Quaternary deposits and landforms

The Quaternary Period spans the last 2 million years, a time dominated by a succession of ‘ice ages’. The process of glaciation, the scouring of uplands by flowing ice, and the subsequent transport of material by ice and meltwater flow into lowland and offshore areas, produced distinctive sediments and landforms. During the Holocene Epoch (the last 11 000 years), following the decline of the ice, the landscape has been dominated by less dramatic processes. Holocene sediments in Britain include peat and alluvium, both of which give vital information regarding the climate and environment since deglaciation.

The study of Quaternary deposits and landforms enables links to be made between the behaviour of ice-sheet systems across continental-scale areas, and the mechanisms and processes of climatic and oceanic change.

Quaternary deposits and landforms in Great Britain

The landscape of Britain is dominated by Quaternary deposits and landforms. Throughout the last two million years successive glaciations have advanced across the landscape, sourced from the upland areas of Scotland, Wales, northern England and Scandinavia. Early in the Quaternary, ice advanced as far south as the Thames valley, with ice possibly even streaming past the Scilly Isles. Unfortunately, the nature of glaciations is that their imprint on the landscape is largely destroyed by any subsequent glacial advance, so most evidence for glacial activity in Britain dates from the most recent cold period, the late Devensian Glaciation, which spanned the period between about 25 000 and 11 000 BP (Before Present). The late Devensian ice was less extensive than earlier glaciations, though its southern limit formed a margin running between The Wash and the Bristol Channel, and in the west ice reached the edge of the continental shelf.

Glacial deposits and glaciated landscapes in Britain are highly variable. The processes that created them are complex, and operated over differing timescales; some were active throughout the period, whilst others switched on and off depending on ice dynamics, climate or factors such as sediment supply. However, as a general rule areas dominated by glacial erosion are to be found in upland regions, such as the Highlands of Scotland and the Lake District. These are characterised by high mountains, steep slopes, and smoothed bedrock surfaces. The valleys separating peaks tend to be ‘U- shaped’ and within these valleys some deposits can be found relating to the final departure of the ice. Moraine ridges mark positions of glacier retreat, and small areas of sand and gravel outwash indicate where meltwater transported the last of the glacier sediment load onto flatter ground. Lowland areas are dominated by depositional processes. Here tills (‘boulder clays’) form thick blankets over extensive areas. In regions that were near the margins of retreating or still-standing ice masses, glaciofluvial material, such as widespread sheets of sand and gravel, is commonplace. Tills and glaciofluvial material are often sculpted by the iceflow to produce landforms such as drumlins (elongate mounds) that give indications of ice-sheet behaviour.

At the Last Glacial Maximum (LGM — possibly between 35 000 and 22 000 BP), much of Britain was completely covered by an ice-sheet, in places over 1 kilometre thick and travelling at between 1 and 1.5 kilometres per year.

This ice acted both as a massive bulldozer and also a huge conveyor belt, simultaneously grinding and shaping the landscape and sediment beneath the ice, and transporting vast volumes of debris created by this erosion to lowland, coastal and offshore areas. The great till plains of Cheshire and Lancashire show how the ice moved out from mountain areas, streamlining the soft sediment beneath it into drumlinoid forms. Beyond the margins of the ice-sheet, huge volumes of meltwater transported many varied grades of material across the lowlands. The flatlands of East Anglia are a testament to the massive meltwater discharges produced by the ice, which were able to carry sand, gravel and cobbles huge distances.

Ice streams are the most dynamic component of modern ice-sheets such as those seen in Greenland and Antarctica, and therefore are important in driving ice-sheet evolution. Studies in Antarctica, for example, have shown that ice streams account for more than 90 per cent of mass transfer within the ice-sheet and leave behind characteristic landscapes when they retreat.

However, some ‘continental’ glacial locations, such as parts of modern day Antarctica, Svalbard and high-Arctic Greenland that endure relatively arid and cold conditions distant from a source of snow precipitation, experience cold-based glacial ice. Although the mechanisms are the subject of some debate, it is acknowledged that warm- based glaciers and ice-sheets are faster flowing, more erosive and more dynamic, than cold-based systems. Cold-based glaciers are often frozen to their bed, largely unable to perform appreciable amounts of erosion, and as a consequence are slower-flowing, producing smaller amounts of till and meltwater. Essentially cold-based ice can ‘protect’ a landscape from erosion throughout a glacial episode.

In Britain during the last glaciation, eastern upland areas such as the Cairngorm massif and Cheviot massif experienced cold-based glacial ice. Further west, warm based ice can be seen to have carved the spectacular troughs and steep mountains of the Lake District, Snowdonia and Western Scottish Highlands.

Quaternary deposits and landforms in the district

Throughout much of the Devensian glaciation large areas of Northumberland lay beneath fast-moving, dynamic parts of the British ice-sheet. The effects of warm-based ice streams can be seen in the landscape surrounding the Cheviot massif, in the Tweed Basin and Tyne Gap, where they have effectively moulded and streamlined the land.

However, the Cheviot massif appears to have deflected much of the streaming ice around it to the north and south, remaining relatively unaltered. In the lee of the massif lay an area of slower-moving ice, and during deglaciation this difference in velocity had a significant influence on the resulting landscape character. In order to simplify description the district has been divided into four areas, illustrated below.

Geological SSSIs

Quaternary of north-east England:

Cheviot Tors [NT 956 215]

Humbleton Hill and Trows [NT 951 275] and [NT 963 283]

Roman Wall [NY 715 667]

Fluvial geomorphology of England and Wales:

Harthope Burn [NT 961 230]

The landforms here are dominated by the underlying Roman Wall Loughs — glacial loughs including the terrestrialised Caw Lough, now a mire

Border Mires – SAC, internationally important mires [NY 88260 95924], Simonside Hills [NZ 024 987], Harbottle Moors [NT 92006 03847] and Cheviot SSSI [NT 90954 20318] all containing blanket and raised mires.

Area 1 – Hadrian’s Wall country, the North Tyne and Redesdale

Bedrock streamlining

The landforms here are dominated by the underlying bedrock. The differential weathering of Carboniferous rocks has produced a cuesta landscape of strong east-west trending ridges, with the dolerite of the Great Whin Sill, on which the Wall is built, forming the largest of these ridges. With this bedrock dominance over the landscape one might not expect evidence of Quaternary glaciation to be significant in the region. However, the form of the Whin Sill and dipping ridges of bedrock strata to its north and south has been accentuated by the action of subglacial erosion and shows obvious streamlining, caused by ice flowing from west to east across Northumberland parallel to the strike of the bedrock. In places, glacial loughs (lakes) have been scoured out in softer ground between harder bedrock strata. The Whin Sill itself shows remarkable topography from the air (p. 22). The section between Shield-on-the-Wall and Sewingshields exhibits classic ‘crag and tail’ topography, with ice smoothed stoss sides (up-ice crag tops), and lineated and streamlined lee side (down- ice) features. Hotbank Crag is a particularly fine example. This section of the sill is further cut at an oblique angle from west-north-west to east-south-east, by a series of subglacial meltwater channels, excellent examples being those at Steel Rigg and Shield-on-the-Wall. Western edges of crags are smoothed, and ‘tail’ features show limited development eastward in their lee. This pattern exists as far north as Henshaw Common and as far south as Thorngrafton. Nowhere else in the district is this bedrock streamlining more apparent. To the east, in the area around the Hallington reservoirs, the strike of the bedrock strata turns north-south and much of the streamlining pattern is lost. Virtually no streamlining can be seen in the bedrock forms from here until the north of the district, between Sweethope Crags and Kirkwhelpington.

