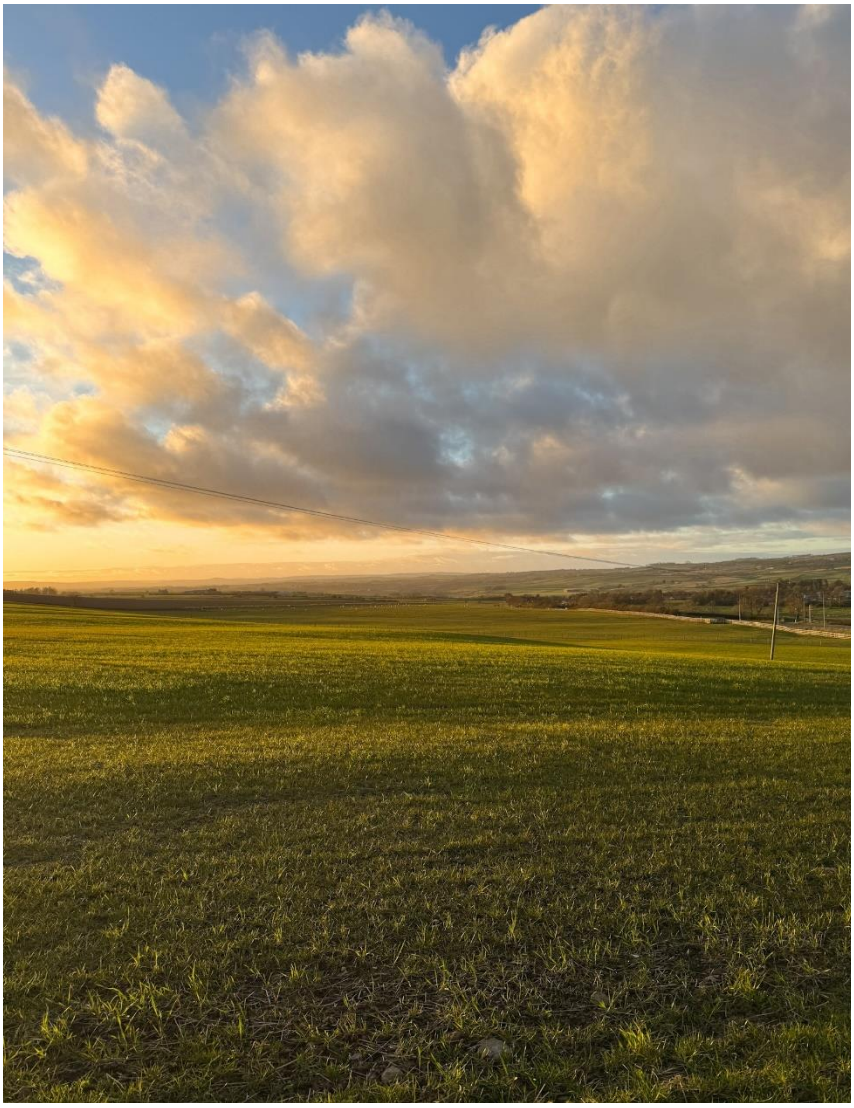
Superficial geology of the Berwick-Spittal area, Northumberland

National Geoscience programme

Open report OR/26/033



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Superficial geology of the Berwick–Spittal area, Northumberland

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Editor

J M Hannaford

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Landscape near South Ord, south of Berwick-upon-Tweed. British Geological Survey image P1081785 © UKRI 2025.

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Foreword

This report was prepared by the British Geological Survey to accompany revised 1:10 000-scale digital superficial deposit and artificial ground maps for an area in Northumberland covering Spittal and part of Berwick-upon-Tweed, south of the River Tweed.

The fieldwork component of the mapping was undertaken in March 2025 and funded by Project Groundwater Northumbria, a Defra-funded Flood and Coastal Resilience Innovation Programme project led by Gateshead Council. The map compilation was completed in March 2026 was funded by the Environment Agency.

Acknowledgements

Thanks to Project Groundwater Northumbria and the Environment Agency for funding the work and contributing valuable information to support the geological investigations. Diane Steele is particularly thanked for supporting the map compilation.

The work was enabled through the cooperation of local landowners in providing land access and important local knowledge about the ground conditions and the history of the area and its landscape.

Sam Roberson is thanked for useful discussions during the map compilation stage.

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Revision mapping of superficial deposits and artificial ground has been completed for a 24 km^2 area of Northumberland, including the area of Berwick-upon-Tweed south of the River Tweed and the coastal village of Spittal. The map compilation was funded by the Environment Agency in 2026, with fieldwork conducted in 2025 under commission as part of Project Groundwater Northumbria (PGN), a Defra-funded Flood and Coastal Resilience Innovation Programme project led by Gateshead Council.

Prior to this survey, the area was last surveyed in the 1920s. The revised mapping is based on new field observations combined with analysis of high-resolution digital terrain data, borehole records and aerial photographs. The distribution of superficial deposits has been revised, reflecting a stronger link between the form of the topography and extent of glacial till and overlying proglacial deposits. The proglacial deposits include a previously unmapped moraine and several areas of glaciolacustrine deposits.

The moraine comprises an undulating sandy ridge approximately 1.5 km in length, which likely reflects a former ice margin position during the westwards retreat of the Tweed ice stream at the close of the late Devensian glaciation (approx. 18 000 to 14 000 years ago). Glaciolacustrine deposits have been recognised in the depression formed to the west side of this moraine and in hollows within the undulating bedrock and till surface within the remainder of the area. These were likely filled by short-lived lakes soon after deglaciation and exhibit variable types of fill, including laminated silty clay, clayey sand and fine sand.

In the southern two-thirds of the mapped area, the till and associated proglacial deposits are relatively thin (less than 3 m) and patchy, with bedrock exposed at or near surface over approximately 40 per cent of the area. The bedrock is commonly highly weathered.

In the northern third of the area, underlying much of Berwick-upon-Tweed, the till cover is more consistent with thicker deposits (over 3 m) present. The till locally overlies glaciofluvial deposits that show evidence of weak deformation, indicating that a minor glacial re-advance may have occurred during the recession. Along the River Tweed, which forms the northern boundary of the area, a series of river terrace and estuarine deposits are developed. These, along with the coastal deposits underlying Spittal, show evidence of raised deposits at about 4 to 6 m above ordnance datum. This likely reflects deposits formed during a period of higher relative sea level soon after deglaciation.

The revised mapping, including both the distribution of deposits and their lithologies, has implications for the understanding of ground conditions and groundwater systems in the area. Further targeted work to characterise the engineering and hydrogeological properties of the deposits would be valuable. These applied applications would also benefit from improved understanding of the thickness of the deposits, which is relatively poorly known due to a lack of borehole coverage and few observable sections in the field. Use of geophysical surveying approaches may help to provide additional thickness constraint for the area.

1 Introduction

1.1 BACKGROUND

Revision mapping of the superficial geology of the Spittal area was undertaken in 2025 to 2026, to provide updated digital superficial geology maps for a region overlying the Fell Sandstone Formation aquifer. The area of interest extends from the River Tweed in the north to beyond Scremerston Hill in the south and covers approximately 24 km^2 (Figure 1). It was last surveyed in the 1920s and currently published superficial geology mapping is based on this legacy data.

Recent work to understand recharge potential to the underlying Fell Sandstone aquifer in the Berwick-upon-Tweed area has highlighted differences between observations of superficial deposits from ground investigation boreholes and the mapped distributions of deposits. A re-survey of the superficial deposits in the area was commissioned to provide updated mapping informed by available borehole data, high-resolution topographical data (including LiDAR-based terrain models) and new field observations informed by modern understanding of glacial processes in ice-stream dominated terrains.

Fieldwork to resurvey the superficial deposits of the Spittal area was undertaken in March 2025 under contract with Project Groundwater Northumbria (PGN), a Defra-funded Flood and Coastal Resilience Innovation Programme project led by Gateshead Council. The final map compilation was undertaken in March 2026 under commission from the Environment Agency (EA).

The following report provides a summary of findings from the re-survey and accompanies the new digital superficial geology and artificial ground maps.

1.2 BEDROCK GEOLOGY

The bedrock provides an important constraint on the distribution and nature of the superficial deposits within the Spittal area. The strata underlying the area have been deformed by folding into an asymmetrical fold known as the Berwick Monocline. The monocline axis occurs close to the coast and trends north-north-west, resulting in general dips for inland strata of 10 to 20° degrees towards the south-east and steep (50 to 55°), eastward-dipping strata along the coast.

The oldest unit, the Ballagan Formation, is exposed in the north of the area, around Tweedmouth. It comprises interbedded mudstone and sandstone with thin cementstones and passes upwards into the Fell Sandstone Formation. The Fell Sandstone Formation comprises a sequence of medium to coarse-grained sandstone beds separated by thin mudstone units. It is overlain to the south and east by the Scremerston Coal Member of the Tyne Limestone Formation. The Scremerston Coal Member comprises mudstone and sandstone with numerous coal seams that were formerly worked at surface and underground within the area.

Limestones within the overlying strata of the Tyne Limestone Formation and Alston Formation were also worked at surface in the region, as indicated by numerous disused quarries, such as just south of the mapped area near Oxford Farm Shop [400784, 646740] and minor workings to the south-west of Scremerston Town Farm [401374, 647629]. Superficial deposits may have been locally removed in areas of worked ground or infilled ground that are associated with former collieries and surface workings.

The lithological variation in the bedrock is a strong control on the lithologies of the overlying superficial deposits, particularly till. Glacial erosion of sandstone is likely to result in sandier till deposits, with finer-grained silty, clayey till derived from erosion of the mudstone units.

