Unlocking ice-flow pathways using glacial erratics

This article was written by Dr Jenna Sutherland. All photos and images are credited to Jenna Sutherland.

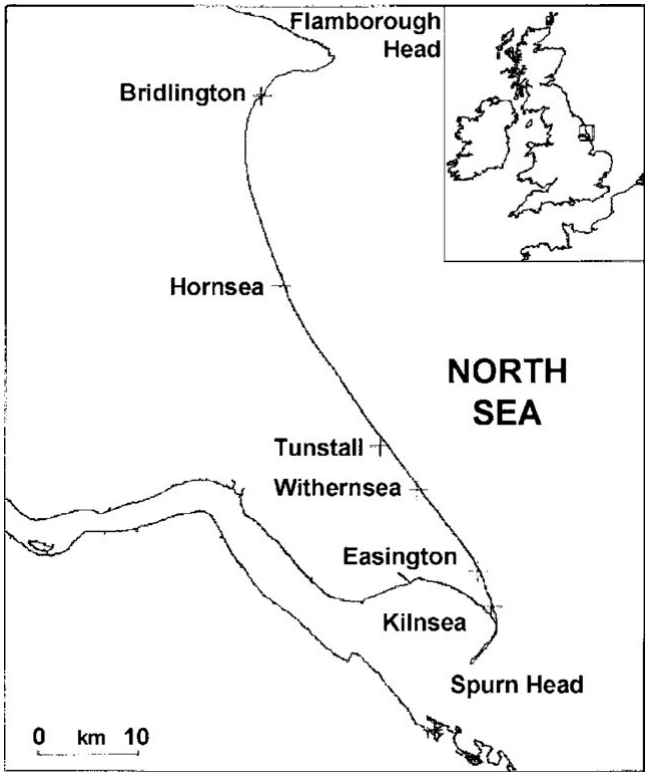
A long history of scientific debate

Along the east coast of the UK, spectacular coastal sections expose sediments that were deposited by the last British Irish Ice Sheet (BIIS) around 21,000 years ago. For many years, Late Devensian sediments along the Holderness coast in Yorkshire were believed to record two separate ice advances from two different ice-flow directions.

These ice advances resulted in two glacial tills, named the "Skipsea Till" and "Withernsea Till"[1]. However, despite decades of research, the processes regarding their deposition remain controversial.

It has also been challenging to link these tills to other deposits in the region. Their relationship to the regional 'stratigraphy' (the branch of geology concerned with the order and relative position of strata, and their relationship to the geological timescale) remains unclear.

In this project, we used the erratic content (an 'erratic' is a far-travelled stone of a different lithology to the local bedrock) of the tills to work out the ice-flow pathways of the last ice sheet to cover this area. These tills are exposed especially well at Tunstall, and this was the focus of the research.



Map of Holderness Coast showing its regional setting. Source.

The focus of this new research was to piece together the sequence of events that led to their preservation.


What the majority of the cliff face looked like at Tunstall. Distinct sediment units can be seen via a change in colour and composition, indicating different depositional environments.

