Evolution of Cotswold Valleys through Time

It may surprise you to know that the main river valleys of the North Cotswolds which we see today are occupied by streams that are mere shadows of the large ancestral rivers that once flowed through them. This article will discuss the characteristics of these river valleys and how and when they were formed.

One of the major controls on landscape evolution is the prevailing climate, and the last 30,000 years or so have seen major variations in our climate, namely cold Glacial periods and warmer Interglacial periods. We are currently in the Holocene Interglacial period which has prevailed for the last ~11,500 years, but prior to that was an extensive period of glaciation, broken only by a brief period of warmth between ~15-13 ka BP (thousand years before present) (the Windermere Interstadial).

Indeed, the Last Glaciation (which lasted from ~30–15 ka BP) was the most severe glacial event of the entire Quaternary period (i.e. the last 2.6 million years). Glaciers and ice sheets covered the entire area north of a line from offshore west of Ireland, the Scilly Isles, South Wales, the English Midlands, South Yorkshire, and the whole of the North Sea north of Norfolk (Fig. 1). Southern England was ice-free, but suffered severe permafrost and tundra conditions, with Mean Annual temperatures ~10-12°C colder than today (French, 1996). Conversely, the following relatively short Windermere Interstadial period (~15–13 ka BP) enjoyed temperatures somewhat warmer than today.

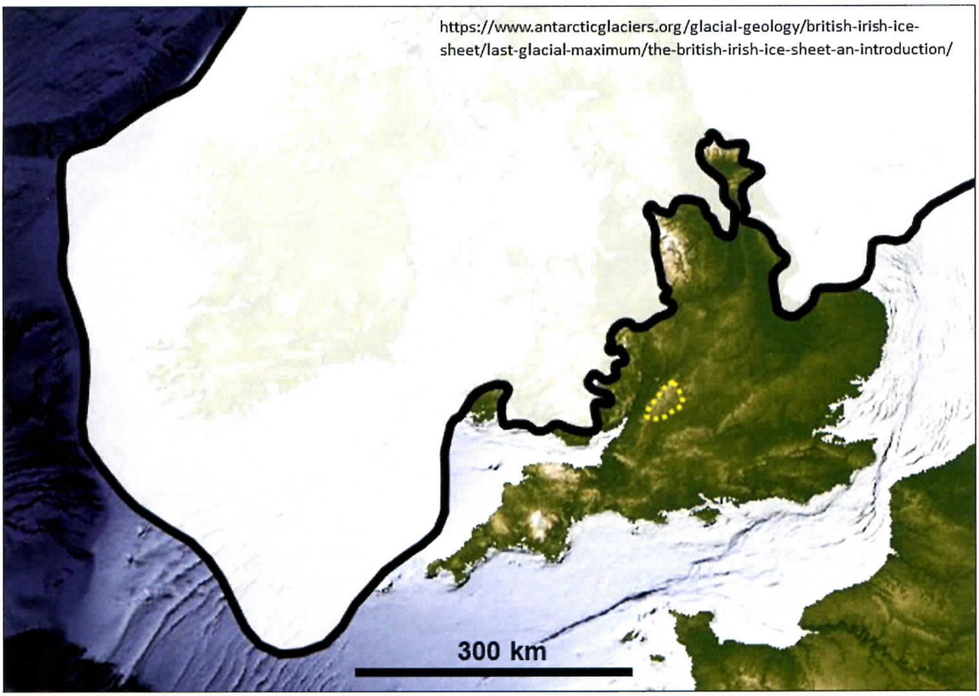


Fig. 1: Reconstruction of maximum ice limits during the Last Ice Age (after Emery (2020)). The North Cotswold area is outlined in yellow.