1.3 TOPOGRAPHY

The highest ground, at 108 m above ordnance datum (aod), lies in the west of the area at Billylaw [397986, 649518]. This summit forms the crest of a bedrock ridge bounded to the south by the Allerdean Burn and to the north by the River Tweed. The ridge rises from lower ground along the Tweed valley to the north-west via a series of steep crags, with intervening dip slopes formed by the alternation of resistant sandstone and weaker mudstones of the Fell Sandstone Formation.

Billylaw itself is underlain by a sandstone unit within the lower part of the Scremerston Coal Member. Further outcrops of this sandstone form a high point at approximately 90 m elevation to the north-east at Springhill [400030, 650615]. The land surface falls towards the south-east and east, with 20 to 30 m-high cliffs exposing bedrock and superficial deposits along the North Sea coastline. These cliffs transition northwards into a steep bank just to the south of Spittal.

1.4 QUATERNARY GEOLOGICAL BACKGROUND

Much of the British Isles, including north-east England and Scotland, was covered by the British–Irish ice sheet during the last glaciation (for example, Clark et al., 2022). The multitude of processes associated with ice sheet growth and retreat resulted in a complex assemblage of glacial sediments and landforms across the previously glaciated area.

Regionally, the glacial geological record indicates several phases of ice flow governed by the respective ice sheet configuration at different points in time (Hughes et al., 2014; Clark et al., 2022). The ice flow history in the area around Spittal can be broadly summarised into an early, north-to-south directed flow and a later, west-to-east directed flow. The north-to-south directed flow was governed by the activity of the North Sea ice stream, which is indicated by landforms to the south of the study area between the Cheviot Hills and the modern North Sea coast (Hughes et al., 2014). As the ice sheet retreated and thinned during deglaciation, the topographically constrained Tweed ice stream became active, which resulted in ice flowing from west to east across the study area (Everest et al., 2005; Hughes et al., 2014). The region was ice-free from approximately 17 000 BCE (Clark et al., 2022).

The geological record of the British–Irish ice sheet comprises a complex amalgamation of deposits directly or indirectly related to glacial processes. Till is the primary glacial sediment, produced predominantly by subglacial erosion and deformation processes at the ice bed interface (for example, Evans et al., 2006 and references therein). The extent of this deposit can, in principle, range from small pockets of tens to hundreds of metres wide to laterally continuous sheets expanding across wide areas (tens to hundreds of square kilometres).

Secondary glacial sediments include deposits formed in glacial meltwater streams and lakes. Glacial meltwater streams can erode and transport significant amounts of material, resulting in both erosional (for example, meltwater channels) and depositional features (for example, glaciofluvial deposits), with the latter typically consisting of sands and gravels. Glacial lakes can develop where meltwater gathers in depressions constrained by the topography, the palaeo-ice margin or a combination of both. Lakes are typically low-energy environments where finer deposits (silts and clays) are deposited; however, depending on the sediment source, lake geometry and the proximity to the inlets, the depositional record can be variable.

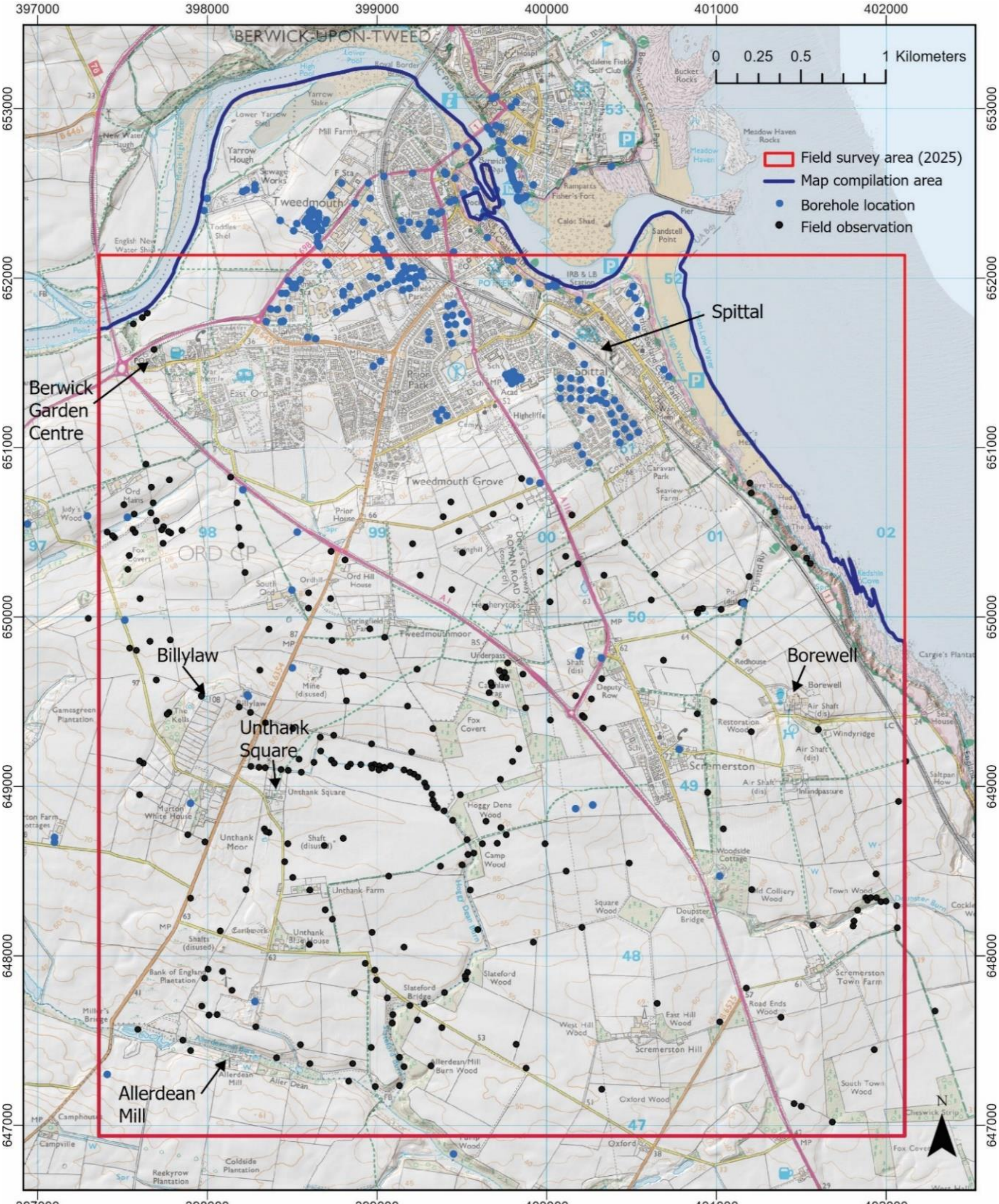


Figure 1 The Berwick-upon-Tweed–Spittal study area (blue outline) showing key locations, boreholes and field observation locations. The extent of the March 2025 field survey is shown by the red box. Contains OS data © Crown copyright and database rights 2026 OS AC0000824781. LiDAR Composite Digital Terrain Model 1m © Environment Agency copyright and/or database rights 2022.

2 Superficial geology

2.1 MAPPING METHODOLOGY

A seven-day walk-over field survey was undertaken in March 2025 to capture observations of the geological materials and landforms visible within the area. The field survey covered a 25 km^2 area from Spittal in the northeast [400500, 651800] to Allerdean Mill in the south west [398000, 647300] (Figure 1). Land access was provided by local landowners on request.

The northern part of the area, up to the River Tweed and including Tweedmouth Industrial Estate, was not surveyed in the field (Figure 1). Revised geological linework for this area has been compiled from borehole records, historic mapping, digital terrain models (DTMs) and aerial photographs.

Observations from natural exposures and hand-augering were recorded using the BGS Geological Data Capture System, which comprises a QGIS system with customised data-capture tools and synchronisation functions using MerginMaps. Modern Ordnance Survey (OS) maps, historic fieldslips, LiDAR-derived DTMs and borehole records were consulted in the field to aid the mapping and identification of landforms.

Information was captured on the lithology of deposits and the exposed thicknesses where available. Based on standard BGS practice, the mappable thickness of superficial deposits is approximately 1 m — deposits are mapped where they generally exceed 1 m thickness — and cover areas larger than about 20 m^2.

However, despite the generally thin nature of the superficial deposits within the area, the base was only observed in coastal exposures and inland stream and ditch sections. In auger holes, depth to bedrock was inferred in most cases where a hard base was encountered, although it is possible that hard bases may relate to the presence of boulders in till, meaning the superficial thickness could be locally underestimated. Conversely, auger penetrations of loose sand, clayey sand and coal brash in some locations have been interpreted as weathered bedrock based on assessments of natural exposures and landforms in the vicinity of the location.

Where other constraints were unavailable, the extents of deposits of superficial materials were estimated based on the landform features and smoothing of topography, with areas of bedrock exposure typically associated with rougher topography due to the presence of metre-scale undulations visible in the field and in the DTM. Smoother areas of topography are therefore likely to reflect the presence of superficial deposits greater than 1 m thick. These interpretations are validated by auger and borehole evidence wherever possible.

2.2 SUMMARY OF GEOLOGICAL UNITS

Approximately 63 per cent of the study area has been mapped as being covered by superficial sediments (Figure 1). The mapped units range from Pleistocene sediments formed predominantly by glacial processes to more recent fluvial, estuarine and coastal marine deposits (Table 1). The remaining 37 per cent of the area has bedrock at or near surface (superficial deposits less than 1 m thick).

