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At the far end of everything: A likely Ahrensburgian presence in the far north of the Isle of Skye, Scotland

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ABSTRACT: A Late Upper Paleolithic (LUP) site containing Ahrensburgian-type stone tools has been discovered at South Cuidrach, Isle of Skye, Scotland. Together with a group of intertidal stone circular alignments also recently discovered on the island, this new evidence for the occupation of northern Scotland also represents the most northerly LUP site in Britain. The timing of the continental Ahrensburgian culture is closely linked to the later part of the Younger Dryas, also known regionally as the Loch Lomond Stadial (LLS), a cold period that saw a significant ice cap and glacier expansion across the mainland of western Scotland. Here, we examine the climatic, environmental and relative sea-level contexts and reflect on the location of this site on an island to the north-west of the Younger Dryas ice mass. South Cuidrach is situated on the north coast of Skye, lying around 25 km north-west of the maximum known local extent of the Younger Dryas ice mass. Most of the lithic assemblage is made from locally available baked mudstone. The site has good access to coastal and riverine resources and readily available ochre, suggesting it was deliberately chosen. Together with the new stone alignments and several other nearby sites, this region now contains more evidence for the LUP than anywhere else in Scotland. The geography and Late Glacial environment of west Scotland comprised a volatile landscape of water, mountains and fluctuating glaciers and coastlines, a challenging area at the north-westerly limit of the European landmass that was very different to the Ahrensburgian core territories in mainland Europe. We anticipate that by examining this new evidence within the various broad geographical and geomorphological conditions, there is significant potential for the discovery of further LUP locations both on and off-shore in this region.

KEYWORDS: Ahrensburgian; climate; Scotland; sea-level; Younger Dryas

Introduction

The last glaciation, known in the UK as the Devensian and in northern Europe as the Weichselian, reached its maximum extent c.26 000–24 000 a BP (years before present) in Scotland (Clark et al., 2022). The ice subsequently retreated to a minimum post-glacial (pre-Holocene) extent during the climatically warm Bølling–Allerød Interstadial between 14 700–12 900 a BP (Clark et al., 2022; Hudson et al., 2023), promoting the migration of plants, animals and humans northwards in continental Europe, closely following the receding ice sheets margins (Wygal and Heidenreich, 2014).

The Bølling–Allerød warming (also known as the Late Glacial Interstadial) was rapidly terminated by the Younger Dryas cooling event from 12 900 a BP when summer temperatures across Europe and the North Atlantic dropped by several degrees (regionally by up to 10°C) (Heiri et al., 2014; Renssen et al., 2015). In areas of the British Isles and northern Europe, this resulted in the expansion of the remanent of the British-Irish and Eurasian Ice Sheets over c.1000 years, during the Younger Dryas (LLS) (Bickerdike et al., 2018; Rea et al., 2020). This cooling terminated abruptly with a rapid temperature increase in the North Atlantic region c.11 700 a BP, with average temperatures reaching levels comparable to today (Cheng et al., 2020). The end of the Younger Dryas marks the transition in the geological timescale from the Late Pleistocene to the Early Holocene (also known as the Pre-Boreal). The abruptness and severity of these climatic changes, including substantial sea-level fluctuation, would have significantly impacted human, animal and plant populations and would have required notable adaptive capabilities to survive.

Evidence for a well-established cultural sequence over this time period has been recorded across northern Europe (as defined by lithic technology and typology), beginning with the Hamburgian Culture. This can be found across northern Europe and into Britain after 15 000 a BP (Jacobi and Higham, 2009; Weber, 2012; Ballin, 2017; Ivanovaitė et al., 2020; Grimm et al., 2021; Pedersen et al., 2022). The Hamburgian was followed by the Federmesser Culture that occupied the same region, between 14 000–12 800 a BP (Grimm et al., 2020). The Ahrensburgian culture follows the Fedemesser and is also found in the same region of northern Europe (Winkler, 2019). The relative timing of the continental Ahrensburgian correlates roughly with the later part of the Younger Dryas and the Early Holocene (Pre-Boreal) (Weber, et al., 2011; Winkler, 2019;

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Baales, et al., 2023) although Mevel et al. (2019) provide a list of radiocarbon dates suggesting a somewhat broader time scale of 12 920–11 500 cal a BP (calibrated years before present, where present is 1950) with one outlier of 10 500–10 060 cal a bp. Grimm et al. (2021) suggest that in north-east Germany, there is evidence for an Ahrensburgian presence from the Late Allerød through the Younger Dryas to the Early Holocene. Thirty-three radiocarbon dates from the Ahrensburgian site of Remouchamps in Belgium suggest a date range of ca. 12 220–10 050 cal a BP (Crombé et al., 2024). A notable reduction in evidence for a human presence during the first part of the Younger Dryas was also suggested potentially due to the cold and wet climate at this time, with the second half bringing warmer, drier conditions (Crombé et al., 2024). The Ahrensburgian is the one of the last of the Late Upper Paleolithic cultures in this region (Winkler 2019).

Until around 20 years ago, there was no clear evidence of a human population in Scotland before the Holocene, although individual artefacts characteristic of LUP cultures had been recovered in a small number of places including Shieldaig on the west coast of mainland Scotland and Balevullin on the island of Tiree (LUP locations shown in Fig. 1). Due to a prevailing assumption that a human population would not have withstood the rapidly deteriorating climate of the Younger Dryas and the associated LLS ice advance in western Scotland (Fig. 1), this evidence was not considered to represent more than an ephemeral human presence, and it was thought unlikely that there was a sustained human population present in Scotland during the Younger Dryas (Ballin, 2017). The earliest directly radiocarbon-dated evidence of human occupation in Scotland is an Early Mesolithic site at Cramond on the Firth of Forth (Ashmore, 2007) that has been re-calibrated to 10 569–10 253 cal a BP with IntCal20 (Reimer et al., 2020).

