern, southeastern and eastern England are also characterized by cuesta landscapes, and there are major scarp slopes bordering the Chalk outcrops in Lincolnshire and in south-east England, where there are scarps bordering the North and South Downs. Although these are the major scarp and dip slopes making up cuesta landscapes, there are many smaller cuestas picking out variations in lithology that make up the diverse geological map of southern and central England.

A second type of area is made up of lowlands, which include the areas of the Fens, the London Basin, the Hampshire Basin, the lower Severn valley and the Trent and Ouse lowlands of eastern England, and also the Vale of Pickering, between the Jurassic rocks of the Yorkshire Moors and the Cretaceous rocks of the Yorkshire Wolds. In these lowland areas the surface rocks and deposits are usually comparatively young and often include sequences of recent Quaternary sediments.

Although the contrast between the Highland and Lowland zones, and also the basic character of the cuesta landscape and of the lowlands, owes much to the underlying rock type and the superficial deposits, there are several other distinctive themes that have influenced the pattern and character of river development in central and southern England.

Firstly, there are still traces of the original east-flowing rivers which were thought to have provided the ancestors of the present river system in Britain. Thus the Trent has east-flowing sections that were complemented by a north-flowing section when rock types allowed the development of subsequent streams. The Thames is also dominantly eastward-flowing, and originally there was an east-flowing major river along the line of the present Solent. Many characteristics of rivers in central and southern England reflect the fact that the headwaters of many rivers originate in the Highland Zone. The fluvial characteristics of some rivers of central and southern England need to be seen as depositional counterparts of fluvial systems of the Highland Zone. Thus headwaters of the Severn and Wye in Wales are associated downstream with the characteristics of the middle and lower Severn, draining into the Bristol Channel. Similarly, the Trent, Ouse and Humber receive characteristic Upland rivers from the Pennines and from the North York Moors.

A second major characteristic of central and southern England is that the recent evolution of the landscape is still firmly imprinted on the scenery. This is particularly significant because the most recent glaciation did not extend over much of this area, and the most southerly maximum limit of Quaternary glaciation was north of the present River Thames. This means that, according to the influence of glaciation, three major areas can be distinguished in central and southern England: one north of the Devensian limit, influenced particularly by deposits in the most recent glaciation; a second, to the south, where there are areas influenced by earlier glaciations; and a third, over the southernmost areas and in south-west England, where there are areas which were periglacial and beyond the maximum limits of Quaternary ice sheets. Whereas, in this southern area, the periglacial influence of permanently frozen ground (or ‘permafrost’) and a much more seasonal climatic regime produced river systems in the past which were different in character, regime and extent from those of today, in formerly glaciated areas there are some thick deposits of till, fluvioglacial sands and gravels, and diversions of drainage such as that of the Severn, which have all influenced characteristics of the present fluvial system. Along rivers such as the Severn, the Trent and the Thames, terrace sequences clearly indicate the stages of river and valley development.

A third theme arises from interaction with the sea. Estuarine influences in the areas adjacent to the Humber, the Bristol Channel, the Severn estuary, the Thames and the Wash arise because river activity and sediment transport and accretion interact with estuarine circulation and sedimentation. The finer sediments that reach estuarine environments may be influenced by different chemical processes involving, for example, flocculation of clays in saline waters. The largest area of alluvium in Britain surrounds the Wash, and sedimentation in this area, and also in the Vale of York, the Thames estuary and the Somerset Levels, has resulted not only from offshore sources from marine sedimentation, but also from peat and salt marsh development.

Human activity is a fourth theme, because it has had a greater effect on the fluvial system of central and southern England than in other parts of Britain. Deforestation is now known to have had a significant influence upon lowland rivers, and considerable amounts of alluvium have accumulated along rivers, including the Severn and the Thames, as a consequence of deforestation over the past 4000 years, which released suspended sediment transported by rivers and accumulated along floodplains. More recent drainage modification, particularly along river valleys in the Chalk areas of central and southeastern England, include water meadows developed for irrigation purposes, which still complicate the pattern of river channels.

A fifth dominant influence is that the rivers of central and southern England are essentially low-power channels, and in this sense contrast dramatically with those of Wales, northern England and Scotland, owing to low relief causing low river velocities; lower precipitation than in other parts of Britain; and because the extent of the permeable rocks is very considerable in this area.

GCR site selection

The present fluvial system in Britain blends together the impact of present processes with the landforms produced by processes of the past, and the sites were selected for the GCR as the best examples to exemplify these two stages.

There is a general sequence of four major types of fluvial landscape in Britain, which can be thought of as proceeding from headwater areas, through gorges, to floodplains and finally to estuarine tidal areas. Each of these major types has particular characteristics, but there are also major contrasts between the upland and lowland zones and between the glaciated and non-glaciated areas. A major distinction within a river valley is between bedrock reaches, mainly in the upstream sections, and alluvial reaches, mainly downstream. Contrasts in river characteristics can be related to rock types and their interaction with relief and water quantity. A further contrast is between areas that have been glaciated, especially in the most recent Quaternary glaciation, and those that have not. In the former there are ample deposits for rivers to excavate and to modify, whereas in the latter there has been ample opportunity for the impact of cold climatic conditions and different fluvial regimes.

A further contrast between the south and east of Britain and the north and west is the degree of human activity which has affected the present fluvial system and which continues to exert pressure upon it. Direct changes are very well exemplified by the distribution of channelization in England and Wales, the sites of dams and reservoirs, where water power has been generated, where gravel or river deposits have been extracted, or where river diversions have been engineered.

Some sites are relatively static in their characteristics and need to be conserved as representatives of features inherited from past types of landscape-forming conditions. Other sites are still dynamic, undergoing active processes that continue to change the landforms.

It has been possible to group the sites into five major categories or 'networks': (A) fluvial landforms associated with a particular process or a particular stage in fluvial landform development; (B) sites associated with a particular aspect of contemporary fluvial processes; (C) river channel pattern and floodplain features; (D) Quaternary channel change; (E) impact of human activity on the fluvial landscape or upon the river system.

A. Fluvial Landforms

1 Terrace

2 Incised meanders

3 River capture/rejuvenation

4 Mountain torrent/slot gorge

5 Waterfall

6 Karstic site

7 Soil pipe/swallow hole

B. Fluvial processes

1 Process event-flood

2 Accelerated erosion

3 Debris flow/cones

4 Sediment movement

5 Floodplain sedimentation

6 Discharge control on capacity

7 Vegetation influence

8 Bank erosion

9 Response to confinement variation

C. River channel pattern and floodplain

1 Meander

2 Wandering

3 Outwash sandur

4 Braided

5 Alluvial fans

D. Channel change

1 Palaeochanne

2 Planform change

3 Underfit stream

4 Palaeofans/sediments

5 Paleo terraces

6 Palaeoconditions

E. Human

1 Mining

2 Reservoir

3 River management