# Slides, Cambers, Slumps and 'Terraces': Part II Cambering

This paper is the second of three papers which describe and illustrate Gravitational Structures in the Cotswolds, i.e., those structures which are formed by the action of gravity on the soil and/or on the underlying solid rock. I have divided these structures on the basis of their size: -

Large features (hundreds of metres to several metres in size)

- Landslides (previous paper, (Jeans, 2021))
- Cambering, and associated structures (this paper)

Small features (paper to follow)

One of the interesting paradoxes concerning the Cotswold landscape is that relatively few of the features which we see today, including cambering, can be explained by currently active processes. Indeed, many features relate back to the last Ice Age (~37,000 – 11,000 yrs. ago). During this time the Cotswolds lay 100-200 km south of the limits of the ice sheets (Fig. 1) but still lay well within the limits of periglacial conditions, i.e., within the zone subject to seasonal and diurnal freeze-thaw cycles at near-surface levels of the ground, and subject to perennially frozen ground (permafrost) at deeper levels.

We can reconstruct what periglacial conditions in the Cotswolds must have been like by: -

1. Looking at present-day permafrost realms (N. Russia, N. Canada),
2. Studying insect fossils (especially beetles (Coleoptera) and midges (Chironomids)) and pollen from glacial (cold) and interglacial (warmer) deposits and comparing them with the present-day species habitats, which gives us estimates of winter and summer temperatures.

Based on these data, it is estimated (after French, 1996) that during the Ice Age, the Cotswolds experienced: -

- Average winter temperature of ~ minus 30 deg. C
- Average summer temperatures of 10-15 deg. C
- Mean annual temperatures ~ minus 6 deg. C
- ~4 months of average temperatures above freezing,

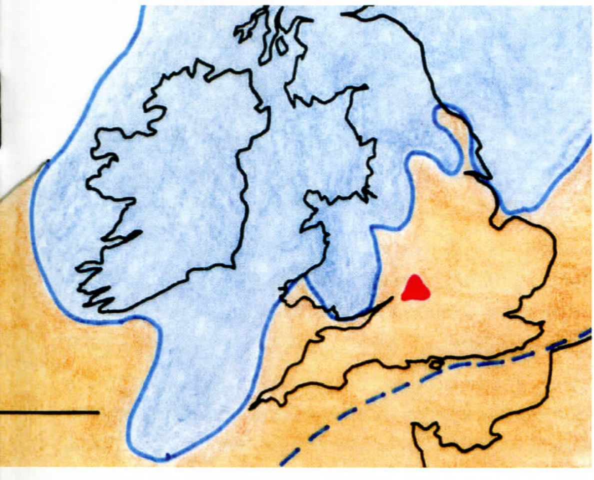

**Fig 1:** Limit of ice cover at maximum of last Ice Age (~23-27 ka BP) and dividing line between continuous and discontinuous permafrost. N. Cotswolds = red triangle; blue = ice cover; brown = land (sea level ~120m lower than present day).
Redrawn after Lukas et al (2017) and Giles (2020)