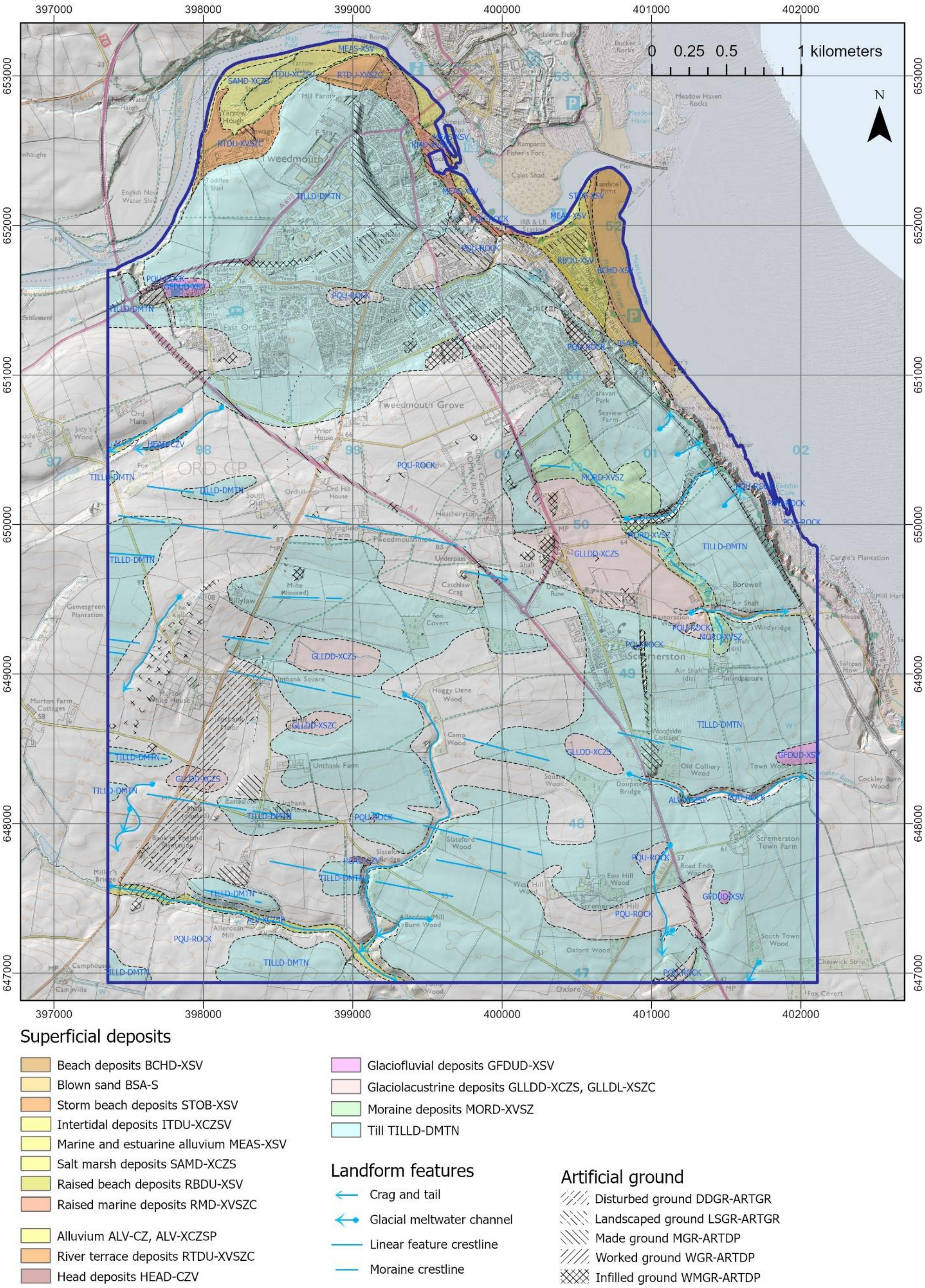


Figure 2 Revised superficial geology in the Spittal area overlain on the LiDAR-derived DTM. Contains OS data © Crown copyright and database rights 2026 OS AC0000824781. LiDAR Composite Digital Terrain Model 1m © Environment Agency copyright and/or database rights 2022.

Table 1 Types of superficial deposit mapped in the Spittal area.

Deposit	LEX code	Description	Distribution
Blown sand	BSA	Well sorted, fine to medium-grained sand typically deposited as dunes in coastal environments.	Thin deposit located to the south of Spittal, between Spittal beach and steep, rising ground to the west.
Beach	BCHD	Sand with some gravel deposited by marine processes between the low and high-water lines.	Extends for approximately 800 m along Spittal beach. Thins and overlies bedrock to the south.
Storm beach	STOB	Sand and gravel deposited as a rounded ridge at the back edge of the beach under high wave energy conditions.	A spit extending into the Tweed estuary north of Spittal.
Raised beach	RBDU	Interbedded gravel, sand and gravel, and sand, forming a raised beach platform above the modern high-water line.	Forms a flat spur at 4 to 6 m aod underlying the town of Spittal at the mouth of the Tweed estuary.
Intertidal deposits	ITDU	Likely to comprise clay and slit with sand and some gravel.	Mapped within an inlet in the Tweed estuary at Yarrow, where it is flanked by salt marsh.
Marine, estuarine and beach (sand and gravel)	MEAS	Likely to comprise sand and gravel deposits formed in higher-energy estuarine settings, where processes are locally influenced by tidal and marine processes.	Deposits along the flanks of the Tweed estuary in Berwick.
Salt marsh deposits	SAMD	Fringing deposits likely comprising fine clay and silt with organic material.	Forms a fringing area at the edge of intertidal mud flats within the inner Tweed estuary.
Raised marine and coastal zone deposits	RMD	Deposit at 4 to 6 m aod within the Tweed estuary, likely to comprise mixed clay, silt, sand and gravel.	Fringing deposit along the southern margin of the Tweed estuary.
Head	HEAD	Deposit formed by downslope movement of material under a range of slope processes. Variable lithology depending on the nature of the source material, but typically containing a mixture of clay, silt and gravel.	Minor channel-floor deposits mapped in the base of two drainage channels.
River terrace deposits	RTDU	Deposits of sand and gravel, possibly with some silt and clay, forming raised, flat, terrace features above the level of active river flood plains.	Areas of river terrace occur along the southern side of the Tweed at levels of 4 to 6 and 8 to 10 m aod.
Alluvium	ALV	Variable deposits with higher-energy, channel deposits comprising sand or sand and gravel, and lower-energy, over-bank deposits predominantly finer-grained sand, silt and clay with organic material and peat layers.	Present along the Tweed near the confluence of the Whiteadder Water, along the Allerdean Mill Burn and locally associated with minor streams.

Deposit	LEX code	Description	Distribution
Glaciolacustrine	GLLDD	Variable deposits including laminated clay and slit, sandy, silty clay and clayey sand formed as infills in shallow hollows in the till surface. Likely deposited during ponding of water.	Present in hollows overlying till and bedrock throughout the southern half of the mapping area.
Glaciofluvial	GFDUD	Sand and sand and gravel deposited by glacial meltwater streams.	Present as isolated mounds overlying till. Deposits are locally overridden by till in the north-west of the area.
Moraine	MORD	Sandy, gravelly silt deposited at a former ice margin.	Forms an undulating ridge extending for over 1 km to the north of Borewell.
Till	TILLD	Variable deposit formed by subglacial processes. Comprising firm to stiff, reddish or orange-brown sandy, silty, gravelly clay in some areas, or medium to pale blue-grey silty clay mottled with pockets of orange silty sand. These variations may reflect deposits derived by glacial erosion of sandstone or mudstone/coal-bearing bedrock, respectively.	Forms a thin, patchy deposit overlying bedrock throughout the area. Typically, less than 2 to 3 m thick where present, with thicker deposits formed in elongate drumlins and on the lee side of rock ridges. More continuous and thicker (3 to 5 m) deposits are found in the north of the area underlying Berwick, and on hill slopes in the east of the area.

2.3 ROCKHEAD

Rockhead at outcrop and at subcrop appears to be weathered throughout much of the area. Borehole records commonly refer to 'rotten' bedrock or 'soft' sandstone or shale within the first 1 to 3 m of rockhead. Descriptions of sand or sand with sandstone fragments at the base of superficial deposit successions in some borehole records are also likely to reflect weathered bedrock.

In the field, weathered bedrock of the Scremerston Coal Member was exposed in a ditch section to the east of Unthank Square [399356, 648874]. To the west, bedrock is overlain by till, but the till thins and the eastern end of the ditch exposure comprises an approximately 3 m section of sand, clayey sand and fractured blocks of sandstone exposed beneath the topsoil (Figure 3A). Areas underlain by weathered bedrock were also characterised by variable soil colour, reflecting the presence of white, buff and yellow sandstones within the Scremerston Coal Formation, as well as dark-grey mudstone and black coal. Deep ploughing of a field south of Murton White House [397905, 648698] showed soil containing abundant sand with sandstone fragments of variable colour, indicating weathered rock is present just below the topsoil (Figure 3B).

Extensive areas of surface coal workings occur along the outcrop of the lower part of the Scremerston Coal Member. These are associated with bell pits, small quarries and areas of disturbed ground, particularly to the north and west of Murton White House [397735, 649115], and between Unthank Square [398340, 649049] and Allerdean Mill [398125, 647445].