This has all changed over the last decade, as evidence for human populations in Scotland during the Bølling–Allerød Interstadial (also known as Late Glacial Interstadial) has emerged with three, possibly four, waves of people/cultures identified through lithic typology and technology (Ballin and Bjerck, 2016; Ballin, 2016, 2019; Ballin et al., 2018). Since no

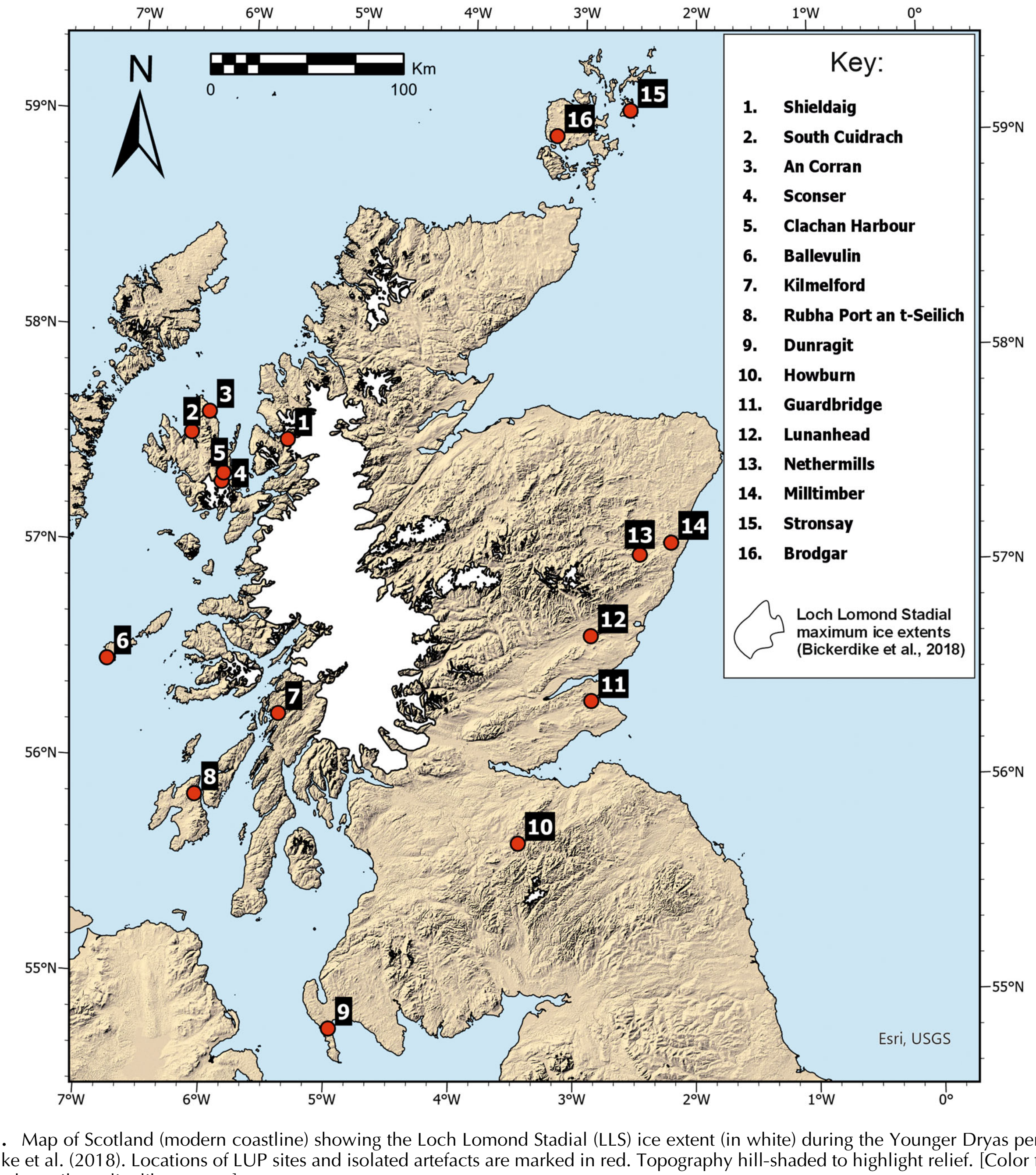

Figure 1. Map of Scotland (modern coastline) showing the Loch Lomond Stadial (LLS) ice extent (in white) during the Younger Dryas period, from Bickerdike et al. (2018). Locations of LUP sites and isolated artefacts are marked in red. Topography hill-shaded to highlight relief. [Color figure can be viewed at wileyonlinelibrary.com]

radiocarbon dates have yet been obtained from any LUP sites in Scotland, we follow the date ranges of continental evidence of human populations during this period (Weber and Grimm, 2009; Weber et al., 2011; Mevel et al., 2019; Winkler 2019; Baales et al., 2023).

The earliest evidence of a LUP presence in Scotland is a Late Hamburgian (Havelte) lithic assemblage from Howburn in the Upper Clyde Valley, south Scotland (Saville & Ballin, 2010; Ballin, 2017, Ballin et al., 2018). Evidence for a Federmesser presence has been recovered at Kilmelfort Cave in Argyll (Saville and Ballin, 2010) and also at Howburn (Ballin et al., 2018). Ahrensburgian points have been retrieved as individual finds from Shieldaig in Loch Torridon and Balevullin on Tiree (Livens 1956; Ballin & Saville 2003); a plain, probably Ahrensburgian, tanged point was retrieved from Millfield on Stronsay, Orkney (Ballin & Bjerck 2016) and one heavily rolled Ahrensburgian-type point was recovered from the island of Islay (Berg-Hansen et al., 2019). A point found at Brodgar, Orkney was tentatively identified as Fosna Hensbacka (Ballin and Bjerck, 2016) although it may potentially be Ahrensburgian (see for example, Buck Pedersen 2009, fig. 22). Indeed, it has been suggested that Fosna Hensbacka and Ahrensburgian may be one and the same (Schmitt, 2018). Several other assemblages across Scotland have features characteristic of the LUP including their large size, excessive reparation of cores for flaking, creating numerous crested pieces and platform rejuvenation flakes, but nothing allowing a more precise cultural affiliation (Ballin & Wickham-Jones, 2017; Ballin, 2019b; Hardy & Ballin, 2024).