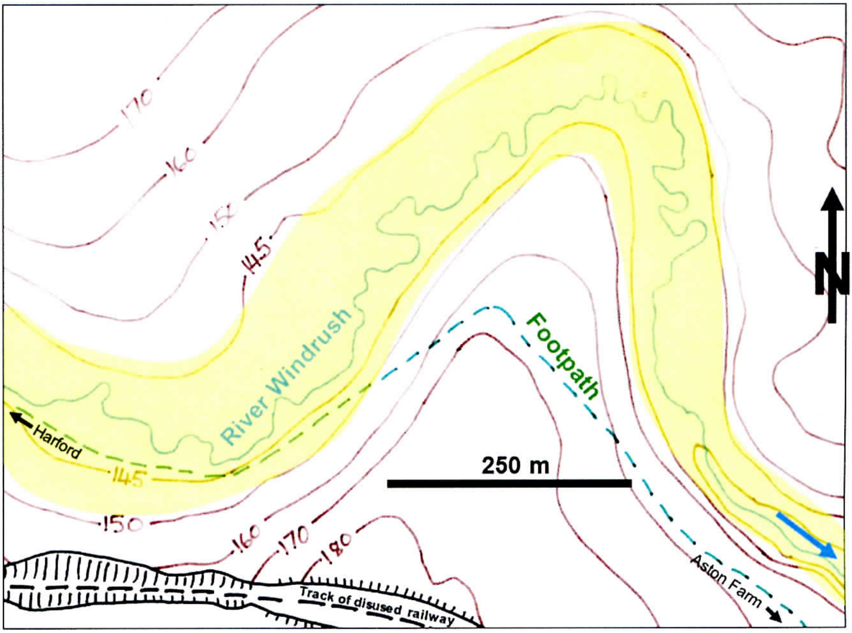


Fig. 2: Sketch map of the Windrush valley between Harford and Aston Farm showing the long wavelength valley meander (yellow shading) compared to very short wavelength meanders of the present river. Contours in meters.

These variations in climate had a dramatic effect on the nature and size of the Cotswold river systems. Rivers are important geomorphic agents because they:-

- Transport sediment (gravel, sand, clay, inorganic material) downstream,
- Erode the river banks and river bed, enlarging the river valley,
- Deposit (some) of their sediment load in the river bed and across the floodplain.

The ability of a river to transport sediment is a function of its rate of flow and the volume of water (discharge). Where discharge is high and flow is fast, more and larger grains or rock fragments can be carried: where discharge is low and flow is slow, most of its sediment load must be deposited and only the finest sediment can be transported.

So how have these variations in climate over the last 30,000 years or so impacted the morphology of the Cotswold river valleys?

Cotswold rivers and their valleys have attracted the attention of geomorphologists for over a century (e.g. W.M. Davis, (1909)) largely because of the mismatch between the size of the present-day valleys (deep and wide) and the size of the present-day streams which occupy them (small and narrow, or even dry).

This mismatch in present-day Cotswolds valleys shows itself as a 'valley-in-valley' form, in which the valley outlines have a long wavelength, high amplitude, meandering pattern, out of all