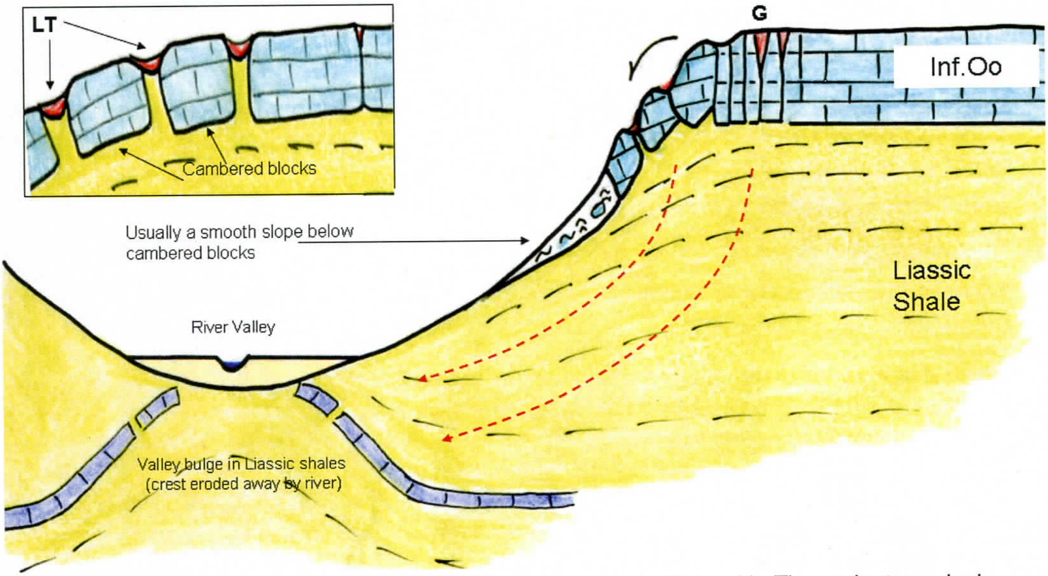


**Fig. 2:** Sketch of typical structures associated with cambering in the Cotswolds. The cambering and valley bulging was caused because shales, weakened by freeze-and-thaw and high water saturation, were squeezed down and outwards by weight of overlying limestone (Inf.Ool).
G = Gulls, which are enlarged fractures in the limestone; LT = Linear Troughs, which are the subsided areas between the cambered blocks. After Farrant et al (2014). Inset after Griffiths and Giles (2017).

- ~6 months below freezing
- ~2-3 months of recurrent freeze/thaw conditions.

It is estimated that the summer melt could have penetrated to depths of 1-3m, and that annual rain/snow fall averaged only 25-50cm, i.e. England suffered a much more continental climate during the Ice Age because the enormous extent of permanent sea ice greatly increased its distance from the sea (Fig. 1)

Freezing of ground water to ice results in a volume increase, causing break-up and disaggregation of rock and soil, whilst the thawing of the ice results in large volumes of water saturating the surface layers of soil and the broken-up rock layers beneath. This freeze and thaw activity provides the necessary lubrication for gravitational processes to operate.

In the case of cambering..........

The major contrast between cambering (Fig. 2) and landslides (previous article) is that cambered blocks have rotated forwards, down the slope, whereas landslip blocks rotate back into the slope. Cambered blocks do not generally move as far downslope as landslides, and no discrete slip surfaces develop: instead, the underlying shale deforms as a soft, ductile mass, driven by the weight of the overlying limestone 'beam'.

Whilst landslides in the Cotswolds have a history dating from the Ice Age through to the present-day, the formation of cambered structures is thought to be intimately related to periglacial conditions and permafrost during the last Ice Age. Several factors are thought to be key:-

- Deep erosion of valleys by rivers carrying large volumes of spring / summer melt water, flowing over impermeable frozen ground,
- Stress release due to the rapid excavation of these river valleys, and
- Repeated freeze and thaw, followed by ultimate melting of permafrost, leading to severely weakened and water-saturated shale layers.

Hence cambering probably occurred prior to or around 11,000 years ago, when the climate started to rapidly warm up after the last cold phase of the Ice Age. No examples of present-day formation are known, and all historic examples appear to be stable.

Associated with cambering are: -

- Gulls, which are open or infilled extensional fractures or joints in the limestone 'beam' running close to, and generally sub-parallel to, the edge of the valley or the escarpment (Fig. 3). When subjected to ground-water dissolution, gulls can be enlarged to create gull fissures (open cracks, too narrow to enter), and even gull caves. The Uley Rift cave extends ~36m into the hillside and is ~16m deep (Self and Boycott, 2004).