Superficial streamlining

Between the dipping Carboniferous strata, glacial action has left another legacy. The lower reaches of each dip slope are filled with glacial till, which has been smeared across the landscape by the streaming ice. To the north of the Wall country around Henshaw, Haughton and Thirlwall commons, till thicknesses increase to such an extent that the bedrock strata are now buried fairly deeply, although their expression may still be reflected in the overlying till topography. Ice streaming in this region has led to drumlinisation of the till, creating a near-mirror of the streamlined bedrock seen further south, though formed of different material. These drumlinoid features are elongate mounds of glacial material up to 3 kilometres long, though most are between 800 and 1500 metres in length. They appear to be rock cored, with Carboniferous rocks forming their spines, and are composed of massive, clay-rich till. The till here contains ‘erratics’, large boulders transported by the ice, some of which have sources as distant as Criffel in Dumfriesshire, Shap and Eycott Hill near Penrith.

To the south of the Tyne valley, east and west of the Allen gorge, more of these drumlinoid forms can be seen, although here they overlie more gently dipping bedrock, and therefore have less surface relief than those immediately to the north of the Whin Sill. In the region where the sill turns to the north, around the Hallington reservoirs, and to the south of Kirkwhelpington some impressive elongated but low relief drumlinoid forms occur, aligned south-west–north-east.

Glaciofluvial deposits

Deposits resulting from glacial meltwater are mainly to be found in the Tyne valley around Haltwhistle and Hexham, and to the west of Chollerton. These deposits form hummocky topography; a result of their mode of deposition at the margin of a wasting ice mass and from incision by meltwater and alluvial streams close to the ice. Oscillating retreating ice margins repeatedly bulldozed and redistributed sediment, whilst all the time more sediment was being supplied by meltwater.

After the ice had disappeared from the area, reworking processes continued to operate. In modern proglacial (in front of the ice) environments, such as parts of Iceland, it is common to find areas of disordered terrain beyond the snouts of retreating glaciers. These areas often contain large buried blocks of ice, sometimes tens of metres in thickness, and hundreds of metres in lateral extent. As these masses slowly melt, a process of topographical inversion takes place whereby higher hummocks that were once ice-cored melt away to leave hollows, sometimes known as ‘kettle holes’, whilst the low areas previously at the sides of the buried ice become filled with debris and form hummocks.

Glaciofluvial deposits are normally composed of sands and gravels, and often contain pebble and cobble beds. Quite often these deposits are bedded as a result of deposition by dispersed meltwater flow. They have a coarse fabric and tend to be free draining.

Fan deposits

A significant fan has accumulated at the mouth of the Allen gorge into the Tyne valley. This is a postglacial deposit that is likely to have formed early in the Holocene Epoch, and may reflect reactivation of the Stublick Fault following unloading by retreat of the ice-sheet. The fan is largely composed of pebble- and cobble-grade debris, and topographically forms a sequence of at least five overprinting fans. The current level of the River Allen is at least 50 metres below the level of the topmost fan surface, reflecting increased incision, or trenching, since formation, and a reduction in debris supply throughout Holocene time.

Peat

Peat is made up of partially decomposed vegetation that has accumulated in waterlogged conditions throughout the Holocene. Its formation was stimulated by increased rainfall and human forest clearance. Blanket mire is peat more than 0.5 metres deep that forms over large areas in hollows and over undulating flattish land. Raised mires form through succession and terrestrialisation from lakes or pools. Peatland habitats are found widely throughout the southern section of the district particularly between the dipping Carboniferous strata, the most important being the Border Mires; a collection of internationally important deep peat sites (up to 12 metres) on the Northumberland-Cumbria border. These peat deposits have been substantially modified by afforestation, drainage, peat extraction, overgrazing and burning.

Alluvial deposits

Alluvium, material resulting from fluvial deposition, is widespread on the floors of the Tyne and North Tyne valleys. These valleys almost certainly represent preglacial drainage pathways, which have inevitably been modified by iceflow. The South Tyne, in places up to 1.5 kilometres wide, is floored with successive deposits of alluvial clay, silt and sand, often overlying glaciofluvial gravel. Sequences of abandoned alluvial terraces are very distinctive in the Haltwhistle region, and most terraces in the Tyne catchment are predominantly composed of coarser sands and gravels, frequently overlying till deposits. This overall coarsening upwards of units through the alluvial and terrace sequence, reflects both the age and changing character of the Tyne valley landscape. The highest terraces are oldest, and were deposited early in the Holocene, or even during the final stages of the late glacial period (about 15 000 years ago). Debris supplies in the area were far greater then due to the recent retreat of the ice than they are at present, and likewise the amount of fluvial discharge was probably greater and more responsive to climate, due to the combination of melting ice and a lack of vegetation to slow river response. Later terraces were deposited during periods where the available debris in the catchment was diminishing and vegetation was more established. Both these factors regulated river response, and reduced the Tyne River system’s ability to carry large bedload clasts.

Area 2 – North and east of the Cheviot massif

Bedrock streamlining

Streamlined landscapes can be seen on the northern flanks of the Cheviot massif, and further to the north in the Tweed Basin. The northern flanks of the massif, around Kirk Yetholm and to the north of the Glen valley, between Westnewton and Branxton, show clear alteration of drainage pathways and valley-side slopes by ice moving from south-west to north-east. Venchen, Staerough, Pawston and Moneylaws hills are all good examples of streamlined masses. Many of these streamlined summits display distinct ‘tail’ features in their lee to the north-east. Between these hills drainage is now concentrated in sub-parallel networks, oriented south-west-north-east, draining to the north-east. It is assumed that prior to glaciation drainage networks would have resembled more typical dendritic patterns, such as those found in the vicinity of the Capehope and Heatherhope burns. Valley side slopes in this area tend to be more linear in comparison to the more convex profiles of valleys to the south.

Streamlining in superficial deposits

To the north of The Cheviot in the region between Hoselaw Loch, Hadden and Coldstream, the landscape is dominated by highly-elongated, relatively low-lying mounds composed of glacial till and glaciofluvial deposits.

This distinctive topography was produced by the action of the Tweed Ice Stream flowing over a deformable bed of glacially-derived material. The majority of these landforms can be classified as drumlins, megadrumlins and megaflutes and their long axes are indicative of ice- sheet flow direction. Furthermore, their degree of elongation is thought to reflect the relative velocity of ice flow. The sub-parallel landforms in this part of the Tweed valley indicate general north-eastward and eastward ice flow, towards the present North Sea coast.

Glaciofluvial deposits

The area to the east of The Cheviot is dominated by glaciofluvial deposits. In general these have been deposited by glacial meltwater, both proglacial and subglacial. There is evidence for prolonged retreat of the major mass of the ice-sheet, with interruptions as the ice halted its retreat and maintained stable positions across this part of the landscape.

The area of the Till valley between Wooler and Powburn displays extensive areas of mounds and hummocks, dissected by channels, predominantly formed by the action of meltwater from the retreating ice-sheet. The mounds are mainly composed of sands and gravels, in places the sands are bedded implying deposition in lakes as ponding of water occurred at the margins of the ice- sheet, however the sand beds are frequently interrupted throughout the vertical sequence by gravels.

These gravel units have erosional lower surfaces and, in section, display channel forms showing that they were most likely deposited by a fast flowing stream or river. The repetition of the sand-gravel-sand sequence up through the stratigraphy indicates that this was a highly dynamic and variable environment. As the major mass of the ice-sheet retreated towards the north, stagnant ice and meltwater formed the landscape at the margins of the ice. The large debris supply, coupled with the availability of large amounts of meltwater enabled this somewhat chaotic and distinctive topography to develop.