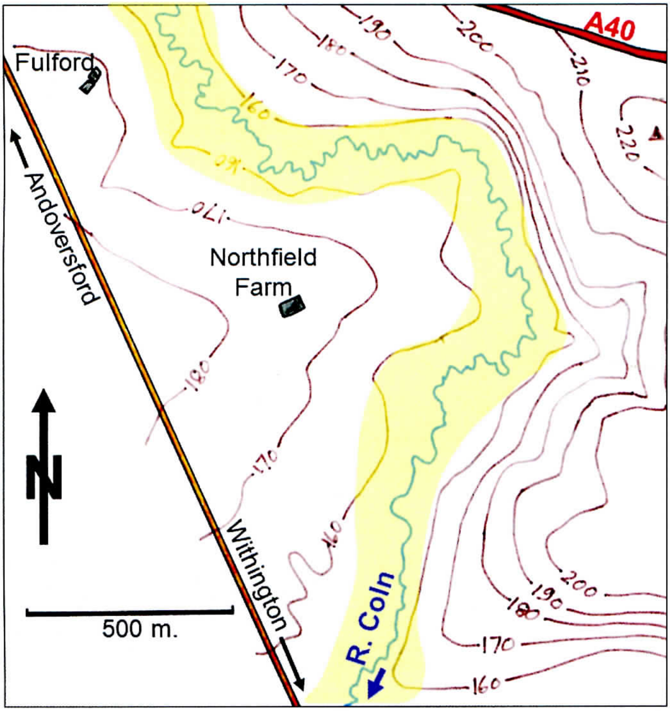


Fig. 3: Sketch map of the Coln valley just NW of Withington, showing the contrast between the large valley meanders (in yellow) and the small meanders of the present-day (misfit) stream. Contours in meters.

proportion to the diminutive size of the present-day streams, which generally have small, very short wavelength, wriggly meanders. These 'misfit' streams are very well seen in the Windrush below Naunton (Fig. 2), the Coln above Withington (Fig.3), and the Leach above Eastleach (see Fig. 4 for location of places mentioned in the text).

Pilbeam (2011) described the Coln valley above Withington, where one large valley meander is occupied by 10 or more meanders of the small present-day Coln river (Figs. 3, 5). Similar orders of discrepancy are seen in the Windrush, Leach, and Evenlode valleys. Studies of river valleys worldwide have shown that there is a relationship between river discharge, bed width, and meander wavelength. Applying this to the Coln valley, Pilbeam suggested that the ancient river which carved the valley meanders must have had a bed width of up to 30m, and a discharge during flood of over 100 times greater than the present streams.

Present-day discharge data from the National River Flow Archive shows that the Dikler at Bourton on the Water, the Churn at Cirencester, and the Coln between Fosse Bridge and Bibury each have Mean Flows of ~1 m3/s, and flows in flood of ~2 m3/s. By comparison, the River Severn at Deerhurst has a Mean Flow of ~100 m3/s, and flood flows of ~200m3/s. Applying Pilbeam's ratio, the implication is that the large meandering North Cotswold valleys must have been carved by rivers comparable in size to the present-day Severn. This must have been a truly remarkable sight!

Given that the catchment areas of these rivers has not changed significantly since the formation