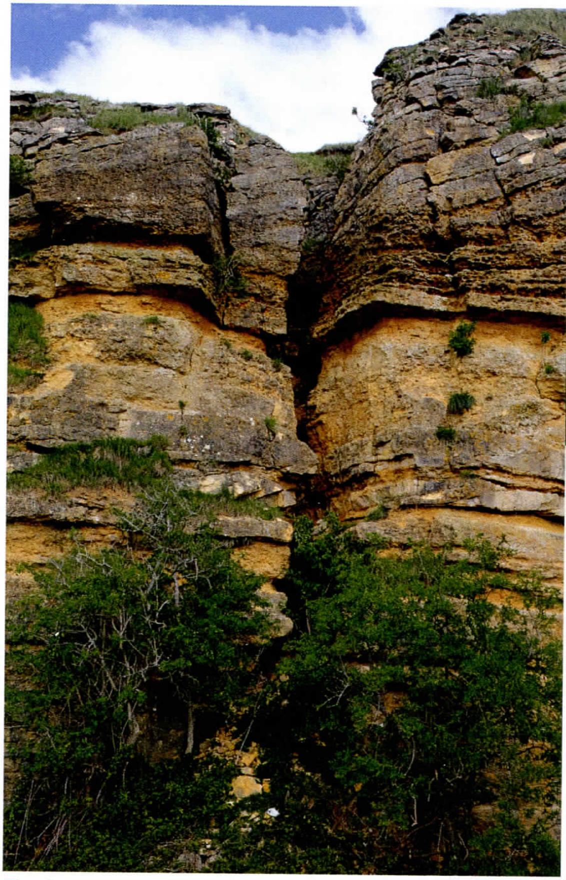

**Fig. 3:** Gull fissure or extensional fracture in Inferior Oolite limestones of cliff face below Cleeve Hill. GR 984260. See Fig. 7 for location.

- Valley bulges, caused by the squeezing up of water-saturated and weakened shales in the bottom of the valley. The driving forces behind this updoming are stress release due to the rapid erosion of the valley, and compression due to the mass of the overlying limestone slab. Valley bulges are difficult to see because they are often eroded away by the river but have been reported from the Frome valley below Sapperton.
- Linear Troughs, which are the largest and most prominent features of cambering. The outward rotation and downslope movement of the cambered blocks creates linear troughs between the blocks.

Linear Troughs can be over 300m long and up to ~10m deep, and at first glance they can be mistaken for dry river valleys, but instead of running downslope like a river valley, they run across the slope, parallel to the contours. The classic examples of cambering and linear troughs in England occur in the Cotswolds (Briggs and Courtney, 1972) in the Windrush and Eye valleys,

**Fig. 4:** Linear Troughs below Hill Farm. GR 143225. For location see Fig. 7.

such as those just below Hill Farm (Fig. 4). These lie in private land, but equally good and clear examples can be well seen from footpaths just north of Broadway Tower (Fig. 5); across the valley from Snowshill (Fig. 6); and at Postlip Warren on the NE side of Cleeve Hill (Barron *et al*, 2016).

**Fig. 5:** Cambered blocks (highs to left and right) and linear trough (centre) just north of Broadway Tower (GR 114 362).For location see Fig. 7.

To provide a link between cambering (this article) and landslides previous article) and to see how both can combine to shape the landscape, the area of the escarpment around Broadway Tower is instructive (Fig. 8).

Just to the north of the Tower there is a pronounced Linear Trough (see Fig. 5) bounded on the west by a large, cambered block which forms the edge of the escarpment. This block has rotated

**Fig. 6:** Linear Troughs,towards the top of the hill, just south of Littleworth Wood, opposite Snowshill. GR 087336. For location see Fig. 7.