Understanding ice-flow pathways

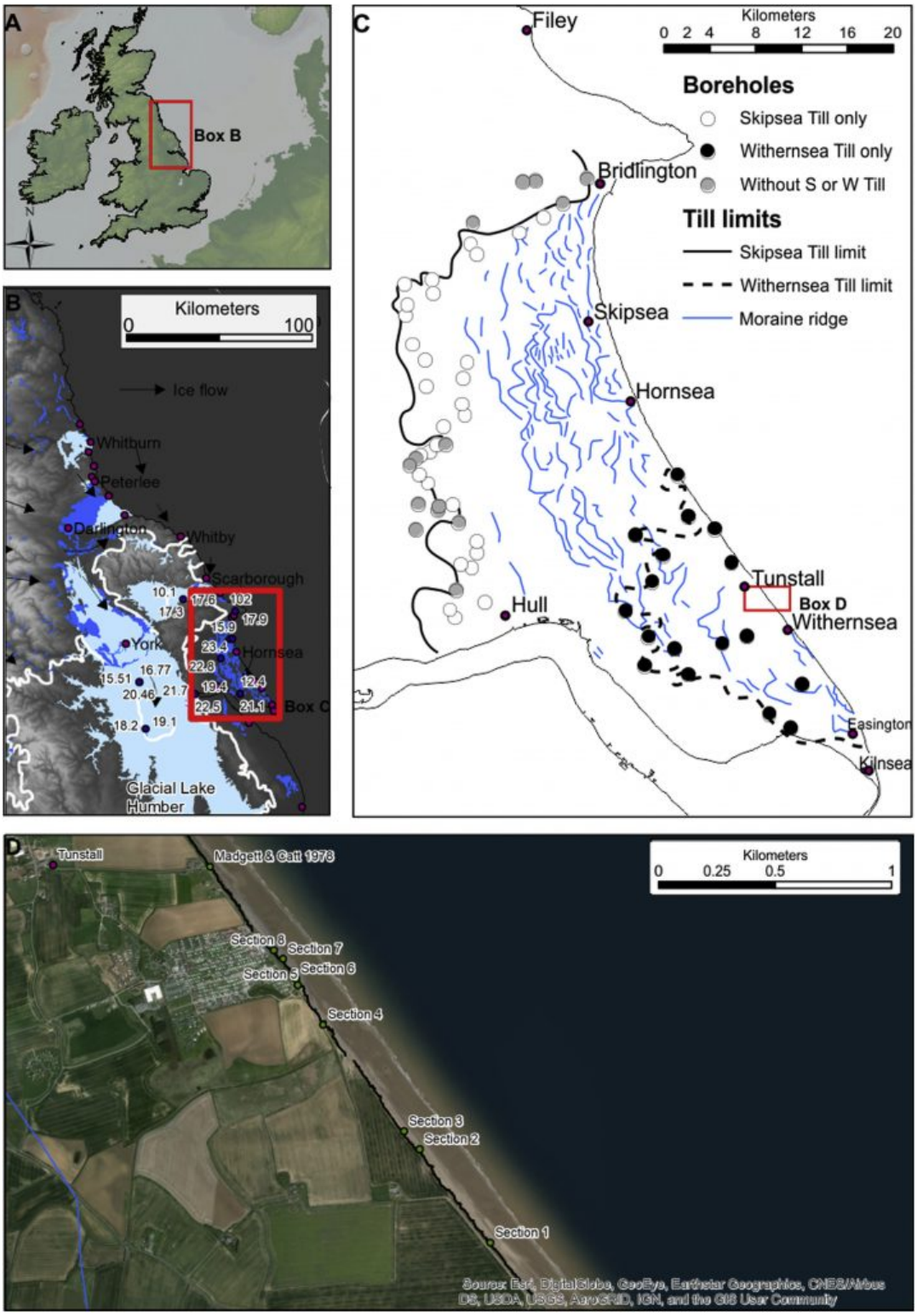
We discovered that the range of rock types (erratics) within the Skipsea and Withernsea Tills were in fact very similar.

This tells us that the ice which deposited these units probably followed the same flow trajectory and reveals that the tills may not have been deposited as separate, discrete events as previously thought, but rather from multiple, minor abrupt shifts of the ice margin.

A rare sunny day on the north east coast. Note the concrete coastal defences and the cliffs of glacial till behind.

How we did it

In this piece of research, investigations were carried out along the east Yorkshire coast at Tunstall beach, an area better known for being one of Europe's fastest eroding coastlines. A large amount of time was spent describing features of the cliff sediments that were, in some places, up 15 metres high.



A. Great Britain and study area highlighted. B. The Yorkshire and Durham coastline, with places named in the text. C. Study area, showing limits of Skipsea and Withernsea Tills (from Evans and Thomson, 2010). Published ages and geomorphology from Clark et al. (2018); Bateman et al. (2015, 2018); Evans et al. (2016). D. Detail of study area, showing location of section logs. Imagery from ArcMap Basemap. From Sutherland et al., 2020.