Lake deposits

East of The Cheviot, there are two areas of ancient lake deposits, both of which are currently being exploited for building resources. The Milfield Plain stretches some 11 kilometres from Ford in the northwest to the south of Wooler, and is 3 kilometres wide at its broadest point between Bendor and Doddington. The plain has been interpreted as an ice-dammed lake due to its location at the margin of the retreating Tweed Basin portion of the British ice-sheet toward the end of the main late Devensian Glaciation. There are no exposures of the lake deposits themselves on the Milfield Plain. However, borehole records show that beneath the topsoil of the plain lie significant thicknesses of soft red clays, interspersed with lenses of fine to medium sands. These sedimentary assemblages support the interpretation of the area as an ice-marginal lake bed. The plain is older than Holocene in age, as it is overlain by a low fan emanating from the Glen valley, itself demonstrably at least 15 000 years old (see below).

Further to the south at Thrunton, the brick clay quarry sits upon a deposit of at least 10 metres of interbedded brown and grey clays; these are likely to have been formed by ponding of meltwater between the retreating ice and surrounding hills.

Fan deposits

Issuing from the Glen valley is a low-angled fan whose toe stretches from Milfield Hill to Akeld Steads. The apex of the fan is sited around Lanton. Holocene fluvial activity of the River Glen has removed a considerable portion of the fan, and dissected through its southern boundary with the lower slopes of Yeavering Bell and Akeld Hill. The fan itself is composed of bedded sands and gravels, with some intricately cross-bedded units, indicating periods of steady flow, punctuated by periods of fluctuating flow. Deposition probably took place in a lake over a relatively long period. The fan’s low-angled upper surface and composition dominated by finer grain sizes indicate that a large degree of the sorting of material had already taken place further upstream. Consequently, the toe area of the fan is dominated by finer grain sizes: medium-grained gravels to medium-grained sands.

The timing of fan formation is relatively clear. As deposition took place in a lake environment, fan construction almost certainly took place during deglaciation between 18 000 and 15 000 years ago, when the British ice-sheet flowing from the Tweed Basin and down the North Sea ponded meltwater against the flanks of the Cheviot massif. Further support for this period is found in the upper surface of the fan itself, where large scale periglacial frost-wedge casts can be found. These are unlikely to have formed during fan construction, as they do not form underwater. However, the onset of a glacial event known as the Loch Lomond Stadial, at around 12 000 BP, saw a return to full glacial conditions across the North Atlantic Margin for a millennium, and saw the regrowth of glaciers in Scotland, Wales and the Lake District. While there was unlikely to have been regrowth of ice in the Cheviot massif, it was most certainly affected by periglacial activity.

Alluvial deposits

Alluvium is widespread on the floors of the Till, Glen and Ingram valleys. In almost all places these three major rivers have dissected glaciofluvial deposits, both removing and reworking the material, and creating flat floodplains and terraces. The floodplain of the River Till across the Milfield Plain is extensive, however the action of the River Till system has not created this landscape, it has merely exploited a pre-existing flat surface; lakebed deposits of palaeo-Lake Milfield, over which it has been able to meander and flood.

Sequences of abandoned alluvial terraces are very distinctive in the Brandon region, and most terraces in this part of the upper Breamish catchment are predominantly composed of coarser sands, gravels and cobbles. These terraces are likely to have been deposited early in the Holocene Epoch, or even during the final stages of the late glacial period (about 15 000 BP), when sediment supplies were far greater than at present due to the recent retreat of the ice. Moreover, the amount of fluvial discharge was probably greater and more responsive to climate, due to the combination of melting ice in the vicinity, and a lack of vegetation cover to slow river response times.

It is unlikely that modern flow regimes in the upper Breamish valley are able to transport significant quantities of the larger grade bedload clasts that are evident. Winter storms and snow-melt events are the primary agents of remobilisation of this material, which was deposited under early Holocene or lateglacial flow regimes.

Area 3 – Lower and Upper Coquetdale

Bedrock alteration

In aerial view the overall character of the bedrock exposure in this area is very different to that found in most other parts of the Cheviots and surroundings. The eastern part of the area is dominated by outcrops of the Fell Sandstone, however the western fringes of Coquetdale are bounded to the north by bedrock that appears to have undergone significant in situ weathering (saprolite). Slopes here are commonly deeply incised by a higher density of drainage networks than found to the north and east of the Cheviot massif. No exposures of weathered material have been found to date, however the landscape exhibits similar characteristics to areas where known saprolitic rocks occur in the north of the Cheviot massif, where several metres of rotted material are to be found at surface (see Area 4).

In the area that forms a triangle between Alwinton, Thropton and Whittingham the landscape has undergone streamlining by ice, and bedrock exposures illustrate the effects of ice moving from west-south-west to east-north-east. Streamlining of the Simonside Hills and the Fell Sandstone hills to the north of Rothbury is less obvious, though the overall plan-form of the outcrops show that the area has been overridden by ice.

Superficial streamlining

Thin till is present in the area to the north-west of Rothbury, though its distribution is patchy, with large areas of streamlined bedrock to be found close to, or at surface. The effects of ice movement are less obvious in the Coquetdale area than to the south, as its proximity to the Cheviot massif ensured that iceflow was slower here. The Tyne Gap Ice Stream flowing south-eastwards from the Kielder Forest area would have encountered both a topographical high, and also possibly a small independent ice centre within the British ice-sheet centred on The Cheviot. This would have had the effect of deflecting iceflow to the south, and causing it to slow at the northern fringes of the stream.

Glaciofluvial deposits

There are few areas of obvious glaciofluvial deposits in the Coquetdale area. One significant example is to be found in the valley of the River Aln, west of Whittingham, where a series of flat-topped ridges run sub-parallel to the main axis of the valley floor. Previous geological surveys have identified these ridges as being composed of sand and gravel, although they have not ascribed a mechanism to their formation. Though no exposure has been found thus far, it is likely that these features are associated with glaciofluvial outwash processes at, or beyond, the margin of a retreating glacier.

Alluvial deposits

There are extensive areas of modern and ancient alluvial deposits in the Coquetdale area. For most of its length, Coquetdale itself displays a wide floodplain, from its upper reaches at Alwinton down to Rothbury where the floodplain narrows through the gap in the Rothbury Forest hills. East of Rothbury the floodplain, although narrower, displays some well-developed terraces in the region to the south of Longframlington. The width of the floodplain upstream from Rothbury is testament to the size of the drainage basin of the Coquet. Its large catchment, coupled with suitable bedrock lithologies and climate, ensure that river load is generally high.

The floodplain development is likely to have been constant throughout the Holocene and alluvium was deposited on top of remnants of glaciofluvial activity from the end of the Devensian glaciation, some of which can be seen to the south of the golf course at Rothbury.

Peat

Blanket mire has formed on flat and undulating ground in these areas, for example the tops of the Fell Sandstone ridges at Simonside and Harbottle. In larger depressions raised mires have formed, the most significant being the Otterburn Mires SSSI sites located across the Otterburn Training Area and sites such as Boddle Moss [NY 994 973] and Caudhole Moss [NZ 045 980] within the Simonside Hills SSSI. Historically, some of these sites have been modified by drainage, overgrazing and burning.

Area 4 – The Cheviot massif

The Cheviots do not display the characteristic features that are usually associated with Britain's glaciated upland areas (p. 56). The reasons for this are several, and are intrinsically linked with the position of the massif in relation to the British ice-sheet and major ice source areas in the rest of northern Britain and Scandinavia.