Demonstrating a Paleolithic presence in Scotland presents challenges and conditions that are different to the LUP homelands in mainland Europe. In Scotland, Paleolithic sites have been found in caves (for example, Kilmelfort) Saville and Ballin, (2010), on raised river terraces (notably in East Scotland), Ballin (2019b, 2021) on interior landscapes as lithic scatters (Howburn) Ballin et al. (2018) or on the coastal edge (South Cuidrach) (Hardy et al., 2021, Hardy and Ballin, 2024). The relative sea-level (RSL) history of western Scotland complicates coastal preservation, as the pattern and elevation of sea levels are temporally and spatially variable, primarily due to the interplay of the ice loading history of the British-Irish ice sheet that extended out to the continental shelf during the Last Glacial (isostasy) and the spatial fingerprint melt of far-field ice sheets (barystatic sea-level rise) (Shennan et al., 2018). As a result, many coastal landscapes that would have formed along the coast of western Scotland during the LUP now lie below the modern sea level (Shennan et al., 2018) or would have been temporarily drowned as the sea level rose to a mid-Holocene highstand recorded by the raised shorelines preserved along much of the modern coast (Smith et al., 2019). Further inland the problem becomes one of visibility as the old ground surfaces are generally covered. Much of the centre and west of Scotland, up to the coastal edge, is covered in peat and blanket bog up to 10 m thick, which started to accumulate around 11 000 a BP (Gallego-Sala et al., 2016). The archaeological record is therefore unlikely to be representative of the full range of site types and distribution.

Focusing on lithic artefacts that are not in primary stratigraphic context may not be ideal under stable geomorphological conditions but in Scotland, this is so far, the only option. While these conditions restrict the type of evidence recoverable (for example, there are currently no radiocarbon dates and no surviving *in situ* deposits), even demonstrating that these populations reached the north west coast of Scotland extends the known world of the likely Ahrensburgian populations. Conditions in this region during the later Younger Dryas and Early Holocene would have been challenging with changes in glacial coverage, rapid melting, resulting in floods, changing river courses and potentially localised earthquakes, within a landscape of steep mountains and fluctuating coastlines. These conditions would have been very different to those experienced by the populations in the lowlands of northern Europe and suggest a need for rapid adaptation.

The complex nature of the fluctuating land and seascapes at this extreme continental edge in what is today, an island in the Atlantic Ocean, suggests the need for a contextual analysis of what these pioneer people would have encountered and how they might have reached here. We therefore begin by describing a recently discovered concentration of Ahrensburgian-type lithic artefacts from South Cuidrach in the north part of the Isle of Skye, Scotland (for a full description and illustrations of the lithic assemblage, see Hardy and Ballin, 2024). We describe the unique geomorphological conditions that enabled this material to survive and be accessible, and also the type of challenges that the people would have encountered. While the evidence is not *in situ*, the abundance and concentration of the lithic artefacts and the unrolled nature of some of the assemblage suggest at least one on land source and at least one source offshore (Hardy et al., 2021). A cluster of single-course stone-built circular features in what is today, the low intertidal/offshore zone at Sconser in central Skye, adds additional evidence for the presence of people here, around 11 000 a BP. We explore the implications of these discoveries within the context of the climate, environmental and RSL change of the time and their location on an island to the north-west of the Younger Dryas (LLS) ice masses that formed over western Scotland. Consequently, we provide new perspectives on movement, land use, distribution, subsistence and adaptations of the Ahrensburgian people on this continental edge of their territory. The complex climatic and geomorphological conditions in the region during the Younger Dryas suggest that the occupation may post date the full glacial melt, suggesting that the sites may date to the Pre-Boreal (Early Holocene); however, with no directly datable materials, we cannot confirm this.

Study sites and methodology

We present the results of fieldwork at two field sites on the Isle of Skye, first South Cuidrach in north Skye, which sits just above the modern tidal range and second, Sconser in central Skye, which is positioned within the modern foreshore. Both provide evidence for LUP populations on the Isle of Skye. The paleo-environmental context of these sites is considered further in the discussion.

South Cuidrach

South Cuidrach (NG 38352 57729) is located in the north of the Isle of Skye on the west coast of the Trotternish Peninsula (Fig. 1). Following many years of monitoring a Late Mesolithic lithic surface scatter here, an archaeological inspection in 2017 revealed a new scatter of LUP lithics on the surface that had been exposed when the excavation of a new farm track disturbed a storm beach (Hardy et al., 2018). The main concentration of these lithics lies at the southern end of the 200 m modern beach (Fig. 2) that comprises locally derived pebbles, cobbles and boulders. It is constrained to the south and north by a raised bedrock platform, likely corresponding to a deglacial shoreline (Smith et al., 2019). The Hinnisdal River empties into Loch Snizort, around 100 m to the south of this. Landward of the modern storm beach is a clast-supported, higher, raised beach (~5 m above the modern beach) comprising rounded pebbles, cobbles and boulders within an unsupported matrix.

Two radiocarbon dates from an *in situ* Late Mesolithic context that lay sealed directly beneath the raised beach provide a maximum age for the beach formation of 7028–6853 cal a BP (Table 1, Fig. 2), in keeping with the age of the Main Postglacial-Blairdrummond shorelines that formed during the mid-Holocene sea-level highstand elsewhere in Scotland (Smith et al., 2019). This is supported by modelling studies, which suggest that RSL at the site would have been at or slightly above the present level (up to 3 m) during the mid-Holocene (c.7000–6000 a BP), before falling to its modern elevation (Best et al., 2022; Bradley et al., 2023; Scourse et al., 2024). There is a topographic depression landward of the raised beach, which comprises ~1 hectare of sphagnum fen fed by a small stream.