Interpreting the depositional processes

Composition, appearance and overall grain size gave us an insight into the glacial erosion, transportation and depositional history of the sediment which was easily identifiable as a subglacial till due to its diamictic nature, and scratched and far-travelled pebbles.

Glacially striated Carboniferous Limestone boulder within subglacial till, the lines or scratches represent the direction of ice flow

Interpreting the ice-flow pathways

But what we were more interested in was exactly where the ice had travelled from. When ice moves along the ground from its source area, it rips up or ‘entrains’ bits of the underlying bedrock and incorporates them into the base layer of the ice. The further the glacier travels, the further the sediments also get transported.

Identifying the rock types within the till helped us to trace the pathway of the ice. Luckily, source areas of rock lithologies are well known thanks to handy maps like these from the British Geological Survey.

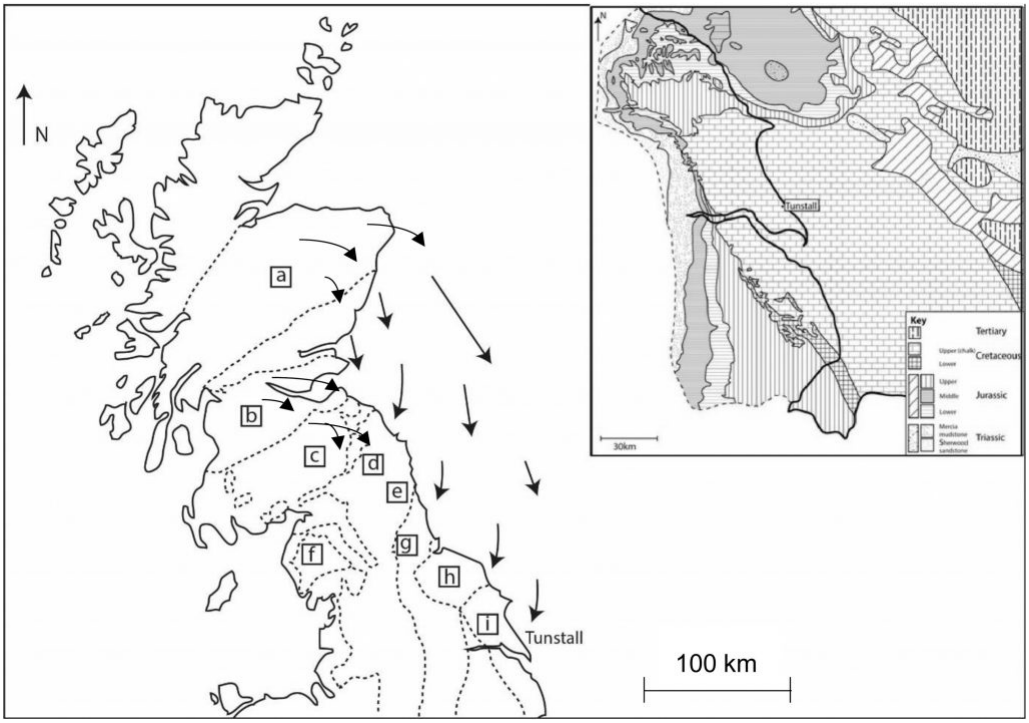
Once we’d matched our rock identifications to their outcrop locations, we were able to ascertain areas across the UK that the ice likely originated from and flowed over.

Representative photographs of key erratic lithologies in each sample a. Greywacke b. Whin Sill Dolerite c. Old Red Sandstone d. Andesitic porphyry e. Sherwood Sandstone f. Magnesian Limestone g. K-feldspar rich Granite h. Rhyolite i. Carboniferous Limestone j. K-feldspar < Quartz Granodiorite k. Cheviot Granite l. Quartzite. From Sutherland et al., 2020.

The lithologies of over 2000 rocks were identified in total, revealing a mixture of different lithologies within the sediment. We identified a large proportion of chalk stones, but that came as no surprise as cretaceous Chalk is the bedrock geology of Holderness and lies directly beneath Tunstall beach.