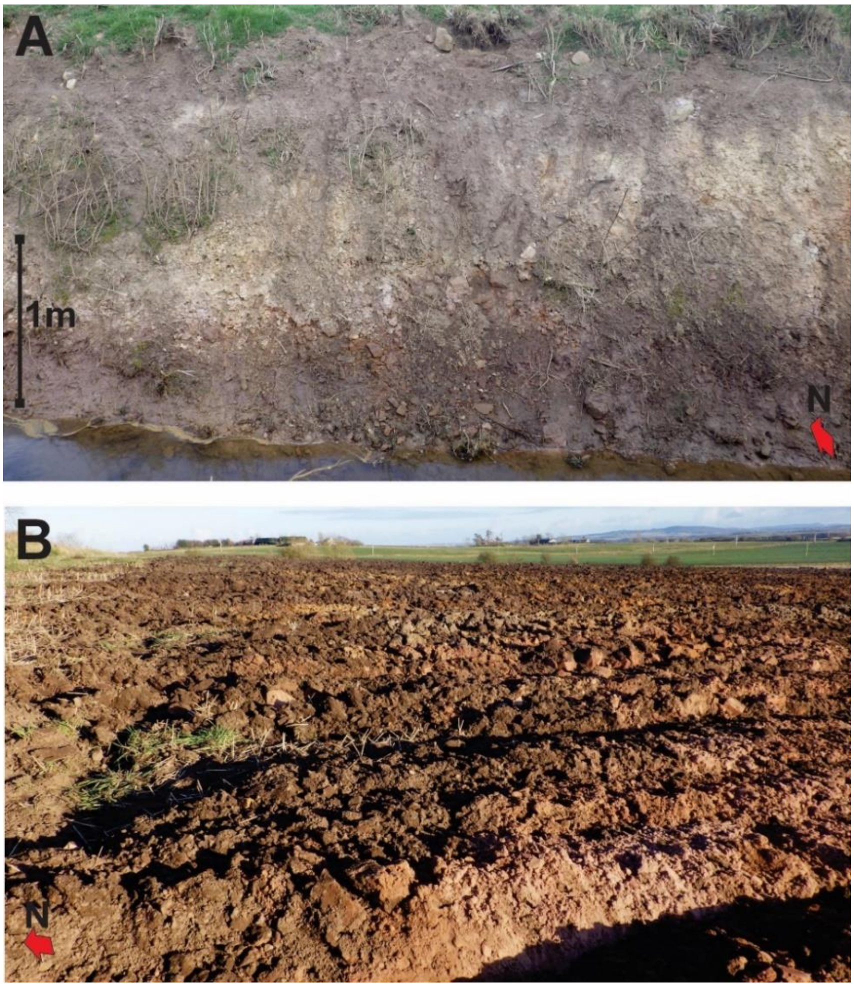


Figure 3 Field images showing weathered bedrock at surface. A: weathered bedrock about 3 m thick below a 0.5 m-thick soil layer in ditch section east of Unthank Square [399356, 648874], viewed towards the north-east. B: sand from weathered bedrock below the soil layer turned in ploughing south of Murton White House [397905, 648698], viewed towards the east. BGS images P1081775 and P1081782 © UKRI 2025.

2.4 GLACIAL DEPOSITS

Approximately 57 per cent of the study area is covered by sediments related to glacial processes. The subaerially most extensive glacial sediment mapped across the study area is till. This is complemented by glaciolacustrine deposits of variable extents and minor amounts of glaciofluvial and morainic deposits. The general associations of these units in the south of the study area are shown in Figure 4.

Till will typically form the oldest deposit in the area as it requires some degree of ice flow activity to form — ice must have covered the area at the time of its formation. Morainic deposits are mostly formed at or near the ice-sheet margin and, in this study, are interpreted to record a former ice-margin position. Glaciofluvial and glaciolacustrine deposits can be formed in direct contact with the ice as well as some distance away from the ice margin, that is, close to the time of deglaciation of the area. These deposits, referred to as 'proglacial', are typically younger and are therefore often superimposed on any existing till deposits. In some cases, glaciofluvial, glaciolacustrine or morainic deposits were overridden by ice again, which deformed the existing substrate and formed an additional till layer on top. Evidence for ice overriding of proglacial deposits was observed in sections at a temporary excavation near Berwick Garden Centre [397725, 651541] in 2022 to 2023, discussed further in Section 2.4.4.

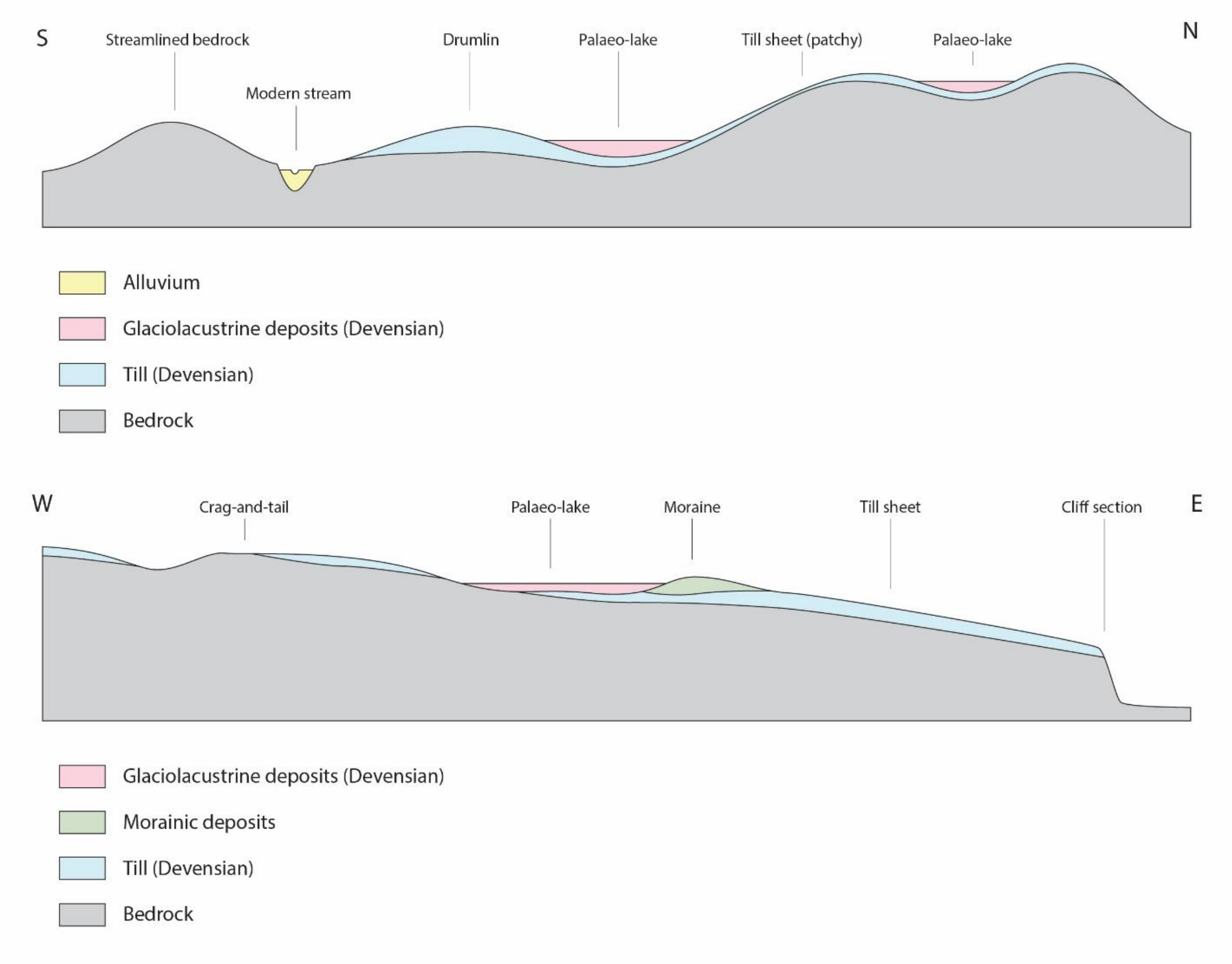


Figure 4 Schematic cross-sections for the area south of Spittal showing the general form and relationship of glacial deposits. BGS © UKRI 2026.

2.4.1 Till

Approximately 52 per cent of the study area is covered by till. In general, the northern and eastern parts of the area have more continuous till cover whereas, in the west and south-west, till cover is more limited and bedrock occurs at or near surface. Where present, till deposits form a generally thin and patchy mantle over the underlying weathered bedrock. The thickest deposits, which may locally exceed 4 m, occur in the low ground in the north of the area between Spittal and the River Tweed. Another area of more continuous till deposits can be found in the east of the area above the coastal cliffs (Figure 5A and 5B). The deposits here reach up to approximately 4 to 5 m in thickness.

The till is most commonly a reddish-brown, firm to stiff, silty, sandy, gravelly clay. The gravel content is of variable lithology but commonly comprises sandstone or mudstone, which usually forms subangular to subrounded grains. It contains thin (millimetre scale), yellow to orange, mottled and locally red strings or patches of fine to medium sand and grey silt. In some localities, black granules or patches were observed, which likely originate from the Scremerston Coal Member (Section 1.2).

At some localities, a stiff, bluish-grey, slightly silty clay, commonly mottled with patches and strings of orange silty sand, was observed (Figure 5C). This deposit typically lacked gravel but was locally associated with reddish-brown, sandier till in sections along the Doupster Burn. The blue-grey clay was observed in numerous locations within the area underlain by the Scremerston Coal Member. It is interpreted as till sourced from the mudstone units within the Scremerston Coal Member and is likely to occur as lenses (or ‘streaks’). Complex intercalations with the more extensive reddish-brown, sandy, gravelly till are likely to be locally present as well.

2.4.2 Moraine deposits

A single moraine feature has been mapped north-west of Inlandpasture Farm [401458, 649114] through Borewell [401437, 649500] to 200 m north of Marshalls Café on the A1167 [400268, 650377]. The landform is approximately 2 km long (ridge length) and is composed of silty, gravelly sand. The feature is marked by particularly dry soil in aerial images taken during dry periods (Figure 6). The interpretation is based on the overall sandier deposit, ridge geometry, lack of streamlined features across the ridge and the general orientation, which does not match the expected bedrock layering at this location.