A programme of test pitting along the length of the storm beach took place in 2018 and 2019 followed by excavation of a 30 m^2 area (Fig. 3). LUP lithics have been recovered from the surface, embedded within the Holocene raised beach and from adjacent sediments (Hardy and Ballin, 2024). The excavation incorporated the southern limit of the raised beach to the near-surface bedrock and continued north to where the beach reached 1.5 m deep (Figs. 3 and 4) (Hardy et al., 2021).

The site is low-lying (around 3 m OD) and close to the current shoreline. The distribution of the lithics and the fact that some are heavily rolled suggest that these are in a secondary context. Immediately offshore, there is a relatively shallow area directly in front (to the west) of the site that, due to lower relative sea levels (RSLs), would have been exposed during the Late Glacial period between approximately 15 500–14 000 a BP and 13 000–8000 a BP (Best et al., 2022; Clark et al., 2022; Scourse et al., 2024), and it is therefore likely that some of the LUP lithics came from this now-submerged area (Hardy et al., 2021).

An *in-situ* Mesolithic site was recovered from beneath the raised beach, and carbonized material was extracted from a hearth and radiocarbon-dated (Table 1). LUP artefacts were also recovered from colluvial deposits to the west of the beach and embedded within the beach itself. A discrete concentration of LUP blades was located immediately to the south of the raised beach limit (in T1 and T2). Their pristine condition and the fact that they were largely deposited vertically within what appears to be a water accumulation suggest a small amount of localised movement. No further deposition of lithics has been found to the south of this deposit as the bedrock slopes upwards and is very close to the surface.

Because these artefacts are evidently redeposited, some of the assemblage is mixed with Mesolithic material. The full lithic assemblage recovered between 2017–2023 contains artefacts that are likely Ahrensburgian, artefacts that are LUP but without specific cultural markers, Early Mesolithic and Late Mesolithic artefacts (Hardy and Ballin, 2024). LUP, probably

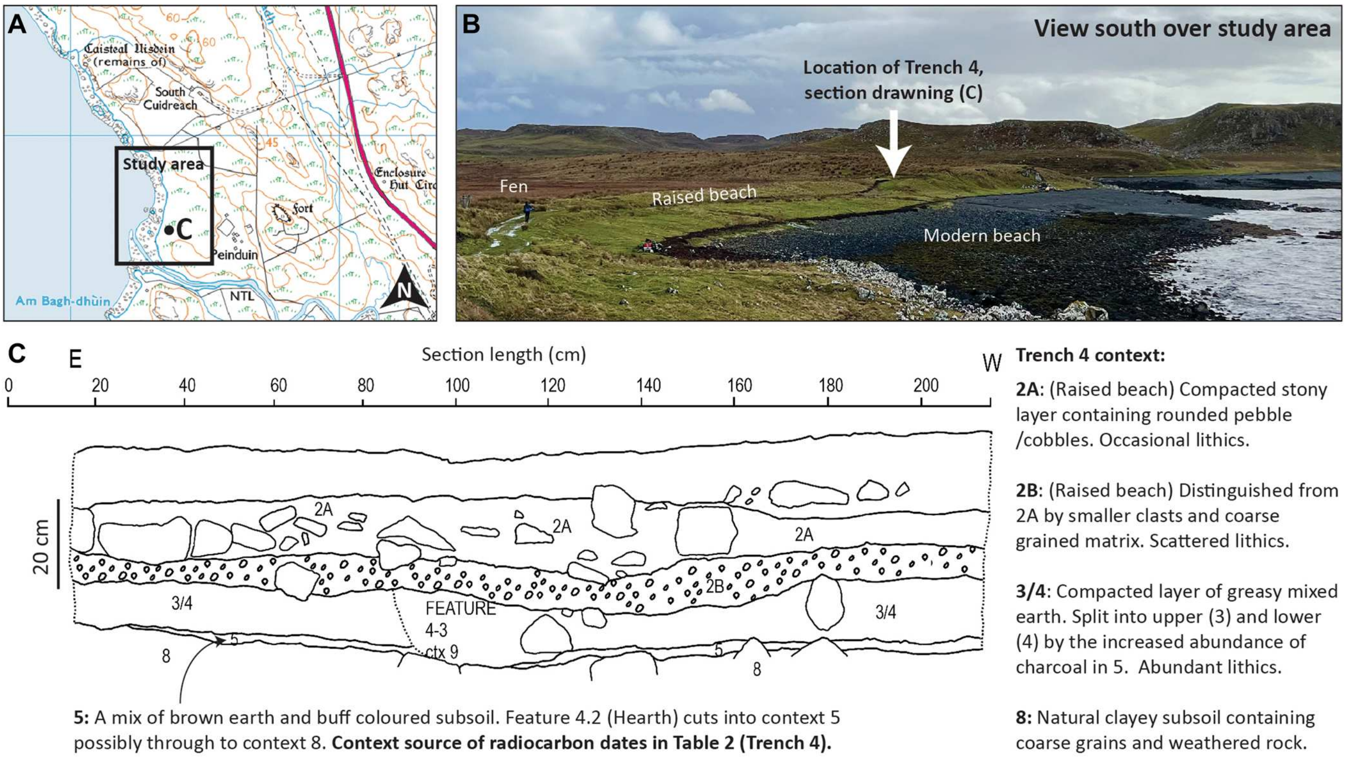

Figure 2. South Cuidrach Late Upper Paleolithic and Mesolithic site. (A) 1:25 000 Ordnance Survey location map of South Cuidrach (source: Digimap, 2024). (B) South-facing photograph of the study area marked in A showing the location of the archaeological site. (C) E-W section of Trench 4 showing the context of radiocarbon-dated charcoal samples (Table 1) beneath the raised beach. [Color figure can be viewed at wileyonlinelibrary.com]

Table 1. Radiocarbon dates from South Cuidrach (context 5 in Fig. 2), calibrated using IntCal20 (Reimer et al., 2020).