The Cheviot massif apparently deflected much of the streaming ice around it to the north and south, remaining relatively unaltered. The massif itself is likely to have supported an ice cap of its own which, during glacial maximum conditions, may well have operated as part of the larger British ice-sheet, however later in the glacial period, as the British ice-sheet thinned, the Cheviot Ice Cap is likely to have maintained its own flow regime.

The massif lies relatively distant from the source of most snow precipitation, which fell predominantly over the uplands in the west of the British Isles. It is also well to the east of the proposed ice divide (i.e. the 'ice-shed' running roughly north-south, dividing eastward flowing ice, from that flowing to the west). As a result it is likely that The Cheviot endured relatively arid and cold conditions throughout glacial periods, being far removed from any maritime influence, and lying in the precipitation shadow of the western hills. Consequently ice build-up on The Cheviot would have been fairly limited, and in conjunction with the arid and cold climate this would have led to a subglacial regime characterised by 'cold-based' conditions (p. 57).

Bedrock alteration

In aerial view the overall character of the bedrock exposure in the Cheviot massif can be divided into two distinct types. The western part of the massif is characterised by slopes that are deeply incised by high density fluvial drainage networks. In the eastern part of the massif slopes are much more linear, and drainage density is significantly lower. The distinction in character between the two landscapes is largely due to the alteration of the bedrock in the west by significant in situ weathering. Few exposures of weathered material have been found to date, however the landscape of the whole of the western Cheviot exhibits similar characteristics to areas where known saprolitic rocks occur in the north of the massif, where several metres of rotted material are to be found at surface. In the area around the valley of the Kale Water, south of Hownam [NT 7717 1640], the rocks are completely weathered to a clay deposit, which in parts may be more than 10 metres thick. The primary igneous textures are preserved, indicating that alteration occurred in situ. There are two main methods by which granites can be weathered: hydrothermal alteration, by which groundwater, usually under pressure, chemically alters the composition of surrounding rocks; and subaerial weathering. This involves long exposure to the elements, with rainfall seeping through the rock, causing the alteration of minerals, and removing the products of these reactions.

Tors

British tors have been the subject of much research throughout the 20th and 21st centuries. Throughout this period there have been two dominant theories of tor formation. A two-stage model, with deep chemical weathering prior to the Quaternary period and then removal of the products of that weathering by mass movement under periglacial conditions during Quaternary glacial periods. A one-stage model has also been proposed, with formation of tors during Quaternary glacial periods as a result of a combination of frost riving and mass movement under periglacial conditions.

The locations of tors appears to be controlled largely by association with the parts of the landscape that do not support weathered bedrock. All but one of the major tors occur in the eastern part of the Cheviot massif, with the best developed examples at Great Standrop, Langlee and Housey Crags.

Glacial meltwater channels

Large numbers of channels cut by glacial meltwater have been identified around the Cheviot massif. Most of these are related to the action of subglacial meltwater, as indicated by their 'up-and-down' long profiles, though some channels are clearly subaerially formed, being the result of extensive outflow of meltwater during deglaciation. These latter channels are associated with extensive spreads of glaciofluvial sands and gravels, forming sheets on valley floors, such as those found in the Ingram valley and the valley of the Kale Water.

Glacial till

There is very little glacial till to be found within the massif itself, with the majority of deposits being distributed around its ice-streamed margins. The small deposits that do exist are found as small lenses and smears of clast- dominated, coarse matrix, rubbly tills on valley sides and in hollows and valley floors.

Peat

Extensive areas of blanket peat have formed in the Cheviots in the cool, wet climate. Blanket peat forms on slopes up to 30%, so the flatter plateaux and summits of the hills and the lower more gradual slopes, as well as in the dips and saddles between more rounded summits, are the main locations for this habitat. Good examples are Cheviot summit plateau, the areas between Hedgehope and Combe Fell [NT 930 190] and Coldburn Hill and Hare Law [NT 903 245] as well as Broad Moss north-west of Hedgehope [NT 960 215]. Where the slopes become steeper, the blanket peat ends and hagging is visible on the margins marking the transition to a heather/acid grassland mosaic on mineral soils.

Alluvial deposits

Alluvium is widespread on the floors of the Harthope, College, Kale and Upper Coquet valleys. These are the only significant rivers draining the massif, and their drainage pattern most likely reflects the dominance of bedrock faults across the Cheviots, rather than valleys created by glaciation. Therefore, in essence the drainage pattern is most likely inherited from pre-Quaternary times, and has undergone little alteration either during glacial times, or afterwards. The most extensive alluvial deposits are to be found in the valley of the Kale Water where modern alluvium overlies glaciofluvial deposits, laid down during retreat of the last ice to have covered the region at the end of Devensian time.

Influence on biodiversity

Quaternary deposits by their very nature and wide distribution have the biggest influence of any geological deposits on the biodiversity of the district. These deposits and the vegetation that they now support have however been substantially modified by humans and what we see now is only a snapshot in time. Future climate change and management will have a strong influence on biodiversity.

A meltwater channel draining north-eastward from Ewartly Shank [NT 9644 1470].

There is significant lateral discontinuity of different Quaternary units, which contributes to changing soils and ground conditions over very small geographical areas. Possibly the unit supporting the most diverse flora and fauna is Holocene peat. The internationally important Border Mires in the Hadrian's Wall area and other raised mires are home to a wide range of plant, insect and animal life including sphagnum mosses, sundews, bog rosemary, large heath butterfly and wading birds such as dunlin. The blanket peat habitats in the Cheviots and Cheviot fringe areas are generally less diverse but do support sphagnums, cottongrass and, at higher altitudes, cloudberry. Areas of till tend to have been cultivated over the centuries, and most of these areas are now pastureland and do not support significantly diverse ecosystems. The exceptions to this are the few remaining species-rich hay meadows (once more widespread). The free-draining soils overlying much of the glaciofluvial deposits in the Cheviot fringe have allowed widespread agriculture, hence much of the biodiversity there has been significantly modified by the actions of humans. Clearance of natural woodland and maintaining open ground by grazing has replaced shrub and woodland by moorland habitat across large areas. This habitat characterised by Calluna heather, with other dwarf shrubs such as bilberry, cowberry and bell heather is now considered important in its own right and sites such as the Simonside Hills and Harbottle Hills are considered internationally important. In other areas grazing has reduced the vegetation to a less diverse acid grassland mosaic. Large scale post-war planting of coniferous forests in some areas has replaced natural vegetation including areas of peatland, but restructuring and felling is reversing this in some areas.

Economic use

The extensive spreads of glaciofluvial and Holocene age alluvial sands and gravels in the district have encouraged a fairly high level of extraction in the past. The alluvial terraces of the Tyne are regular in depth and are predominantly composed of graded gravels, the finer material having been washed out. These terrace gravels tend to be primarily composed of Carboniferous sandstones with some lower Palaeozoic greywackes, with limestone and some igneous rocks. Extraction has taken place all along the Tyne from Gilsland [NY 635 665] in the west, to Crawcrook in the east, with numerous small-scale pits being worked predominantly in the alluvial terrace material. Possibly the most extensive working of the glaciofluvial material has been at Prudhoe Gravel Works. The Milfield Fan is predominantly composed of sands and graded gravels. There have been extensive sand and gravel workings at Woodbridge Farm Quarry at Milfield since the 1960s, and this quarry is still in operation. The Lanton Quarry is set to continue working after Woodbridge Farm Quarry has closed, and in 2000 had estimated reserves of 1.8 million tonnes. Further to the south Branton and Low Hedgeley quarries have also produced significant yields of sand and gravel, though their operations are winding down, with the Branton site now having been largely restored to artificial lakes. At Thrunton the brick clay quarry continues to extract laminated glacial lake clay.