2.4.3 Glaciolacustrine deposits

Topographical depressions that are interpreted as proglacial palaeo-lake basins occur locally across the area. This interpretation is based on their lithological composition and close association with low-relief areas surrounded by higher elevations.

The most extensive basin lies in the east of the study area, north of Scremerston [400652, 649232], and is bound by the moraine ridge described in sections 2.4.2 and 2.4.5 to the east. The full depth of glaciolacustrine deposits filling in the depression has not been proved, but at least 1 m of clay, silt and sand in variable proportions were recovered from auger holes at multiple locations across the feature.

The extent of the lake deposits is mapped based on the extent of flat ground visible in the DTM. The western edge lies at an elevation of approximately 65 m aod, which is consistent with the height of the moraine ridge to the east.

Smaller basins filled with glaciolacustrine sediments are found north-east, south-east and south-west of Unthank Square [398416, 648957], as well as north of Scremerston Hill [400601, 647727]. Compared to other deposits mapped in the study area, these show a higher degree of lithological variability between the basins, with fills of laminated clay (Figure 5D) or very sandy material, observed in ditch sections and auger holes. The distinct nature of the basins and their infill deposits supports their interpretation as minor individual lake systems that may have formed relatively short-lived features during deglaciation of the area.

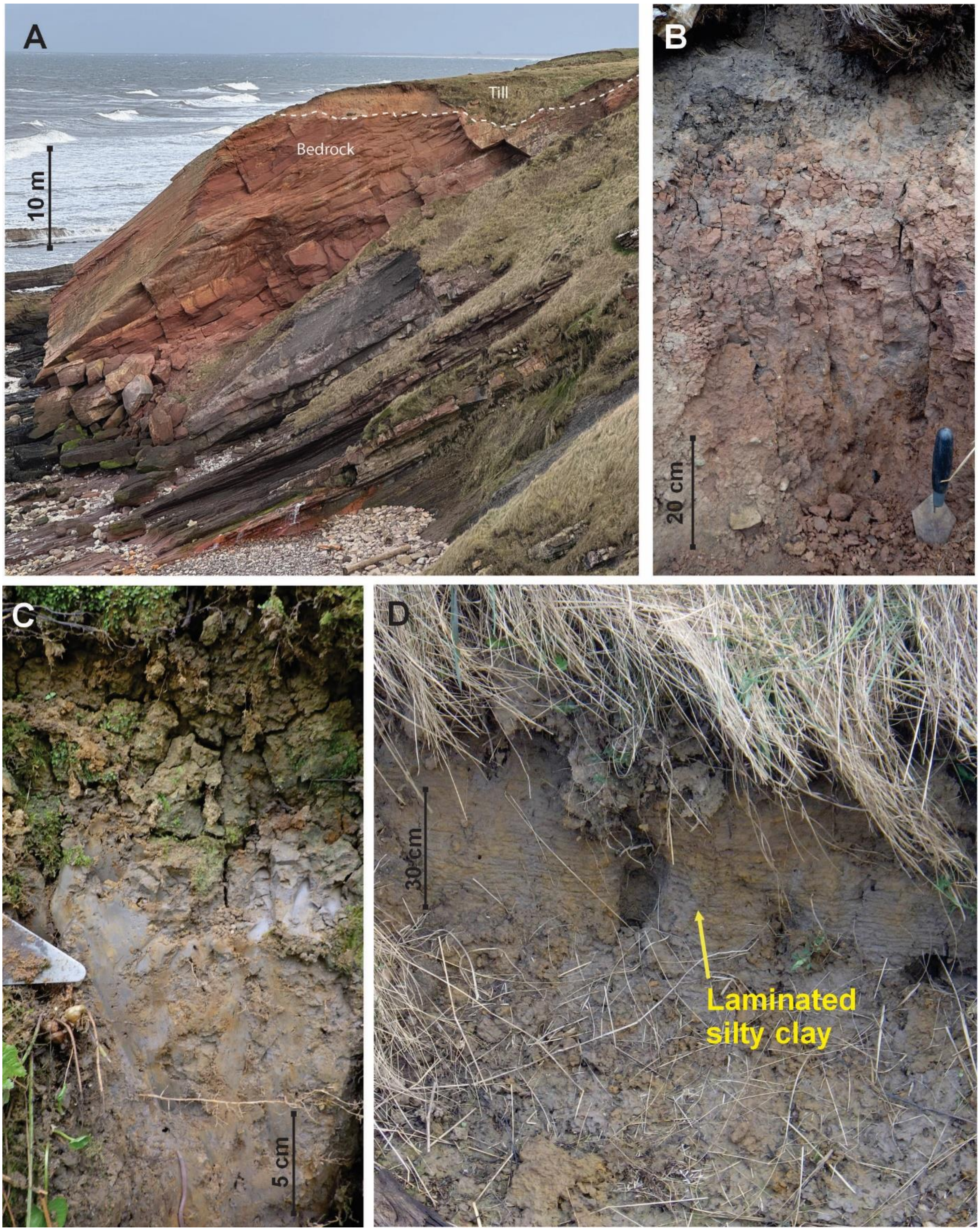


Figure 5 Exposures of till and glaciolacustrine deposits. A: reddish gravelly till on bedrock in cliffs near Borewell; view to the south-east; B: mottled, reddish till exposed in the cliff above the southern end of Spittal beach; view to the west; C: till comprising stiff, blue-grey, silty clay mottled with orange sand in a stream section in the bank of the Doupster Burn near Scremerston Town Farm [401926, 648300]; D: laminated, grey, silty clay in a ditch section through glaciolacustrine deposits east of Unthank Square [399030, 649116]. BGS images P1081784, P1081722, P1081749 and P1081764 © UKRI 2025.

Figure 6 Aerial photography showing areas of dry soil associated with the moraine ridge near Borewell. Aerial photography from July 2006. UKP/Getmapping Licence No. UKP2006/01.

2.4.4 Glaciofluvial deposits

Sand and gravel deposited by glaciofluvial activity is of limited extent within the area. It has been mapped in three locations, based on field observations and indications from historic mapping. Small, isolated mounds are found to the north-east and south-south-west of Scremerston Town Farm [401593, 647946]. These are minor deposits of silty sand and gravel that were likely deposited on top of the till.

In the north of the area, a temporary section through glaciofluvial deposits was exposed during ground excavation works behind the Berwick Garden Centre [397725, 651541] around 2022 to 2023. At the time of the field survey (March 2025), the section had been covered by retaining walls and was no longer accessible. The interpretation of this area is based on field photographs and descriptions of the section taken during fieldwork for the BGS revision mapping of the bedrock of the Berwick-upon-Tweed area for the EA in 2022, and a temporary exposure report submitted to the BGS Digital Accession Database by a member of the Edinburgh Geological Society in September 2022.

The exposure at the garden centre revealed up to 5 m of interbedded sand and sand with some fine to medium gravel. The strata are cross-bedded, with thin, silty sand layers and ripple lamination in places, indicating deposition in a dynamic outwash environment with high sediment input and variable flow conditions. The sand and gravel deposits are overlain by 1 to 2 m of till on the southern side of the exposure and deformation is indicated by asymmetrical folding of the thin silty bands, minor faults and low-angle thrusts (Figure 7). The glaciofluvial deposit is interpreted to have formed prior to a minor re-advance of the ice, which is evidenced by the deformation within the unit, the presence of till overlying the sand and gravel, and the elongated deposit outline.