Lab code	Site code	^{14}C Date ± error	Delta-13C	Context	Dated material	Cal a BC (2-sigma range)	Cal a BP (2-sigma range)
SUERC-101064 (GU59260)	SC213	6577 ± 26	−27.2‰	Trench 4, context 5	Charcoal *Corylus avellana*	5562–5478	7511–7427
SUERC-101065 (GU59261)	SC214	6504 ± 26	−25.6‰	Trench 4, context 5	Charcoal *Salix sp.*	5528–5378	7477–7327

Figure 3. Drone photograph of South Cuidrach, looking north over the Hinnisdal River, showing the modern and raised beach, with the fen visible to the right of the farm track. Inset figure, plan of test and shovel pitting at the end of the farm track (for location see Fig. 2). Key. TP: test pit (0.5 × 0.5 m) SP: shovel pit. 0.20 × 0.20 m); BM: temporary benchmark; T; trench, either 2 × 1.5 m or 2 × 2 m). [Color figure can be viewed at wileyonlinelibrary.com] [Correction added on 26 April 2025, after first online publication: Figure 3 has been revised in this version.]

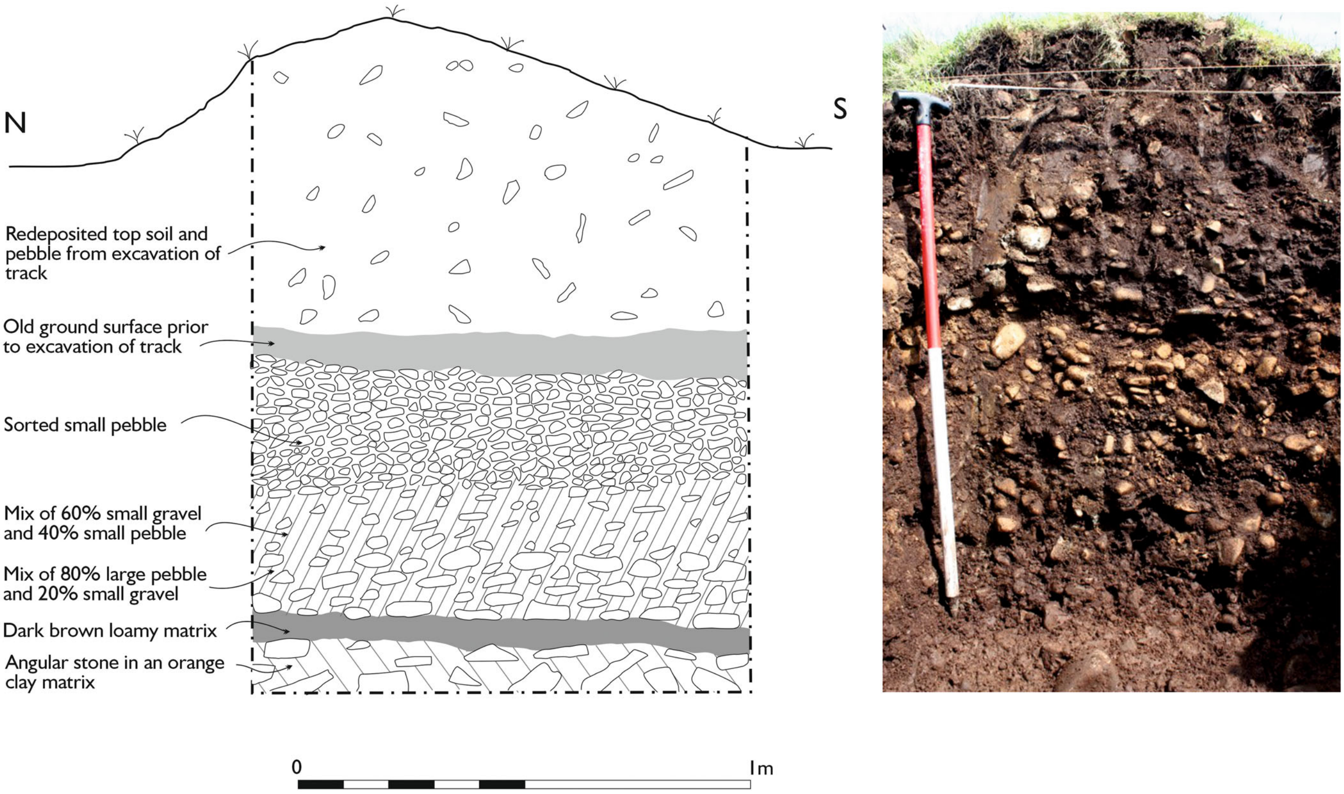

Figure 4. West-facing section through the raised beach. Location immediately north of the test pitting sites shown in Fig. 3 insert; 57°32′00″ N, 006°22′22″ W (OS national grid location NG 38370 57691). [Color figure can be viewed at wileyonlinelibrary.com]

Ahrensburgian artefacts include tanged point fragments, opposed platform blade technology, complex burins, a scraper with an acute edge-angle and a discrete assemblage of broad blades (Hardy and Ballin, 2024). While this assemblage does not contain undamaged Ahrensburgian points, the evidence suggests that it is indeed Ahrensburgian—based on the lithic analysis (Hardy and Ballin 2024) and because there are few other alternatives (Fig. 5).

There is no diagnostic evidence for any other LUP culture in the region. There is, though, a scatter of evidence across Scotland for an Ahrensburgian presence and artefacts that are more likely to be Ahrensburgian than anything else (Ballin and Saville, 2003; Mithen et al., 2015; Ballin and Bjerck, 2016; Berg-Hansen et al., 2019). Therefore, the positive evidence for the broader Ahrensburgian presence and the negative evidence for any other LUP cultures in north Scotland, supports the lithic evidence from South Cuidrach as representative of an Ahrensburgian presence here.