Traditionally, peat has been drained and cut for fuel in the district, but in recent years it has been extracted on a commercial basis and sold for horticultural use. Peat is currently extracted at two sites in Northumberland on the north-eastern margin of the district, Kemping Moss [NT 997 376] near Lowick and Greymare Farm [NU 07365 35998] near Belford.

Extraction at a third site, Bell Crag Flow, within the National Park, has ceased and the site is being restored by blocking drainage ditches and removing self-seeded conifers. There is now a presumption against opening new peat extraction sites as the peat habitats are now recognised as being important for biodiversity, carbon storage and water retention.

Even though the Tyne valley has extensive sand and gravel deposits, it is clear from the scale of historical extraction that they have limited future potential. The deposits occur in narrow units (less than 500 metres lateral width), and are less than 10 metres thick in most places. Other UK sources of such material are more economically viable. By far the largest potential future source of sand and gravel resources remains the Milfield Fan. However the extent to which it has already been excavated may prevent further development due to fears over the complete loss of the feature. The Milfield Plain may prove to support thick sequences of glaciolacustrine (related to the glacial lake) muds and sands, of use to brick clay and sand resource industries. However, this area of high quality land is currently extensively farmed, and is beneath the eastern flank of The Cheviot, close to the National Park borders, and thus any proposed extraction may meet with local difficulties. The proximity of sites to the National Park renders the area sensitive to further large-scale resource extraction and stringent planning and environmental conditions would have to be met in any proposals for future working of the sand and gravel deposits.

Conservation issues

The Quaternary deposits of the district are largely robust, and current farming and resource extraction practices have had little effect upon their overall distribution and stability. However future development of the Tyne valley floodplain and possible sand and gravel extraction could remove possible key sites and sections with the potential to lead to greater understanding of ice- sheet behaviour in the region. The glaciofluvial and river terrace sequences of the Tyne, around Haltwhistle and Hexham give clues to the late glacial and Holocene drainage history of the area, which is yet to be reconstructed. Future development of the Milfield Plain area with associated sand, gravel and brick clay extraction may begin to remove possible key sites and sections that may lead to greater understanding of ice-sheet behaviour in the region.

Wider significance

The Quaternary landscape of the district is one that has increasing significance for the earth science community. Understanding of ice-sheet behaviour is evolving rapidly. Our interpretation of deglaciated landscapes is now heavily influenced by modern polar studies, and this has led to our increased knowledge of the behaviour of the British ice-sheet. Using this increasingly complex model, inferences can now be made about the effects of past climate change on this dynamic ice-sheet, and also on the effects of sea level rise and subtle variations in internal glacial processes. The Hadrian's Wall country exhibits the classic landscape of a palaeo-ice-stream track, now recognised as being highly significant in the regulation of the mass balance of ice-sheet systems.

The Cheviot fringe area, with its extensive lake, fan and glaciofluvial deposits may provide significant opportunities for earth scientists to add vital pieces of information to our fragmentary record of the period during and immediately after the decline of the last great ice-sheet in Britain. The lake bed of palaeo-Lake Milfield is a potentially vital source of environmental data relating to the collapse and disappearance of the last great ice-sheet in the region, some 15 000 years ago. Lake sediments may contain records as diverse as pollen, diatoms, volcanic ashes or tephras and beetle and plant remains that may give detailed and high resolution information regarding this critical period in recent Earth history. There are also gaps in our knowledge about the vegetational history and human impact upon it. Particular omissions in the record exist in the north and western parts of Northumberland. Examination of Quaternary deposits, particularly peat habitats, could yield important information. This links to the NNPA archaeological research agenda and should build on previous palaeoenvironmental research in the region.

The Quaternary landscape of the Cheviot massif appears to be very unusual in Britain. It is an upland area that has undergone glaciation during the Quaternary, most recently during the Devensian. However it still preserves features relating to the action of longer term, less physically dynamic processes, i.e. tors and deeply weathered bedrock. The preservation of these normally sensitive features in a landscape that has undergone glaciation is extremely unusual. Understanding why this occurs is a key challenge for future scientists, as it appears to stand contrary to accepted wisdom concerning glacial erosion in upland areas, namely that glaciers perform large amounts of geomorphological work throughout a glacial cycle. If the landscape of the Cheviot massif is inherited from an earlier period of Earth's history, then this assumption must be challenged.

Figures

(Figure 40) Limits of the late Devensian Glaciation of Britain (after Boulton, 1977 and Carr et al., 2006).

(Figure 41) Locations of areas described in this section (Hillshade image derived from NEXTMap © Intermap Technologies Inc.).

(Figure 42) The streamlined bedrock of the Whin Sill (arrows indicate location of subglacial meltwater channels) (Hillshade image derived from NEXTMap® © Intermap Technologies Inc.).

(Figure 43) Sycamore Gap: a possible subglacial meltwater channel, cutting through the Whin Sill © Graeme Peacock www.graeme-peacock.com.

(Figure 44) Streamlined topography around Coldstream. Modification of the landscape due to high velocity ice at the base of the Tweed Ice Stream. Dashed lines indicate crests of mega-scale glacial lineations (Hillshade image derived from NEXTMap® © Intermap Technologies Inc.).

(Figure 45) Section at Roddam showing medium (fine dashed line) and coarser (thick dashed line) bedded sands punctuated with channel system activation (gravels).

(Figure 46) Reconstruction of palaeo-Lake Milfield, with area of extant glaciofluvial fan at Milfield. Fan apex is at 55 metres OD, therefore the lake shoreline has been drawn at 60 metres. Water levels will have fluctuated throughout the life of the lake (Hillshade image derived from NEXTMap® © Intermap Technologies Inc.).

(Figure 47) View from south of Doddington, looking west. Simplified reconstruction of palaeo-Lake Milfield, showing probable lake extent (blue) and location of fan (brown).

(Figure 48) Ice-wedge cast in section at Woodbridge Farm Quarry. Ice wedges form under intensely cold conditions, as water freezes in vertical cracks in soils, and repeated freeze-thaw cycles widen the crack, into which larger debris is sorted by the freezing and thawing, causing swelling and shrinking of the soil.

(Figure 49) Ripple cross-bedded sands in section at Woodbridge Farm Quarry.

(Figure 50) Cobble gravels in section of River Breamish at Branton. Imbrication, or stacking of the clasts is clear, as is the less coarse alluvial deposit in the upper part of the section, relating to lower energy flow regimes. These most likely occurred long after the coarse material was deposited by glacial meltwater flow. Subsequent late Holocene activity has seen downcutting through the older deposits.

(Figure 51) Panoramic view from near Glanton Pyke, looking southwards toward Whittingham. The ridges marked ‘a’ and ‘b’, are clearly visible on the valley floor and were probably formed by glaciofluvial outwash processes.

(Figure 52) View from Pondicherry near Rothbury, looking southwards over the Coquet floodplain. Recent Holocene fluvial activity has ensured the floodplain has remained active. Low relief, linear ridges of glaciofluvial deposits are visible on the southern side of Coquetdale.

(Figure 53) Proposed flow regime in the Cheviot region (after Clapperton, 1971), with cold- and warm-based ice shown by blue/pink colouration of arrowed flowlines. Position of mega-scale glacial lineations shown in yellow (Clark et al., 2005). After Everest et al., 2006.

(Figure 54) Distribution of in situ weathered bedrock and tor features in the Cheviot massif (Hillshade image derived from NEXTMap® © Intermap Technologies Inc.).

(Figure 55) The tor developed in the Cheviot Granite at Great Standrop. The residual mass of rock appears as a pile of rock slabsThe tor developed in the Cheviot Granite at Great Standrop. The residual mass of rock appears as a pile of rock slabs.