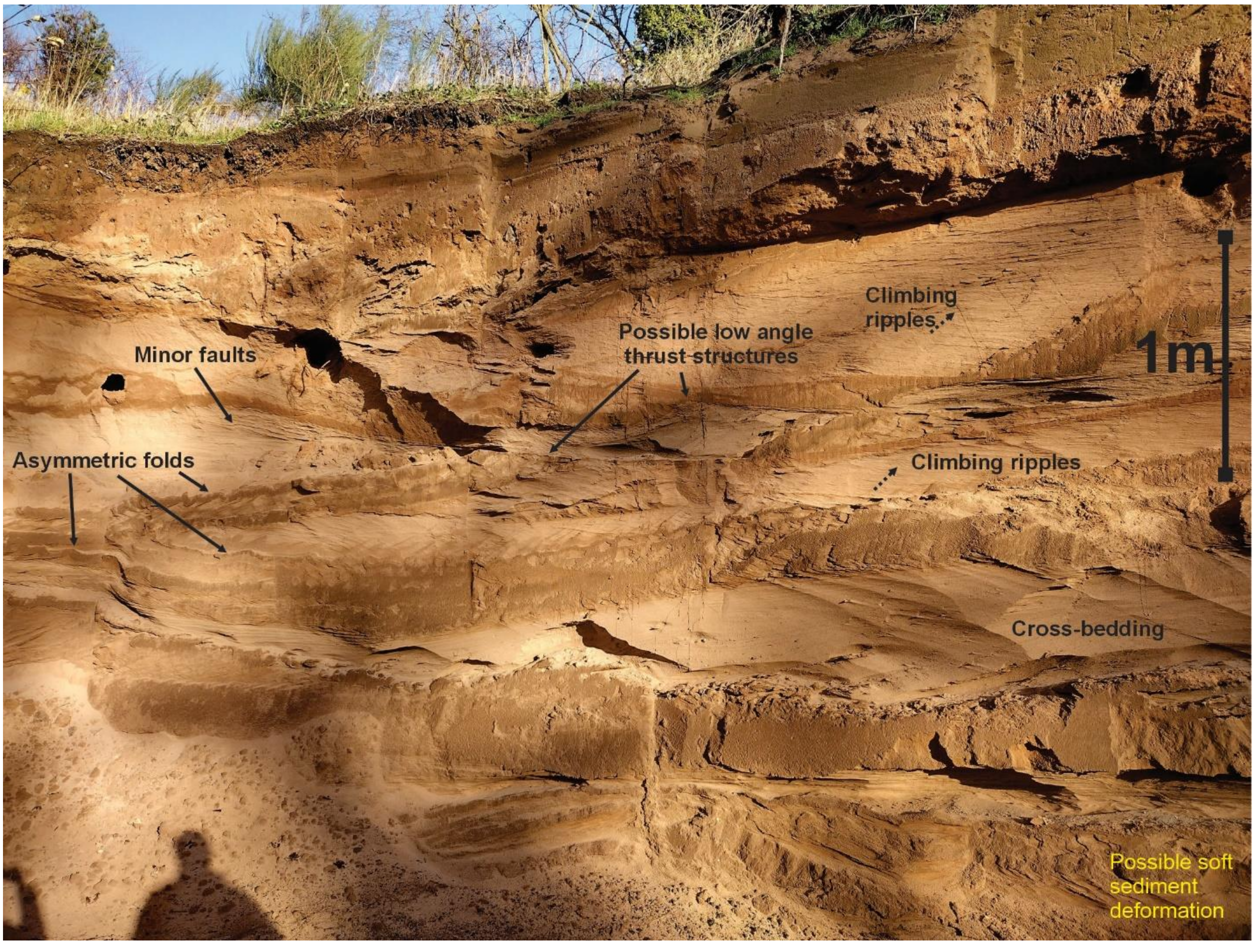


Figure 7 Section in stratified glaciofluvial sand and gravel deposits seen in an excavation near Berwick Garden Centre [397725, 651541] during a BGS bedrock survey in 2022. The sand and gravel units are cross-bedded and ripple bedded, indicative of deposition within a relatively high energy and sediment-rich stream system. Minor faulting and folding indicate that the strata were weakly deformed after being deposited, potentially as a result of overriding by ice during a glacial readvance. The section is no longer exposed so was not visible during the 2025 field survey and has been interpreted from the photograph. BGS image P1081783 © UKRI 2022.

2.4.5 Glacial landforms

The glacial landforms record mapped in the study area are closely linked to the deposits described in Section 2.4.4. The mapped landforms include a moraine ridge, glacial lineations and meltwater channels.

2.4.5.1 Moraine ridge

The interpreted moraine ridge comprises an undulating ridge crest with elevations between 65 and 70 m aod. It is bisected by two meltwater channels (Section 2.4.5.2) but was likely a continuous feature prior to this incision. The feature is generally between 80 and 300 m wide, with its widest parts found to the north. A relatively distinct ridge crest can be identified throughout (Figure 6).

2.4.5.2 Meltwater channels

Two drainage channels bisect the morainic deposits described in Section 2.4.2 and form eastward outlets to the palaeo-lake north of Scremerston [400652, 649232] described in Section 2.4.3. Both channels originate at about 60 m aod, one at Borewell [401340, 649433] and one 780 m to the north-west [400805, 650035]. An additional meltwater channel with a similar orientation was mapped south of Scremerston. All the channels described have removed most of the superficial cover so that their outline is mapped as bedrock. Three minor meltwater channels in till were also mapped along the coast.

A further drainage channel, interpreted to be at least partially formed by glacial meltwater, was found running from north-east of Unthank Farm [398627, 648407] towards the south, where it merges with the Allerdean Milll Burn. The channel bisects several features mapped as glacial lineations and was likely draining the palaeo-lake basin northeast of Unthank Square [398416, 648957] described in Section 2.4.3.

Additional meltwater channels were mapped south of Ord Mains Farm [397664, 650728], south and north-west of Murton White House [397969, 648841] and south-west and south of Scremerston Town Farm [401600, 647908].

2.4.5.3 GLACIAL LINEATIONS

Elongated features created by the flow of ice can be identified throughout the study area. These have a predominant west-north-west to east-south-east orientation, which is consistent with the second phase of ice flow mentioned in Section 1.4. The crest lines of the mapped features are typically several hundred metres in length.

2.5 RIVER AND SLOPE DEPOSITS

2.5.1 Alluvium

Alluvial deposits formed by deposition within modern river channels and active floodplains are present along parts of the River Tweed in the north, Allerdean Mill Burn in the south, and elsewhere associated with minor streams.

In the north-west of the area, bars along the margin of the River Tweed channel have been mapped as alluvium, comprising mixed deposits of clay, silt, sand and gravel. The river is tidal in this area but, as the bars are associated with the confluence between Whiteadder Water and the River Tweed [397300, 651795], they are interpreted as formed dominantly by fluvial processes.

In the south of the area, alluvial deposits likely comprising peaty, sandy, silty, clay are mapped along the Allerdeanmill Burn [397920, 647470]. The extent of the alluvial deposits is defined by the flat, marshy ground flanking the burn within Aller Dean. Organic material, including plant remains and peat, is likely to be present within these deposits, both distributed within the silty, sandy clay and locally as beds or lenses within the deposits. The alignment and form of the Allerdeanmill Burn indicates that it is a glacial meltwater channel and likely formed a conduit for subglacial or proglacial drainage during the last glaciation. It is possible that coarser-grained deposits such as sand and gravel deposited by glacial meltwater flows are present at depth below the alluvium, but there is currently no available data to confirm this.

Minor alluvial deposits have also been mapped in association with a minor, unnamed stream near Ord Mains in the west of the area [397495, 650563] and along the Doupster Burn near Scremerston Town Farm [401220, 648150]. The former deposit comprises very soft, silty clay, which may reflect very low-energy deposition within the base of a glacial drainage channel.

2.5.2 River terrace deposits

River terraces occur along the Tweed valley in the north of the area, forming relatively flat benches at about 5 m aod and 8 to 10 m aod. These features, which are associated with gravelly soils on the historic fieldslips, are visible on the DTM and their form and preservation on the incised bend of a river meander indicates that they are likely fluvial rather than estuarine features.

2.5.3 Head deposits

Very minor areas of head deposits have been mapped 300 m to the south-east of Ord Mains [397720, 650523] and near Slateford Bridge, approximately 700 m south-east of Unthank House [399054, 647750]. These deposits resulted from sediment mobilisation along the slopes and base of small drainage channels and comprise a gravelly, silty clay reworked from till on adjacent slopes.

2.6 COASTAL AND ESTUARINE DEPOSITS

Deposits formed along the coast and Tweed estuary reflect deposition since the retreat of the ice sheet. Areas of raised deposits occur at elevations above 4 m aod at Spittal and along the Tweed estuary. These deposits are above the modern high-water line and likely relate to deposition under higher relative sea-level conditions in early post-glacial times.

2.6.1 Raised beach deposits

The town of Spittal is developed on a spur of land between 4 and 6 m aod, which protrudes northwards into the mouth of the Tweed estuary. The spur forms a terrace with a gentle slope down to the north, which is interpreted as a raised beach deposit. The deposit is penetrated by borehole NU05SW 3 (BGS ID: 647859), which proved approximately 20.9 m of superficial deposits that, from their base at rockhead, comprise approximately 0.9 m of 'light mud' overlain by 20 m of interbedded gravel, sand and gravel and 'sharp' sand. The beds vary between 1 and 3 m in thickness, with 'rising' (running) sand in the lower part and harder beds of cemented gravel ('bound') at several levels within the succession. A similar sequence and thickness (approx. 22 m) of deposits was observed approximately 180 m to the north in borehole NU05SW 1 (BGS ID: 647857).

2.6.2 Raised marine and coastal zone deposits

A narrow terrace, 4 to 6 m in elevation, fringes the southern edge of the Tweed estuary as far as the rail bridge [399178, 653096]. In the east, this terrace appears to be linked to the raised beach at Spittal, but boreholes indicate it may be locally enhanced by made ground in this area.

Inland from Spittal, the raised marine deposits are likely to reflect estuarine deposition in the protected channel behind the raised beach at Spittal. Boreholes from the area of the dock and old bridge [399500, 652555] record up to approximately 8 m of sandy, fine to coarse gravel (BGS ID: 736771; 736750).

2.6.3 Beach deposits

Beach deposits comprising sand with some gravel extend southwards for 800 m from the tip of the spit at the mouth of the River Tweed. The deposits thin to the south of Spittal, where they form patchy cover overlying bedrock exposures on the foreshore.

2.6.4 Storm beach deposits

A minor area of storm beach deposits has been mapped at the northern end of the raised beach platform at Spittal. This formed as a low, rounded ridge that lies largely between the high- and low-water lines at the northern end of Spittal beach. The ridge, which is composed of sand and gravel, is interpreted to have formed under high tide and high wave-energy conditions.

2.6.5 Blown sand deposits

Blown sand deposits have been mapped as forming a thin wedge of sediment between Spittal beach and the rising till slope to the west. The deposit comprises well sorted, 'clean' sand and was associated with small areas of vegetated dunes on historic fieldslips from the primary survey of the area. This area has now largely been built over and the dunes are not visible. The distribution of blown sand deposits has been revised based on new field observations and high-resolution terrain data, in addition to the historic mapping and available boreholes.

2.6.6 Marine and estuarine alluvium

Marine and estuarine alluvium has been mapped along the margins of the River Tweed in the north of the area. These deposits lie within the active tidal channel of the Tweed (between the low- and high-water lines) and are likely to be influenced by both estuarine and coastal processes during tidal transitions. The deposits comprise sand and gravel, reflecting strong tidal currents, and relatively coarse-grained material supplied from the River Tweed and local coastal system.

2.6.7 Intertidal deposits and salt marsh deposits

A small area of intertidal deposits has been mapped in the inner part of the Tweed estuary at Yarrow Slake [398648, 653074]. This area is flanked by salt marsh, visible on aerial imagery as a vegetated plan bisected by numerous tidal creeks. These deposits have formed in a protected basin away from the main tidal channel of the Tweed estuary.