There are currently two other known sites with non-diagnostic Late Pleistocene/Early Holocene lithics in the local region: An Corran, north-east Skye (Saville et al. 2012) and Clachan Harbour, Island of Raasay (Ballin et al., 2011) (Figs. 1 and 9). Additionally, Shieldaig, where a likely Ahrensburgian tanged point (on flint) and two hard hammer broad blades on baked mudstone suggestive of LUP technology were found (Ballin and Saville, 2003; Hardy et al., 2016), is in Upper Loch Torridon on the mainland directly opposite north Skye about 45 km by sea (or overland, around 135 km).

Stone circular alignments, Rubha Garbh, Sconser

Several stone circular alignments between 3 and 5 m in diameter are dispersed through the intertidal and subtidal zone of a large tidal flat named Rubha Garbh (Rough Point), at the southern shore of the entrance to Loch Sligachan in central Skye (Hardy et al., 2021) (Figs. 1, 6, and 9). This area lies immediately to the east of the loch entrance, which is partially closed off by a narrow spit protruding from the opposite shore to the north. The tidal flat is generally level and approximately 1 km long and 0.5 km wide at the lowest tides, with the flat and shallow area extending well beyond the Mean Low Water Spring (the elevation of the lowest typical tides) elevations.

The survey was undertaken through walkover inspection and preliminary snorkelling in 2019, 2021, 2022. Although the exact number, size, distribution and form of the possible stone alignments remain uncertain due to the presence of seawater, seaweed and many stones that appear to be lying on top of recent marine sediments, visual inspections and a drone survey putatively identified up to twenty embedded circular stone alignments across this area, all falling within a limited size range of 3–5 m. They are distributed across the lowest part of the normal tidal range, with at least one that seems to extend beyond it, although the preliminary distribution must be regarded as tentative. They are only visible at the extreme spring tides and are exposed around 2–3 hours per year.

Test pitting was undertaken in 2022, in two circles (C8, C9—Figs. 7 and 8) within a single tidal exposure. The waterlogged and relatively unconsolidated nature of the sediments mixed with some larger stones made it difficult to maintain precise edges on the trenches. The increasing frequency of stones and the presence of water in the trenches also made it impossible to reach the natural geological layer before the tide rose again to cover the trenches.

The stone circular alignments are constructed of boulders of approximately 0.25–0.5 m in diameter. In many cases, the stones or boulders seem to be embedded to a substantial depth into the

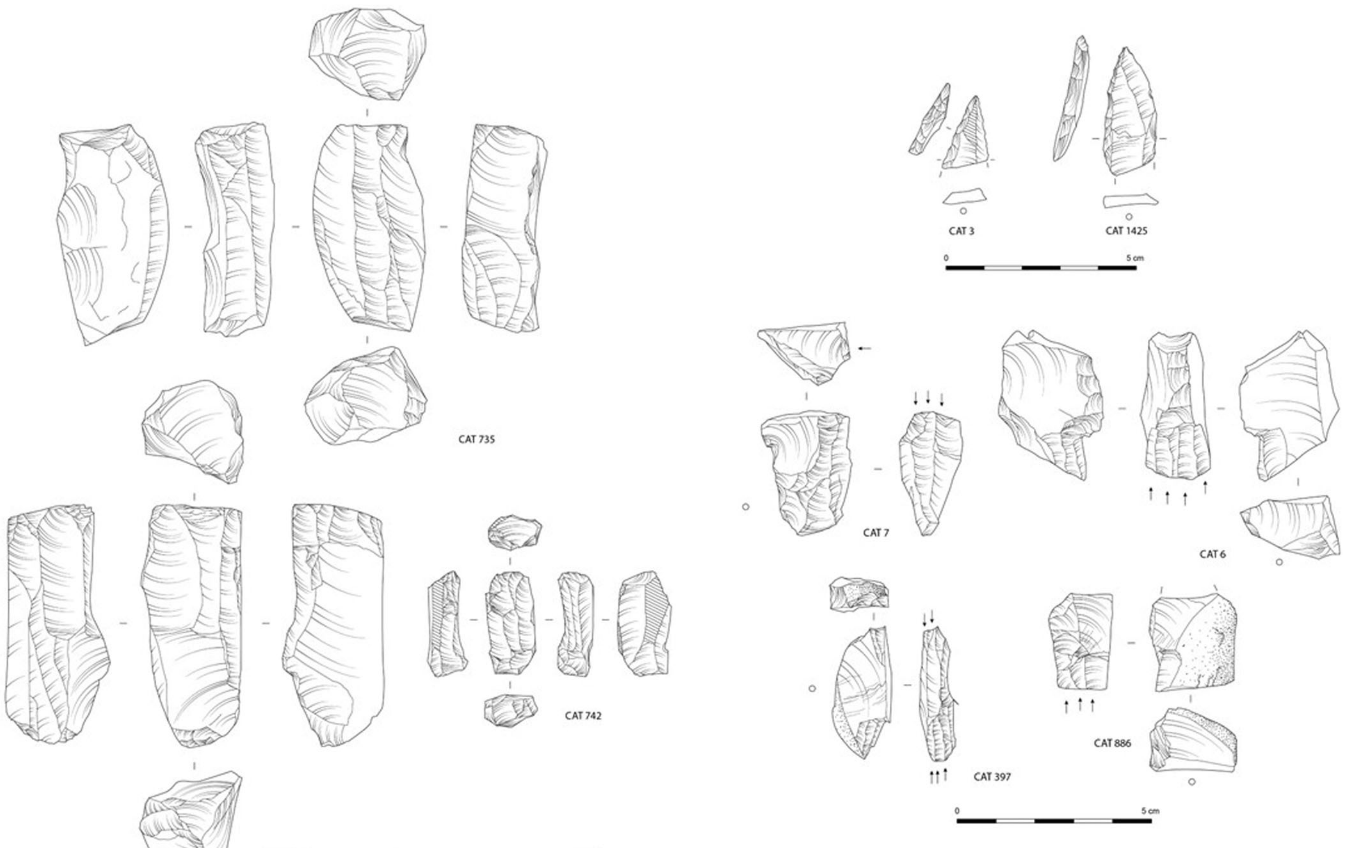

Figure 5. Examples of artefacts from South Cuidrach. (A) Cylindrical opposed platform cores; (B) Possible tips of tanged or backed points; (C) Burins (reproduced from Hardy and Ballin, 2024, with permission).