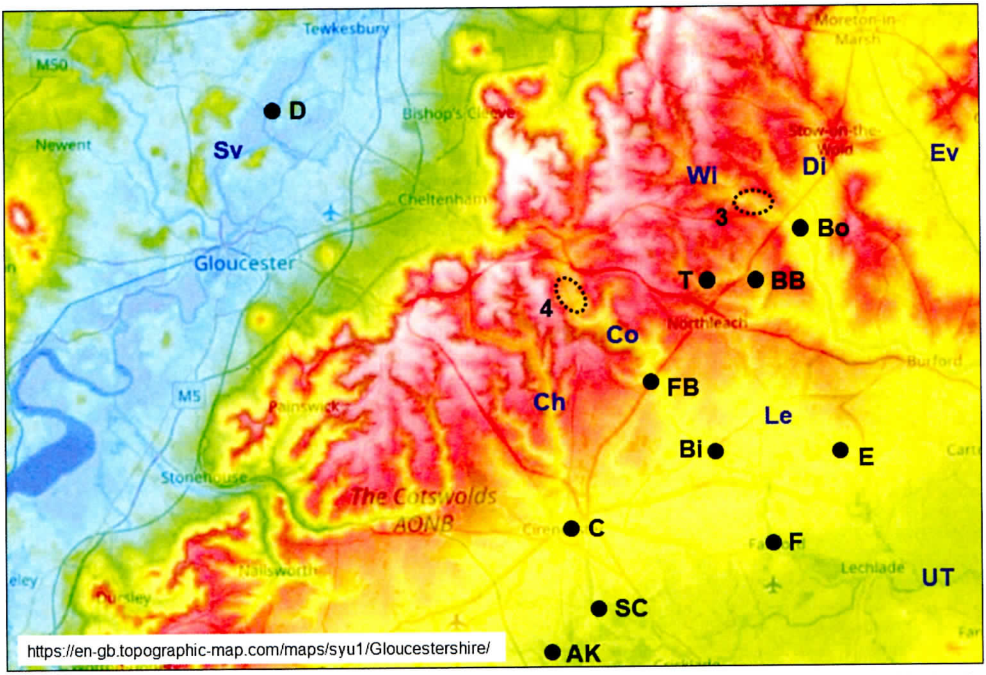


Fig. 4: Map of localities mentioned in the text. Rivers (in blue): Sv = Severn; Di = Dikler; Wi = Windrush; Co = Coln; Le = Leach; Ch = Churn; Ev = Evenlode: UT = Upper Thames. Places (in black): D = Deerhurst; Bo = Bourton on the Water; BB = Broadwater Bottom; T = Turkdean; FB = Fosse Bridge; Bi = Bibury; E = Eastleach; C = Cirencester; SC = South Cerney; AK = Ashton Keynes; F = Fairford. Sketch maps (Figure number in black): 3 = R. Windrush below Naunton; 4 = R. Coln above Withington.

of the Cotswolds escarpment some 400,000 years ago, this huge implied discharge, compared to the small size of the present-day streams, must be the result of climatic factors, i.e. increased water availability during the last glaciation.

This sounds counter-intuitive, but the high river discharge which occurred during glacial times (Fig. 6A) was due to:-

1. Flow of huge volumes of spring-summer melt waters from the winter ice and snow pack, and
2. The impermeable nature of the prevailing permafrost which prevented water loss through soakaway, both in the river beds and down the valley sides, and
3. The lack of vegetation due to the prevailing tundra conditions, meaning surface water run-off and solifluction was very efficient, and hence abundant soil and rock debris was easily transported to the rivers.

The resulting large rivers would have cut the large valleys we see today. They would have received and carried significant volumes of limestone gravel, some of which was deposited in the river bed, whilst most was carried further downstream to the valley of the Upper Thames,

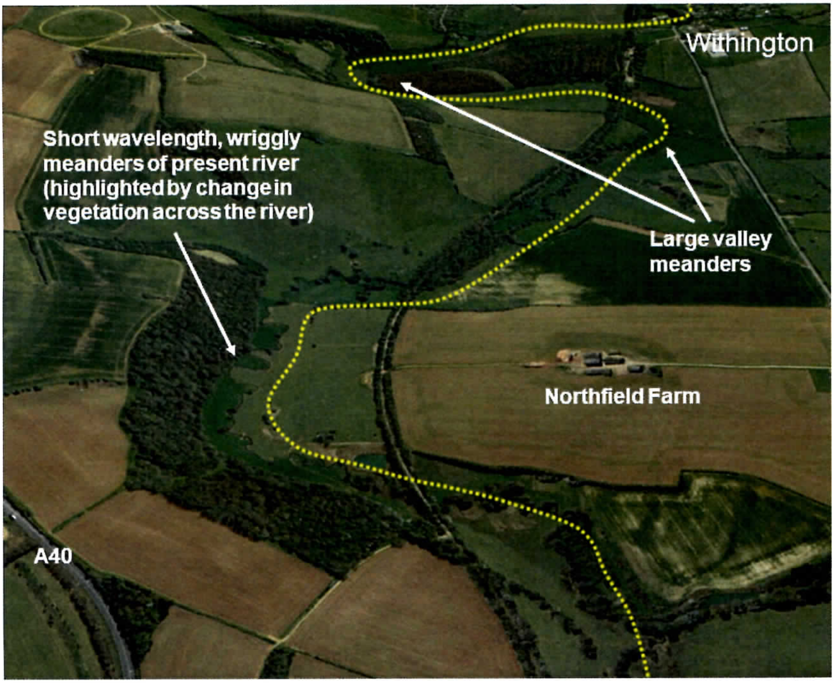


Fig. 5: Google Earth view looking south over the Coln valley towards Withington. Note the contrast between the small, wriggly meanders of the present river, compared to the large, sweeping curves of the ancient valley meanders.