3 Artificial ground

3.1 MAPPING METHOLOGY

Artificial ground is a product of human-induced changes to the land surface arising from excavation of superficial deposits or bedrock, or from deposition of materials. A minimum distribution of artificial ground has been mapped in the study area to account for areas of made and worked ground that can be clearly identified from DTMs and historic mapping. These tend to form relatively discrete areas associated with:

- modern and historic road and rail routes
- mining and quarrying sites
- areas altered by significant landscaping

Areas of made ground associated with general residential, commercial and industrial development have not been included.

Artificial ground in the area south of Berwick was originally captured informally by Burke et al. (2024) to aid the derivation of superficial hydrogeological domains. These areas were identified and attributed following the artificial ground classification scheme of Ford et al. (2006). Spatial extents were identified using historic OS maps dating from 1886 to 1938, modern OS maps, aerial photographs and the EA LiDAR 1 m-resolution DTM.

The data from Burke et al. (2024) was incorporated in a new artificial ground layer, which was checked with field observations and extended to include the area of Berwick south of the River Tweed. Additional areas of artificial ground were added to the remote linework following fieldwork (March 2025) and further analysis of historic fieldslips, OS maps and DTMs during the map compilation. The distribution of mapped artificial ground is shown in Figure 2.

3.2 MAPPED ARTIFICIAL GROUND FEATURES AND DEPOSITS

Types of artificial ground mapped within the Spittal area are shown in Table 2. Many of these features are associated with historic quarrying and mining activities, including spoil tips, quarries, shafts and bell pits. A distributed area of historic workings on coal seams in the Scremerston Coal Member has been mapped between Allerdean Mill and Unthank Square.

Artificial ground is also associated with cuttings and embankments along roads and railway lines. The latter include historic (now disused) industrial railways linking collieries near Unthank [398400, 648157] and Scremerston [400969, 648500] to the main railway network and the harbour at Tweedmouth.

The composition of made ground can be highly variable, depending on the nature of the activities at the site. Borehole records indicate that made ground within the Spittal and Tweedmouth areas includes:

- disturbed superficial deposits
- rubble
- stony clay
- mixtures containing ‘ashes’, bricks, metal, timber and plastic

Contamination with ‘heavy oil’ is also noted in some records in areas of former industrial sites.

Many areas of made ground are not penetrated by boreholes and the composition of these deposits is not known.

Table 2 Types of artificial ground mapped in the Spittal area based on the classification of Ford et al. (2006).

Unit type	Map code	Description	Example features
Worked ground	WGR	Areas where the natural land level has been lowered by removal of geological materials.	Quarry; road or rail cutting; excavation
Made ground	MGR	Areas where the natural land level has been raised.	Road or rail embankment; spoil tip
Infilled ground (worked and made ground)	WMGR	Areas where material has been removed and subsequently backfilled.	Infilled quarry; infilled clay pit; backfilled cutting
Disturbed ground	DDGR	A complex area of surface disruption associated with excavation, deposition and subsidence.	In the study area, this reflects an area disturbed by many minor pits, excavations and spoil deposits associated with historic coal working
Landscaped ground	LSGR	Engineered landscapes where areas of cut and fill are difficult to separate out.	Levelled ground for sports fields or industrial sites

4 Mass-movement deposits

Mass-movement deposits of mappable extent were not recorded within the survey area. In inland areas, the lack of observed mass-movement deposits may reflect a combination of low slopes, relatively resistant bedrock and limited thickness of superficial deposits.

Along the coast, minor slope failures were observed in superficial deposits near the southern end of Spittal beach at the transition between the bedrock cliff in the south and the till-mantled slope underlying Spittal to the north (Figure 8). In this area, failure scarps rarely exceed 30 m across and deposits are largely removed from the base of the cliff by wave erosion. Along the coastal cliff to the south of this point, both the bedrock and overlying superficial deposits are likely to be subject to localised collapse due to coastal erosion.

Figure 8 Head scarp of a minor landslide in till near the start of the coastal cliff section at the southern end of Spittal beach [401202, 650730]. The surface of a steeply dipping sandstone bed forms the dip slope seen in the bottom right of the image. Overlying till deposits have slipped on this bedrock surface but deposits have been largely eroded from the base of the cliff. View to the north. BGS image P1081720 © UKRI 2025.

5 Discussion

Changes in the distribution of superficial deposits between the older survey and the newly revised maps reflect changes to the distribution and extent of deposits as well as the attribution of units (Figure 9). The total coverage of superficial deposits in the new mapping has slightly increased to 63 per cent, up from 60 per cent in the original BGS Geology 1:50 000-scale map. This primarily reflects changes to the extent of the mapped glacial deposits, which are now mapped as present in 57 per cent of the area, compared to 54 per cent in previous BGS Geology mapping. This increase is due to revisions of the distribution of till, which has the largest subaerial coverage of all the superficial deposits present.

The new mapping demonstrates a closer link between the presence of till and the landforms. The latter include a series of elongated lineations oriented west-north-west to east-south-east, which reflects glacial erosion and deposition processes at the bed of the Tweed ice stream. The lineations include streamlined bedrock, crag and tails (a bedrock high with a sediment tail) and drumlins mainly composed of till.

Areas of bedrock exposure, particularly in the west, are primarily associated with glacial erosion, providing a source area for the till deposited further east. It is likely that the till sheet developed beneath the Tweed ice stream was patchy and dynamic during the most active phases of ice flow, with longer-lived till deposits formed on the lee side of obstructions. This includes deposits on the dip slopes of Fell Sandstone Formation ridges to the west and the till 'tail' formed behind Catchlaw Crag [399742, 649674]. The revised distribution of till therefore likely better reflects the dynamic relationship of bedrock erosion and sediment deposition in a complex subglacial environment, when the thinning and wasting of the North Sea ice stream resulted in the cessation of fast ice flow.

Lithological variability was identified within the till deposits during the field survey. Two main variants (lithofacies) were seen:

- a reddish-brown, gravelly, sandy, silty clay
- a blue-grey, silty, clay that is sometimes mottled with silty sand

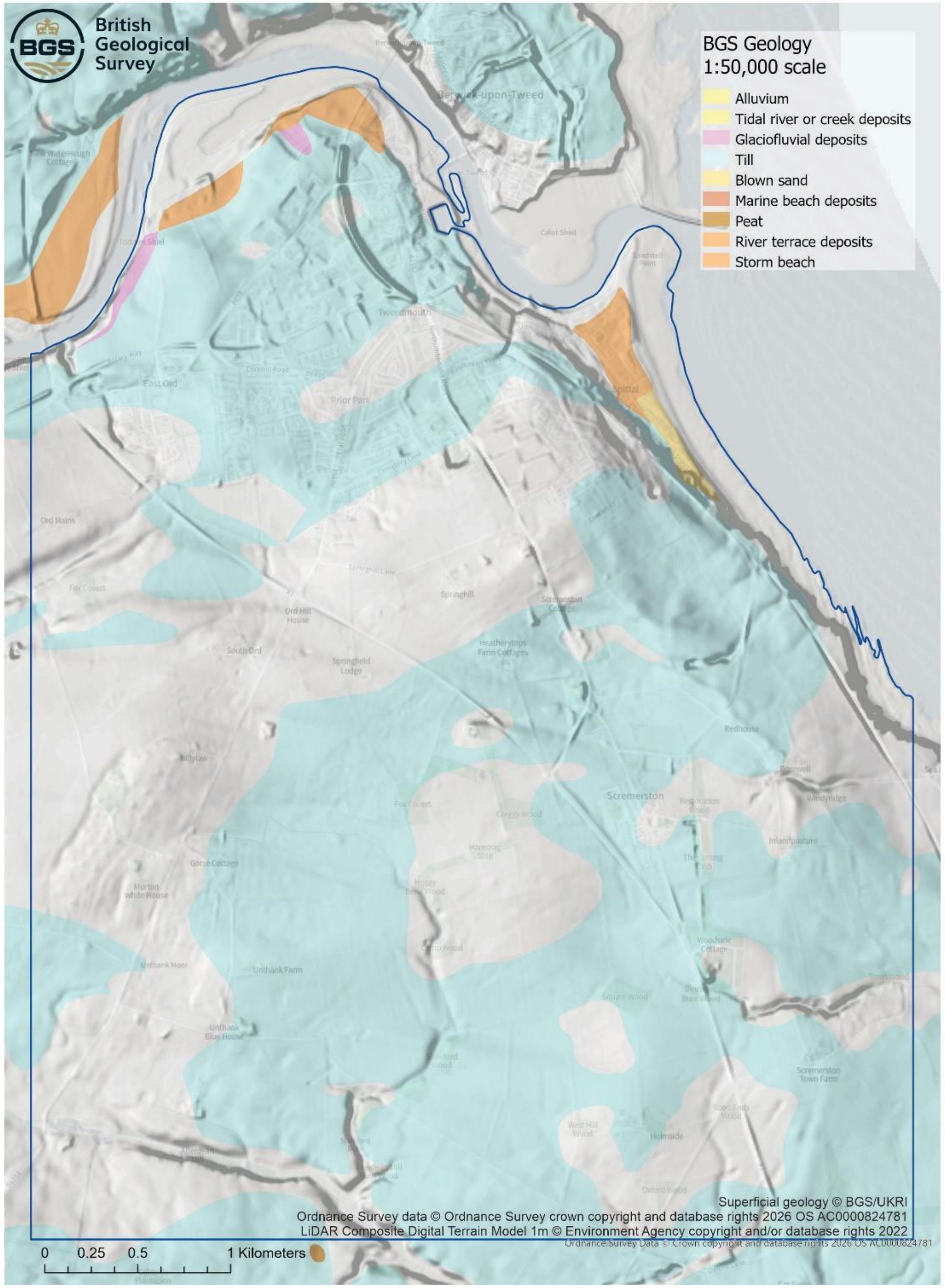
These deposits occur in dispersed locations and were only observed in close proximity in one location, a relatively poor exposure along the Doupster Burn east of Scremerston Town Farm. Here, there was an apparent lateral transition from mottled, reddish-brown, sandy clay to a strong, blue-grey, silty clay (Figure 5C). No clear stratification of the different till units was observed within the area and it was not possible to map distinct till units from the available observations and data. However, the blue-grey clay was seen only in areas underlain by the Scremerston Coal Member. Locally, a similar coloured, soft, bluish-grey clay was observed in auger holes in association with weathered mudstone and coal, which has been interpreted as reflecting glacial erosion of mudstone (and potentially coal-bearing) units within the Scremerston Coal Member. By contrast, the reddish, sandy till is likely to be sourced from the sandstones of the Fell Sandstone Formation. Bedrock control on the properties of till deposits has previously been described in former ice-streamed areas, associated with glacial erosion over bedrock highs (Szabo and Angle, 1983; Schieb et al., 2010). Further mineralogical analysis of the different till facies would be helpful in exploring the link between potential bedrock source areas and till variability.