Magnesian Limestone, Old Red Sandstone, Greywacke, and Whin Sill Dolerite are examples of other lithologies that were present in abundance but all of which we know aren't local to the area. We use these far-travelled erratics to calculate the ice-flow pathways of the last British-Irish Ice Sheet at the Last Glacial Maximum.

Overall, the range of rock types within the sediments suggested that ice was sourced from southern Scotland and flowed southwards, incorporating material from north-east England such as The Cheviots, and the western margin of the North Sea basin. The ice-flow pathway was similar for both tills, and we could not statistically discriminate between them.



Revised iceflow pathways inferred from the simplified bedrock geology map of Northern Britain with outcrop occurances of the lithostratigraphical group. a. Grampian Highlands b. Midland Valley c. southern uplands d. Cheviot volcanic complex e. Northumberland f. Lake District volcanic complex g. County Durham h. Cleveland basin i. Yorkshire basin Insert – Detailed map of the solid geology from the Tees estuary to The Wash (adapted from Kent and Gaunt, 1980; Busfield et al., 2015). From Sutherland et al., 2020.

Summary

This new research supports other work[2,3] that has shown that the various ice lobes of the last British-Irish Ice Sheet were far more dynamic than initially thought, abruptly advancing, oscillating and retreating within the period 22 – 17 thousand years ago.

The key message from our study shows that lithological and structural subtleties within the sediments along the east Yorkshire coast are more complex that what is currently recognised and supports the idea that we should rethink regional stratigraphy's and correlations.

The two tills represent an oscillating ice margin, with ice-marginal recession between the deposition of two subglacial tills. The two tills both represent ice flow from southern and central Scotland. The ice then flowed southwards down the eastern coast of England. Both tills therefore have a provenance from northern Britain. The two tills have a very similar clast content, showing no change in provenance.

This work is a small step towards understanding more about the dynamism of the BIIS during the Last Glacial Maximum, used in predicting the likely response of future ice sheet change.

Assessing sedimentary structures and collecting fracture measurements from the tills on Tunstall beach

Funding and Publications

This research was funded by the Quaternary Research Association (QRA) New Research Workers Award. The research was undertaken as part of Jenna Sutherland's MSc Quaternary Science dissertation research in the Department of Geography, Royal Holloway University of London, supervised by Dr Bethan Davies (RHUL) and Dr Jonathan Lee (British Geological Survey). It was published in the *Proceedings of the Geologists' Association* in 2020.

Below is the publication from this work:

Sutherland, J. L., Davies, B. J., and Lee, J. R. 2020. A litho-tectonic event stratigraphy from dynamic Late Devensian ice flow of the North Sea Lobe, Tunstall, east Yorkshire, UK. *Proceedings of the Geologists' Association* 131(2), 168-186.

Further reading

- Explore the geology of the UK using the BGS Map Viewer
- Learn more about coastal erosion in Holderness in this ArcGIS Story Map
- Read more about Glacial Sedimentology
- Learn about glacial erratics

About the Author

Jenna completed her PhD in the School of Geography at the University of Leeds in 2020. Her research was focussed on the interaction between proglacial lakes and outlet glacier dynamics during the Last Glacial Maximum in New Zealand. Her broader interests lie in reconstructing palaeo-glacial environments and relating the sediment-landform record to past landscape evolution.

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References

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2. Boston, C. M., Evans, D. J., and Ó Cofaigh, C. (2010). Styles of till deposition at the margin of the Last Glacial Maximum North Sea lobe of the British–Irish Ice Sheet: an assessment based on geochemical properties of glacigenic deposits in eastern England. *Quaternary Science Reviews*, *29*(23-24), 3184-3211
3. Davies, B. J., Livingstone, S. J., Roberts, D. H., Evans, D. J. A., Gheorghiu, D. M., and Ó Cofaigh, C. (2019). Dynamic ice stream retreat in the central sector of the last British-Irish Ice Sheet. *Quaternary Science Reviews*, *225*, 105989.