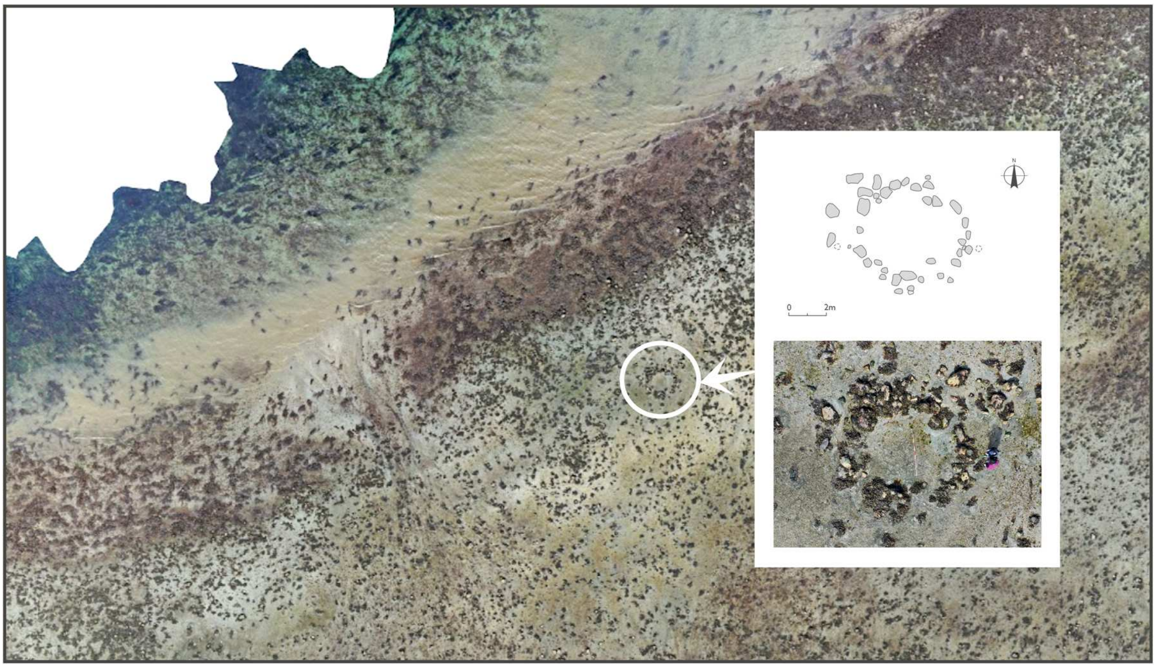

Figure 6. Drone surveyed the orthomosaic map of the Sconsor foreshore, showing the circular stone alignment (C1) within the Sconser foreshore (see location in Fig. 8). [Color figure can be viewed at wileyonlinelibrary.com]

Figure 7. Photograph of the test pit in trench 2 in C8 showing the N-facing section (red scale is 0.5 m). [Color figure can be viewed at wileyonlinelibrary.com]

marine deposits and rest on the lower clay, which represents a former land surface. The surface also contains many smaller stones and boulders that appear superficially similar although not as large and embedded only a few centimetres into the recent marine sediments. Full excavation of a representative sample of these features is needed to properly characterise their stratigraphic context. However, even without such data, and without certainty of the nature of each feature, the large number and intertidal and subtidal distribution of the circular alignments provide strong indirect evidence that the group of features is anthropogenic. While other intertidal and low tidal alignments exist in places on the Scottish west coast, these are associated either with fish traps or the 19 C kelp industry. They have a different morphology and there are no other known intertidal features in this region that can be matched to the morphology and intertidal and subtidal distribution of this group of features. Additionally, their general uniformity and a extension from the intertidal into the subtidal zone without apparent changes in that morphology suggest that they pre-date modern sea level, and by extension, they represent a group of terrestrial features. Although there are currently no specific cultural indicators at Sconser, other than one non-diagnostic flint artefact recovered from C3, and no direct parallels in Scotland, a similarity with a site type that pre-dates modern sea level stabilisation can be found in Scandinavia. Fretheim et al. (2018) provide illustrations of 23 roughly circular alignments of stones of similar size and shape in Norway, many of which have been radiocarbon-dated. The calibrated ages range from (11 070–10 438 cal a BP (IntCal20, Remier et al., 2020). The similarity between these circular alignments and those at Sconser is remarkable and supports the interpretation of a Late Pleistocene/Early Holocene age.

Elevation survey and stone circular alignments age estimate

The position of the stone circular alignments at Sconser lies within the Last Glacial Maximum ice limit that extends out to the continental shelf (Clark et al., 2022). Therefore, they must postdate the retreat of ice between the Isles of Skye and Raasay from c.14 700 a BP (Bradwell et al., 2019, 2021), at a time when lower RSL following deglaciation (Best et al., 2022) permitted activity within the modern intertidal zone. To provide a better-constrained estimate of the age of the features, a survey of their elevation was conducted and compared to a deglacial RSL model.