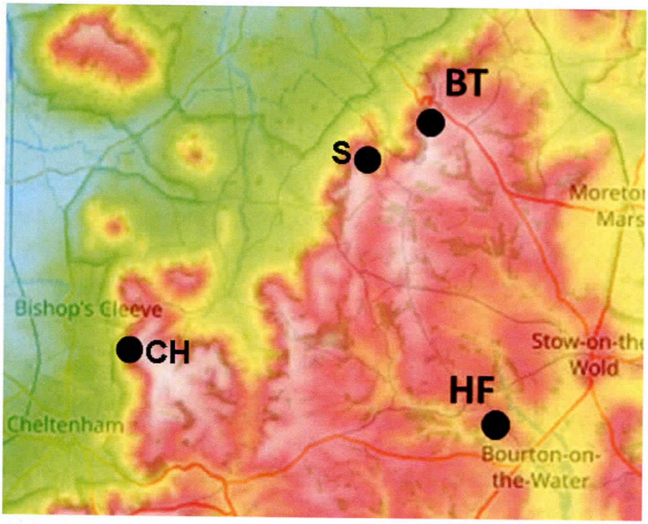


**Fig. 7:** Digital Elevation Map showing the location of cambered features described. BT = Broadway Tower area; HF = Hill Farm; S = Snowshill; CH = Cleeve Hill cliff face.

from the usual gentle south-east dip of the plateau to a 7° dip downslope to the west. Below the edge of the escarpment and dropping down towards Broadway the Liassic Shales form a hummocky slope of landslipped debris, interrupted by the Marlstone Rock bench. Between this bench and the scarp, one has the degraded remains of large-scale landslides forming an undulating, even step-like slope, whilst below the bench one has a terrain of small-scale landslips and mudslides which locally overrun Medieval ridge and furrow field patterns towards the base of the slope.

Whilst both cambering and landsliding are the result of water-logged Liassic shale slopes underlying the massive Inferior Oolite limestone, landslides appear to be most common along the Cotswold escarpment, whilst cambering is best developed along incised (wet or dry) river valleys on the dip slope of the Cotswolds.

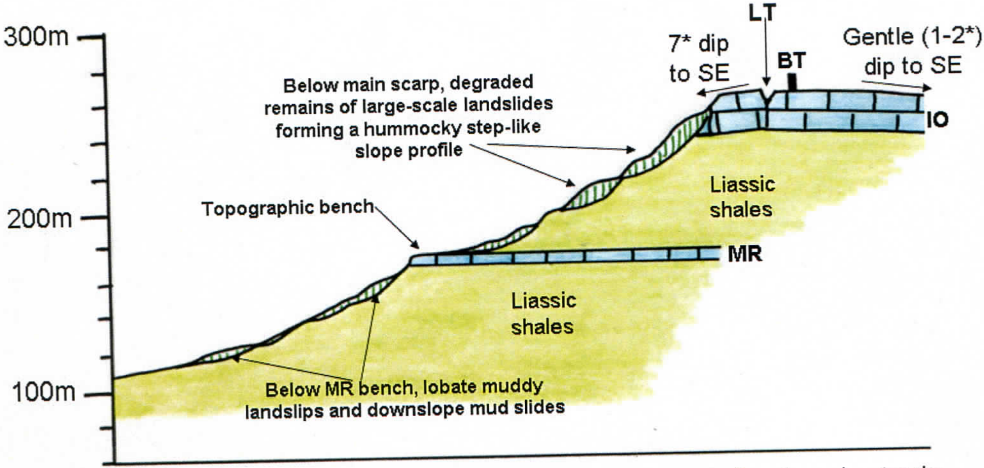


**Fig. 8:** Sketch section from NW to SE across the Cotswolds escarpment near Broadway showing the relationship between cambering at the crest of the escarpment and the hummocky landslipped ground on the Liassic shales below.
BT = Broadway Tower; LT = Linear Trough near Broadway Tower; MR = Marlstone Rock; IO = Inferior Oolite Limestone. Vertical exaggeration = ~5x.

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**Acknowledgements:** Many thanks again to Robin Lauckner, Tom Prudence, and Bob Thompson for their comments, which greatly improved the clarity of this paper.

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