(Figure 56) Section in deeply weathered bedrock near Hownam; clearly showing the preservation of primary igneous texture.

(Figure 57) A meltwater channel draining north-eastward from Ewartly Shank [NT 9644 1470].

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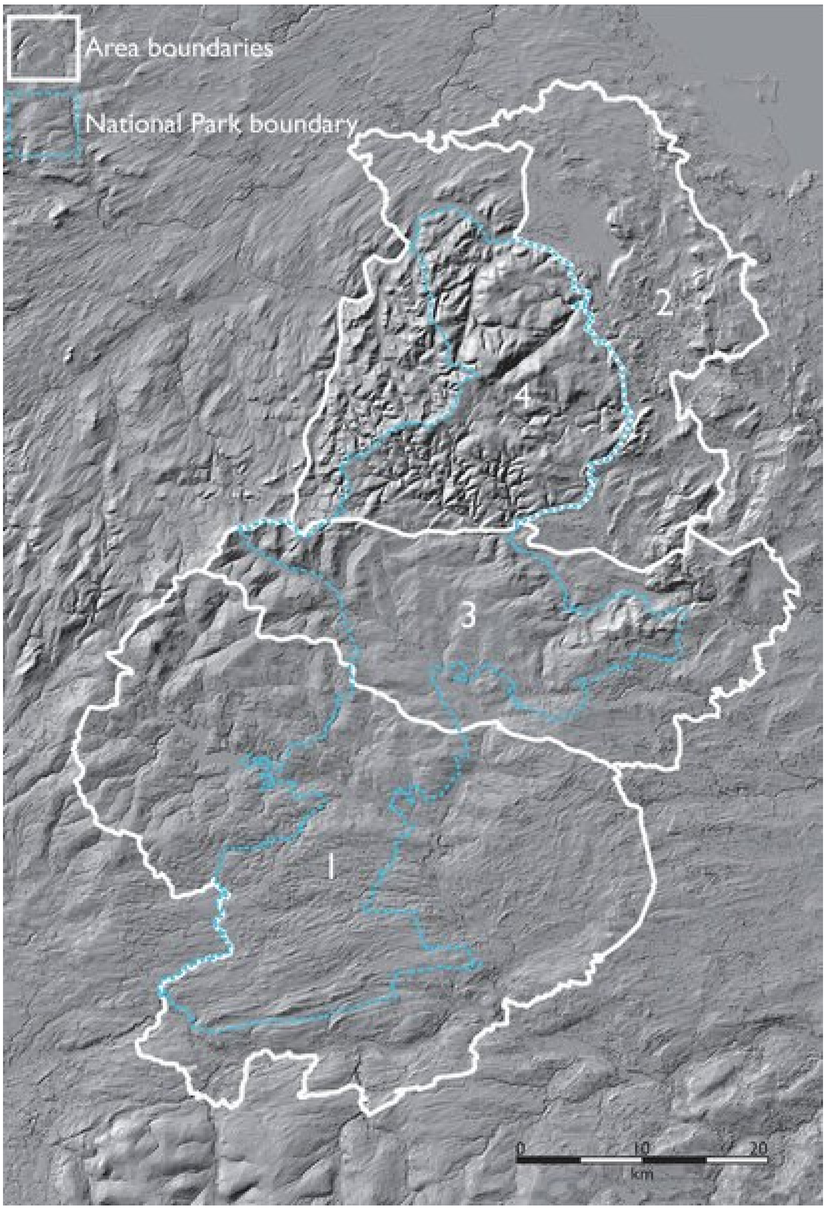

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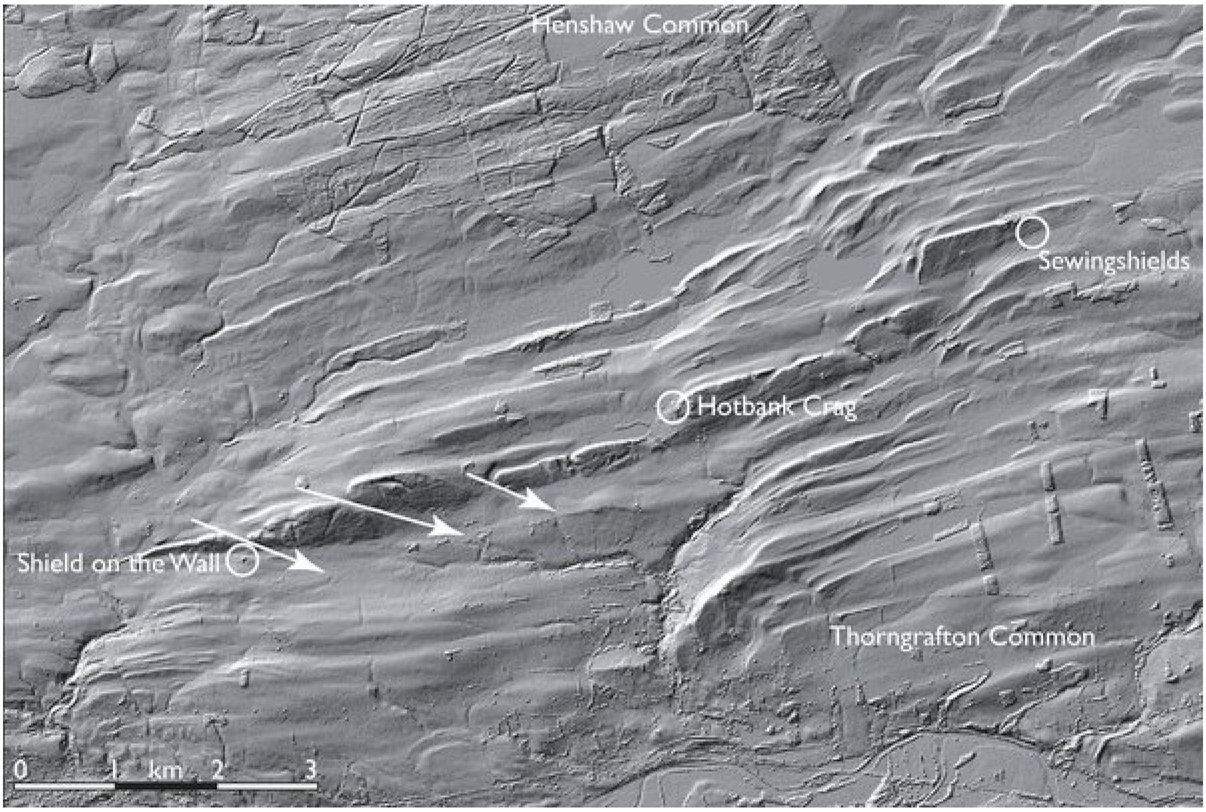