The new mapping also recognises deposits associated with deglaciation of the area, particularly the moraine system and the glaciolacustrine deposits. The moraine is considered likely to relate to a former ice margin position during westwards ice retreat across the area. A possible fan or slump feature is visible in the DTM on the eastern side of the feature approximately 900 m north-east of Borewell [400855, 650232], indicating that this side of the feature was likely to have been ice free.

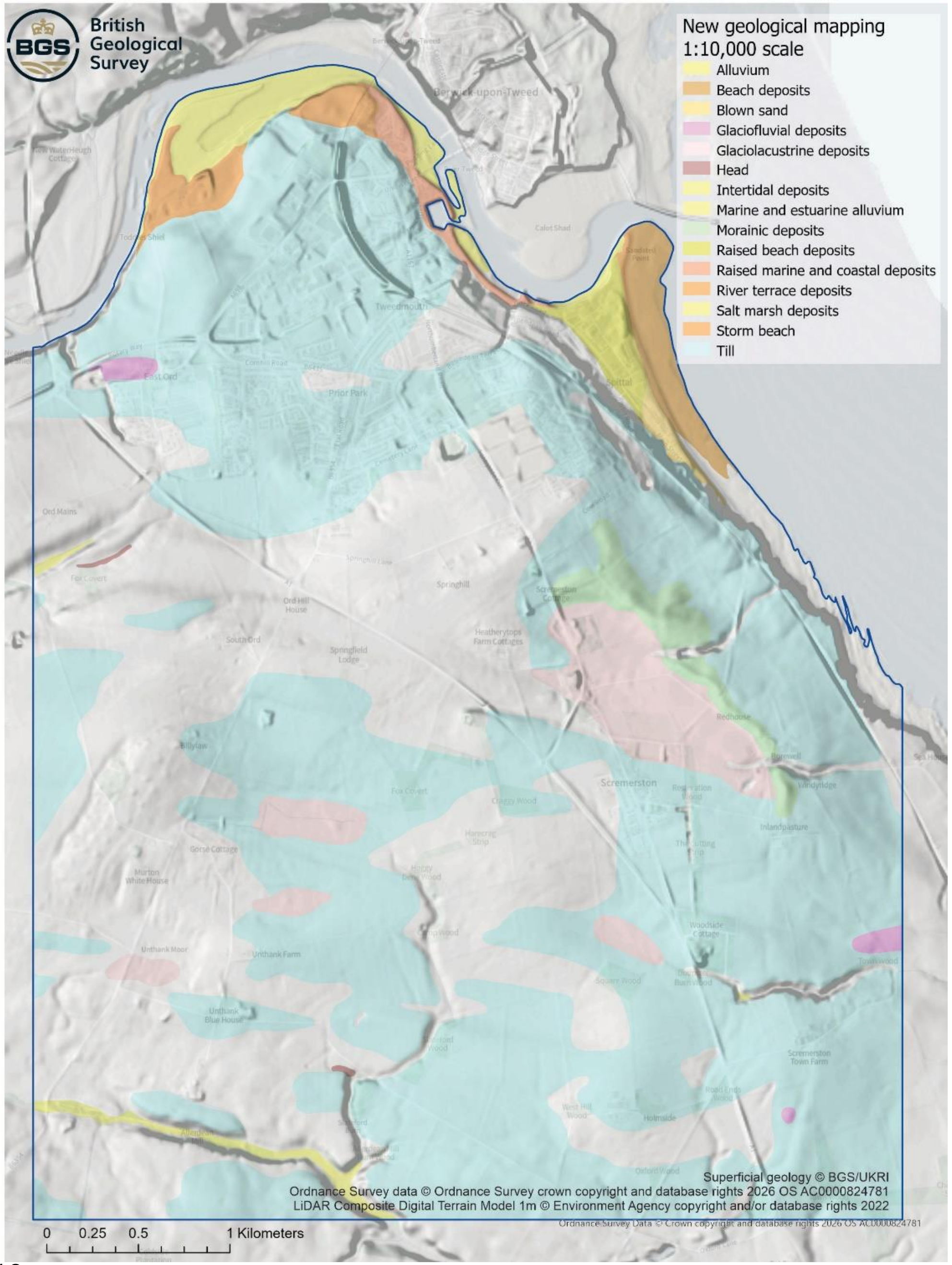
The glaciolacustrine deposit that formed on the western side of the moraine was likely deposited after further westwards retreat of the ice led to the formation of a small, proglacial lake that was dammed by the moraine. Further, likely short-lived, proglacial lakes formed in hollows within the till or bedrock surface as the ice continued its westward retreat. The proglacial deposits in the area, which include the glaciofluvial deposits, are relatively thin and sparse, reflecting the overall limited meltwater activity or glaciofluvial sediment load. The exposure at Berwick Garden Centre shows evidence for glacial overriding of glaciofluvial deposits, indicating that localised re-advances may have occurred during deglaciation.

Figure 9 (Following page) Comparison of current BGS Geology 1:50 000-scale superficial deposit mapping (left) with newly revised 1:10 000-scale mapping (right). Contains OS data © Crown copyright and database rights 2026 OS AC0000824781. LiDAR Composite Digital Terrain Model 1m © Environment Agency copyright and/or database rights 2022.

BGS Geology 1:50 000 scale superficial mapping (based on 1920s survey)



New 1:10 000 scale superficial mapping (2026 Berwick-Spittal study)



6 Conclusions and recommendations

Revision mapping in the Berwick-upon-Tweed–Spittal area has provided an updated interpretation of the distribution and nature of superficial deposits and artificial ground. The latter provides a new dataset that was not recorded in previous surveys. The artificial ground map reflects the minimum distribution of these deposits associated with road and rail infrastructure, historic mining and modern landscaping, focusing on features visible in the field and high-resolution terrain data. Distributed areas of made ground associated with residential, retail and industrial development, as well as agricultural practices, may also occur, but have not been included as their presence and extents cannot be reliably estimated based on current data availability.

Understanding the distribution of artificial ground has important applications for development and groundwater management. For example, areas of worked ground or infilled ground that penetrate superficial deposits into bedrock may provide potential recharge pathways to bedrock aquifers. However, limitations in the understanding of the composition of made ground mean that the impact of these deposits on groundwater systems or ground conditions is poorly known. Targeted investigations to better understand the composition of these deposits would be valuable for future applications of the map data.

The revised superficial deposit map provides more detail on the types of deposits present in the area than was included in earlier geological maps. These advances in the mapping have been enabled by combining analysis of high-resolution topographical data with the field data from the 2025 survey to better understand the links between the form of the terrain and the distribution and nature of glacial deposits.

The new mapping highlights the presence of morainic and glaciolacustrine deposits associated with the deglaciation that occurred towards the end of the late Devensian. These deposits are associated with a range of lithologies, including laminated silty clay and silty sand, highlighting greater lithological diversity in the superficial geology than previously mapped.

The identification of glacially overridden sediments near the Berwick Garden Centre highlights the possibility of more complex sediment associations related to glacial re-advance dynamics in the Berwick-upon-Tweed area. Whilst detailed analysis may ultimately be limited by data availability, further analysis of the superficial strata in this area would be valuable to better characterise the lithological heterogeneity and groundwater implications. Options for targeted, shallow-borehole investigations and geophysical techniques could be considered the help improve the data coverage.

Field observations have also highlighted lithological variability within the till deposits, potentially related to the influence of different bedrock lithologies beneath the late Devensian ice sheet. The variation between reddish, sandy till and blue-grey, clayey till may occur at relatively local scales and is not mappable from current data. However, it may still be an important consideration in relation to ground conditions and groundwater recharge.

Further work to characterise the engineering and hydrogeological properties of deposits in the area would be valuable for improving understanding of the impacts of the revised map data for a range of applications. This could include targeted, in situ field testing of properties such as strength and permeability, as well as laboratory tests.

There is also a need for improved thickness data for the superficial deposits. Whilst a geological map reflects the area covered by a minimum of 1 m of superficial deposits, local variations in deposit thickness are significant sources of uncertainty in groundwater management and infrastructure development. The accuracy of current thickness models for the area is limited due to few boreholes and relatively few field sections.

Capture of additional borehole data from available site investigations into the BGS Single Onshore Borehole Index database would help to extend the borehole data coverage and provide greater constraint for superficial thickness modelling as well as geological characterisation. In areas of low borehole coverage, use of shallow geophysical techniques to image the base of superficial deposits would provide additional constraints. This could be particularly valuable for clarifying the thickness and nature of the fill deposits within areas identified as glaciolacustrine basins.

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The British Geological Survey holds most of the references listed and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at https://of-ukrinerc.olib.oclc.org/folio/

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