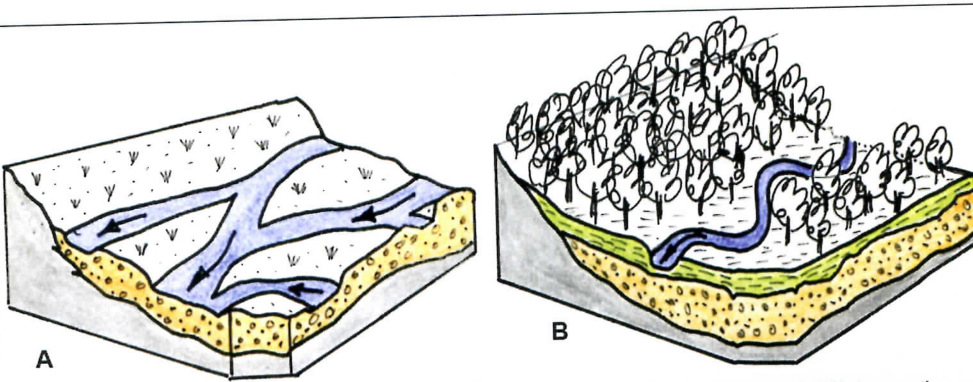
where the rivers' gradient (i.e. their energy) reduced, and large swathes of gravel were deposited. These are now seen as the flooded gravel pits of the Cotswold Water Park, around South Cerney and Fairford.

The change in climate at the start of the Holocene (~11.5 ka BP) marked an end to the high-volume river systems in the Cotswolds. Conditions rapidly warmed with annual average temperatures increasing by 7-10°C in 100-200 years (Pryor, 2014), and the supply of water to the rivers decreased dramatically (Fig. 6B), due to:

1. Lack of spring melt flood water
2. Melting of the permafrost, allowed surface water to percolate down into the limestone, reducing runoff, and
3. Increasing vegetation cover stabilised slopes and river banks, also reducing runoff.

Hence, these Holocene streams were much reduced, and consequently only able to transport and deposit very fine-grained sediment.

Local North Cotswolds geology supports this dramatic variation in river size and sediment load from the glacial to interglacial periods. Fig. 7 shows a scrape made in the valley of Broadwater Bottom, North of Farmington, in which at least 90 cm of limestone gravel (glacial deposition) is overlain by ~80 cm of reddish silty clay (interglacial deposition). The imbricated nature of the gravels indicates they have been deposited by flowing water, rather than being a slump deposit.



Typical river valley in Glacial times: patchy, herb-dominated, tundra ground-cover; unstable river banks and slope-wash feeds sediment into river. High-energy, snow-melt fed channels deposit coarse gravel across floodplain

Typical river valley in Interglacial / Holocene times: forested and grassy valley slopes and floodplain; single low-energy meandering stream with stable river banks. Little sediment delivered to river. Gravels of preceding cold period now overlain by clays and silts deposited across floodplain during high water.

Fig. 6: Sketches of typical Glacial and Interglacial/Holocene valley forms. A is followed by B, producing gravels overlain by silty clays.

An additional example comes from a willow tree uprooted by a winter storm in the valley below Turkdean (Fig. 8).

The exposed root system retains a surface layer of silty clay, underlain by limestone gravel. These examples confirm the observation of Hazelden and Jarvis (1979) that the floodplains of the North Cotswolds and Upper Thames valleys commonly comprise 0.5–1.0m of reddish silty clay overlying, with a sharp boundary, a variable thickness of limestone gravel.