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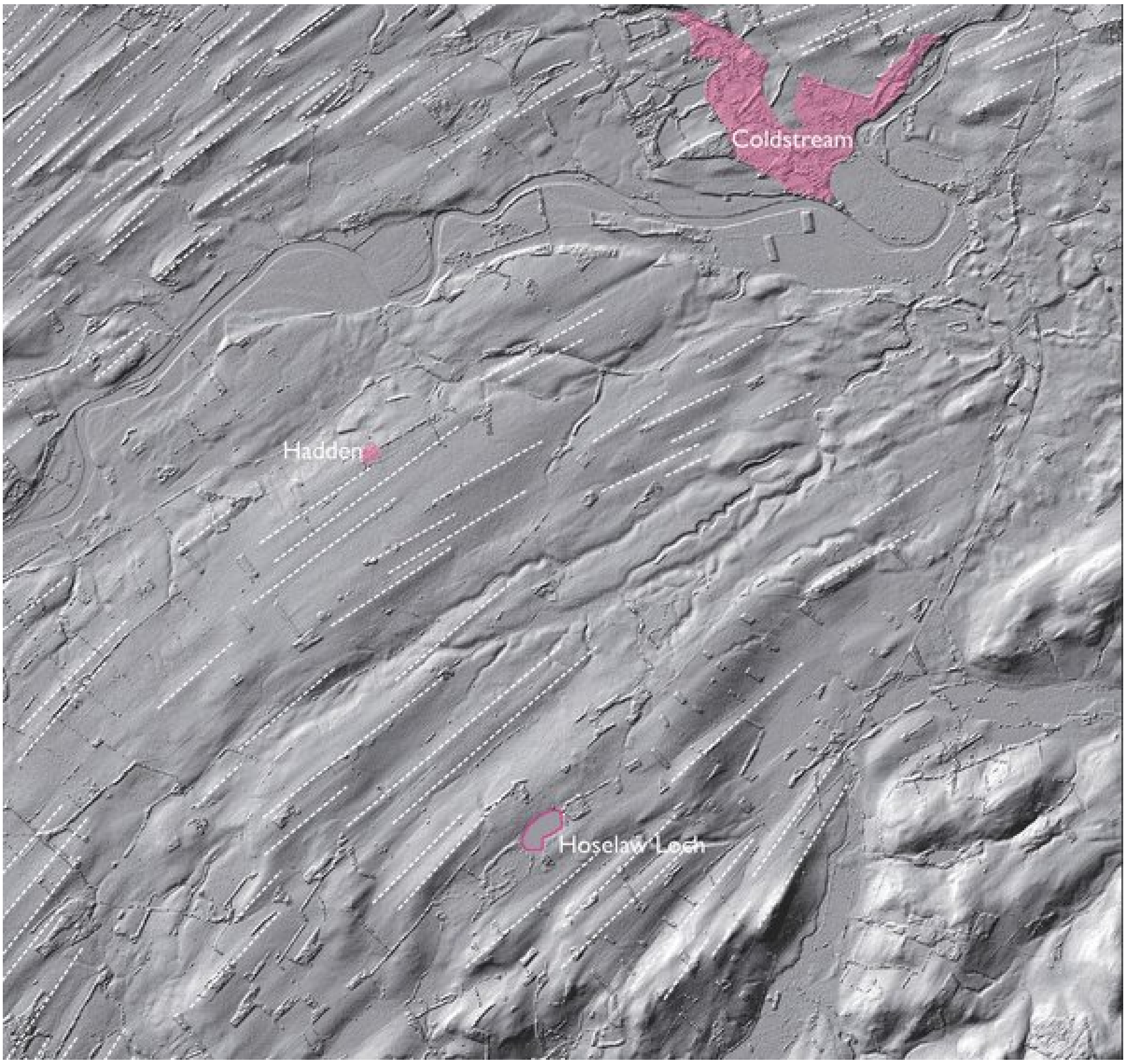

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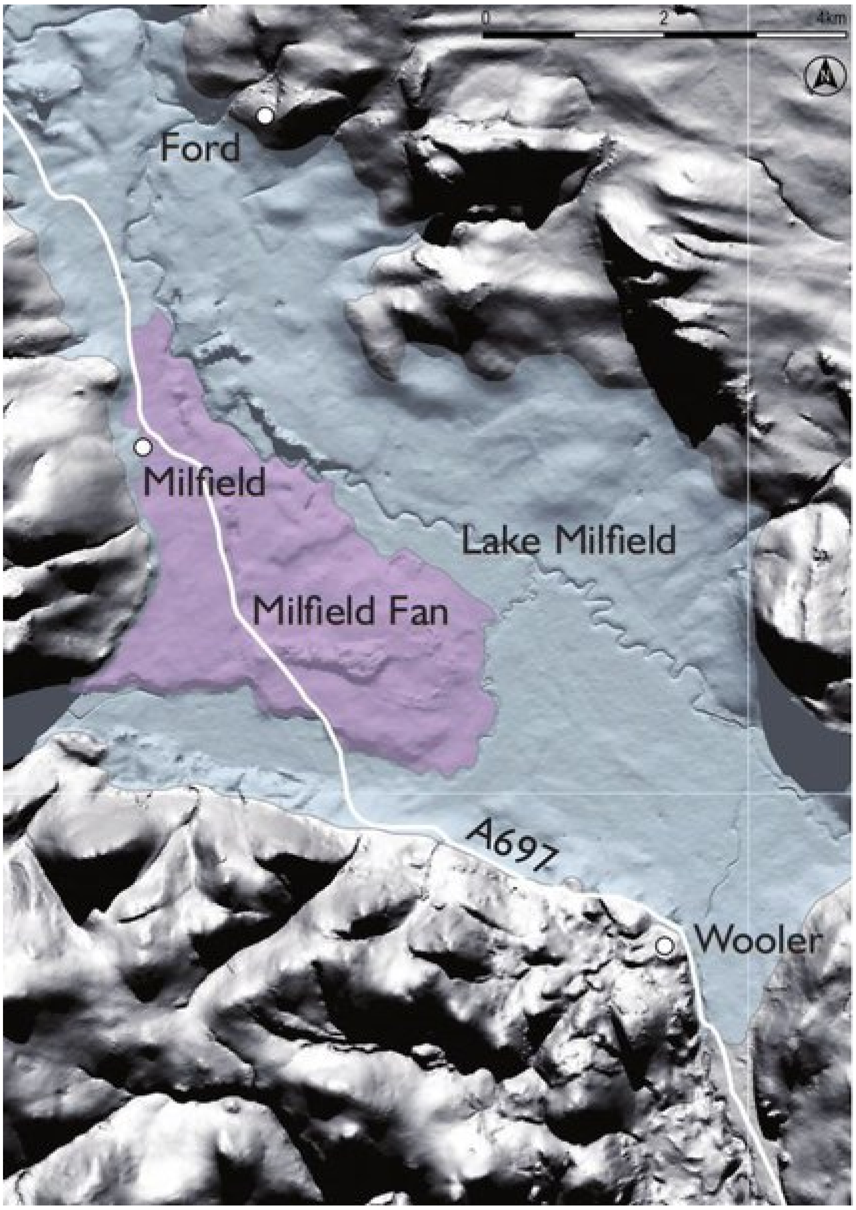

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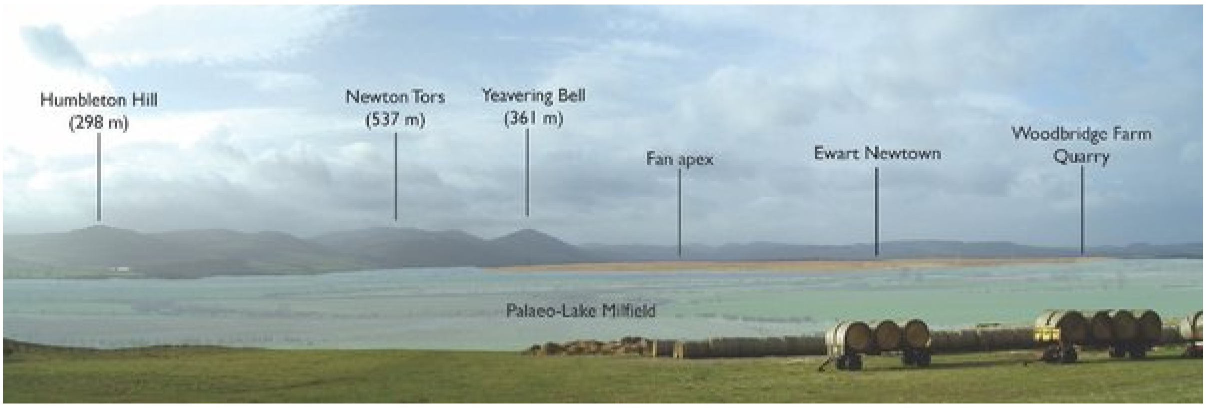

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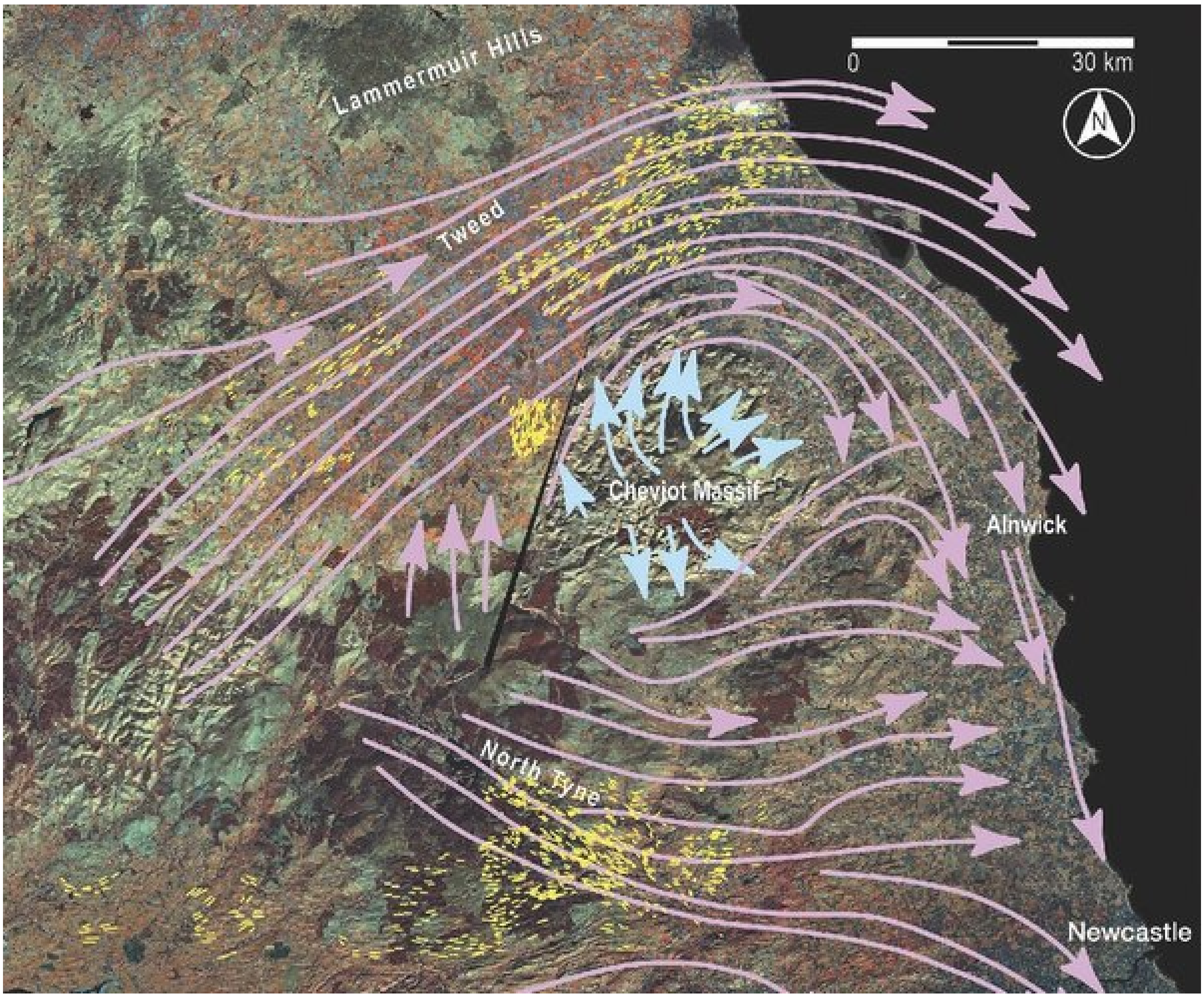

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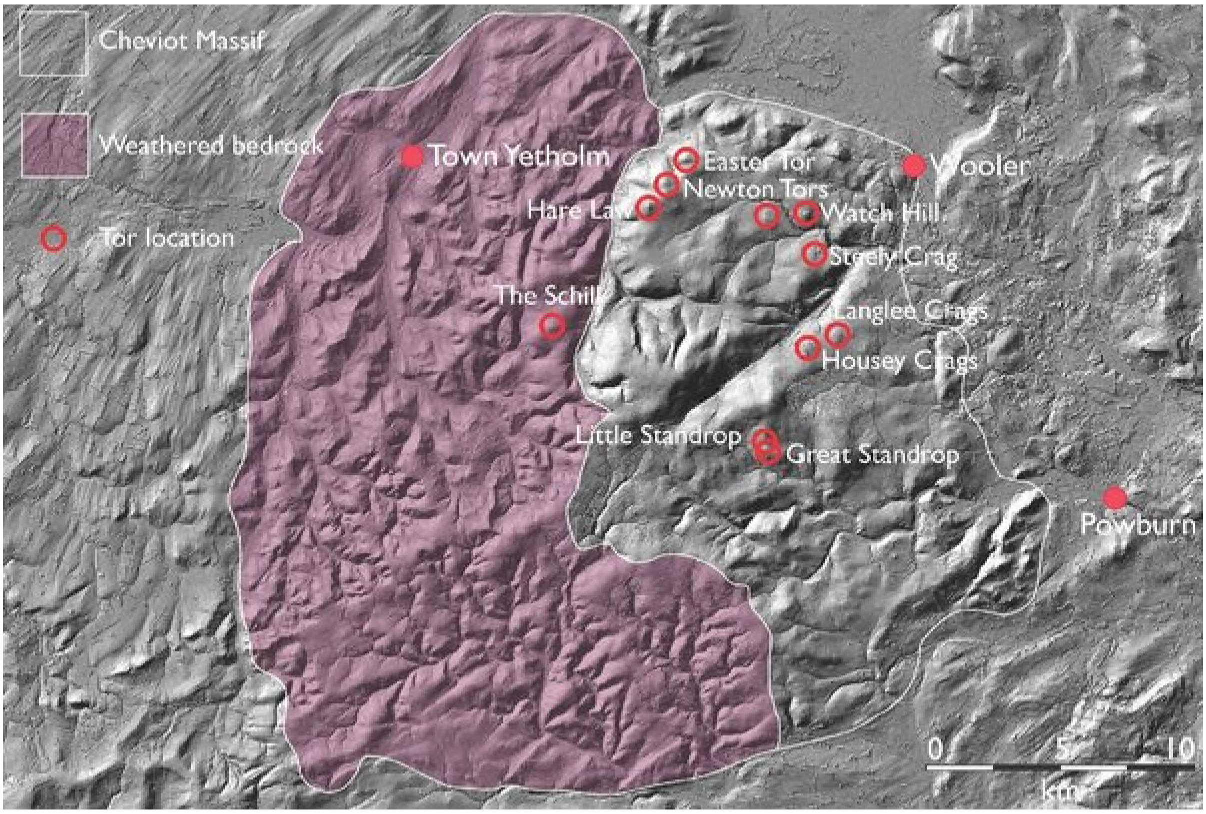

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