On the assumption that the gravels were deposited from high-discharge streams during glacial times, and the reddish-brown silty clay is the deposit of low-discharge streams in interglacial

Fig. 7: View of scrape in Broadwater Bottom, with older gravels overlain by younger silty clay of the floodplain.

Fig. 8: Uprooted willow, showing silty clay surface layer (was reddish-brown, but weathered to dark grey because waterlogged) overlying older gravel layer held in the roots.

periods, what ages are attributable to these deposits, and hence when were the large valley meanders carved?

A site at Ashton Keynes (~10 km south of Cirencester) studied by Lewis et al (2001) shows (see Fig. 9), ~4m of limestone gravel, the lower part of which was deposited during the (cold) main Glacial period, whilst the upper part was deposited during the brief cold period which followed the Windermere Interstadial (the so-called Loch Lomond Re-advance (13-11.5 ka BP)). These two sequences are separated by discontinuous pockets of peat which have been radiocarbon dated to the warm Windermere Interstadial (15.0–13 ka BP) which therefore controls the timing of deposition of the underlying (i.e. older) and the overlying (i.e. younger) gravels. The gravels are overlain by ~1m of reddish-brown silty clay deposited during the (warm) Holocene period.

This analysis enables a link to be made between sediment type; prevailing climate; and age, which can be applied to the river valleys of the North Cotswolds, as follows:-

- The incised valley meanders were mainly cut during the Last Ice Age (~30-15 ka BP), with the required volume of river discharge being due to the spring snow-melt; the lack of vegetation; and the pervasive permafrost. The gravels which the rivers deposited are composed of Cotswold limestone, and hence local in origin, with none of the exotic Triassic gravels which characterise the older Anglian and pre-Anglian gravels (Jeans 2020).
- The rarity of alluvium dating to the Windermere Interglacial is because most of it would have been eroded from the river valleys by the later high-discharge streams of the cold Loch Lomond Readvance (~13–11.5 ka BP).

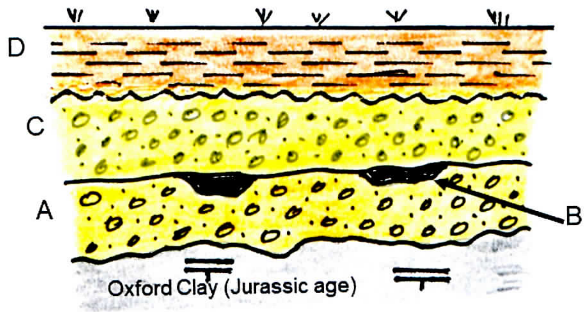


Fig. 9: Conceptual sketch of Ashton Keynes section (after Lewis et al (2001).
A = Gravels deposited during Main Glacial period (i.e. prior to 15.0 ka BP);
B = Peat-filled channel, deposited during the Windermere Interglacial (15-13 ka BP);
C = Gravels deposited during the Loch Lomond cold period (i.e. ~13 – 11.5 ka BP);
D = Holocene reddish-brown silty clay (younger than 11.5 ka BP).

- The reddish-brown silty clays which overlie the gravels are hence of Holocene age, dating from ~11.5 ka BP and younger. (A further increase in the supply of fine alluvium into Cotswold river valleys occurred as run-off due to the advent of agriculture, starting with Neolithic forest clearance (from ~5.8 ka BP), and accelerating from ~4 ka BP with the advent of Bronze Age ploughing of the valley sides).

This history is consistent with the age dating of the Ashford Keynes outcrops, but until an effort is made to age-date more of the deposits of the Cotswold rivers, it must remain a theory only. It is possible that the large-scale valley meanders were initially cut much earlier (e.g. during the Wolstonian ice age (~270–240 ka BP) or even during the Anglian ice age (~450–420 ka BP)), and then re-occupied and enlarged during the last ice age.

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