A drone survey and the creation of an orthomosaic map of the foreshore were undertaken by a local volunteer, Jamie Booth, at an extremely low tide in March 2021 and were processed in Agisoft Metashape to produce a Digital Elevation Model (DEM). The coverage of the drone survey extended from the fish trap in the west of Rubha Garbh to the approximate centre of the intertidal flat, covering the initially viewed area of the possible stone circular alignments (Fig. 8). The orthomosaic map has a ground pixel resolution of approximately 10 cm^2 across an area of approximately 600 by 450 m and shows individual stones in far greater clarity and contrast than other available aerial imagery. An elevation survey was conducted in March 2023 during the lowest annual spring tide to tie the drone survey to the UK Ordnance Datum (OD) and to develop an elevation-corrected bathymetric model of the Sconser foreshore. A Leica System 500 dGPS was used to survey the elevation of a

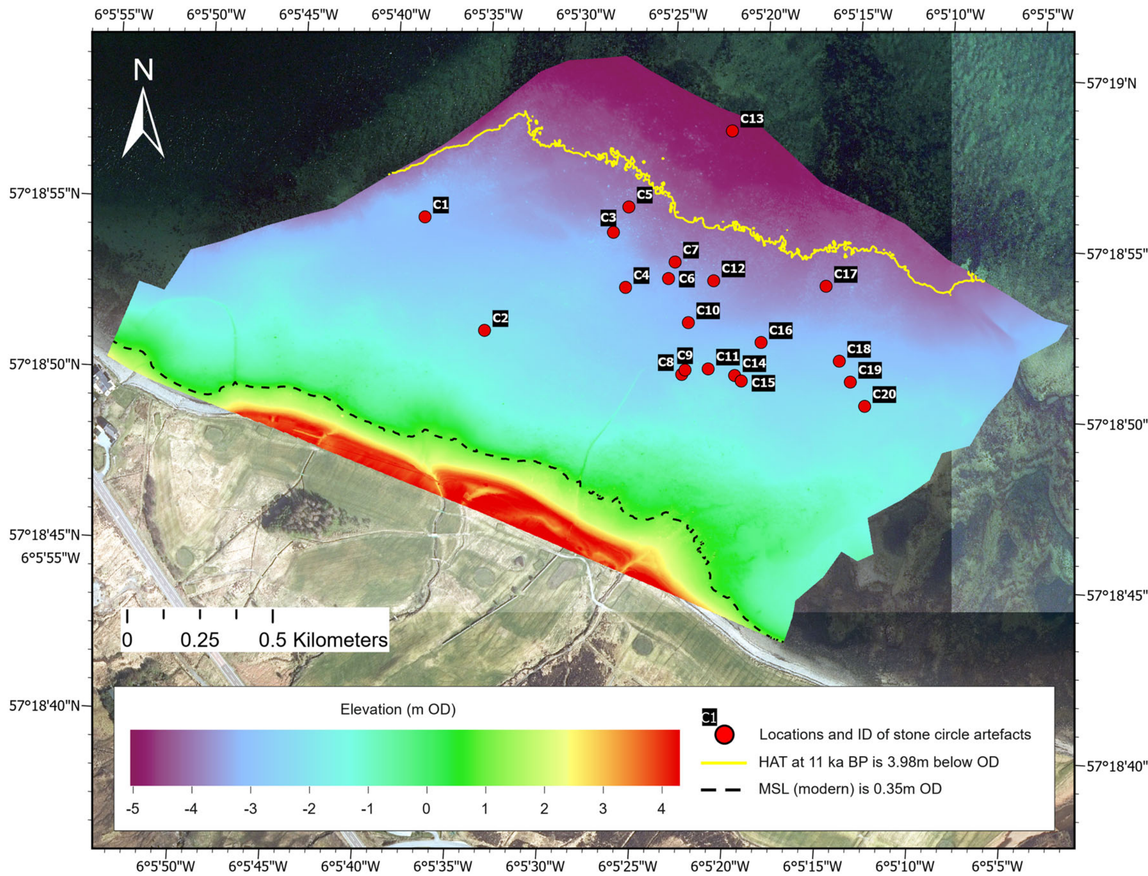

Figure 8. Bathymetry of the intertidal zone at Sconser, measured using photogrammetry and elevation survey, along with the locations of stone circular alignments (numbered C1–20) (Hardy et al., 2021). Estimates of the paleo relative sea level (Bradley et al., 2011; Scourse et al., 2024) and the elevation of the highest astronomical tide at Broadford Bay constrain the timing of the lowest elevation of the highest tides during the Late Glacial and Early Holocene to around 11 000 a BP (marked in by the yellow line). Aerial photography from © Getmapping Ltd (2024). [Color figure can be viewed at wileyonlinelibrary.com]

temporary benchmark (TBM) just above the high tide mark, with post-processed kinematics (PPK) applying ephemeris corrections from the Loch Carron Ordnance Survey base station (Ordnance Survey identifier: LCAR). A total of 20 control point locations were then surveyed to the TBM using a theodolite level across the foreshore, with their locations recorded with a Garmin 12 XL handheld GPS and supplementary photographs taken at each location. The 20 control point locations were spatially distributed, at points easily identifiable in the drone imagery and possible to reach given the tidal constraints. Elevation corrections from the survey were applied to the drone survey DEM in ArcGIS Pro Version 3.1.4. Results from the elevation-corrected bathymetric model show a gently sloping (~0-3%) intertidal zone upon which the stone circular alignments are situated. They occur in the range of 1.83–4.14 m below modern mean sea level (MSL) (Fig. 8).

An estimate of the elevation of deglacial RSL was acquired from the PALTIDE data portal tool (Ward et al., 2016; Scourse et al., 2024), which sources RSL estimates from a glacial isostatic adjustment model (Bradley et al., 2011). This model-estimated RSL was—3.26 m at 12 000 a BP, −7.13 m at 11 000 a BP and −2.46 m at 10 000 a BP. Given the stone circular alignments were very likely formed above the highest tides, a 3.15 m OD tidal correction (based upon the known elevation of the modern highest astronomical tide at Broadford Bay) is applied to these RSL values to provide an estimate of the elevation of the highest astronomical tide (HAT) paleo-shoreline. This means that c.11 000 a BP is the only time during the deglaciation that the highest tides (approx. −3.98 m OD) would have been at or below the elevation of the majority of the stone circles (Fig. 8). From 10 000 a BP onwards, RSL was at or above the elevation of the stone circles (Bradley et al., 2011; Best et al., 2022), restricting their formation.

The estimates for the position of the HAT paleo-shoreline are considered approximate, given uncertainties such as the accuracy of the bathymetric survey, which can only be undertaken in a very short (~3-h) window during the very lowest astronomical tides. In addition, any changes in sedimentation/erosion will affect the position of the modelled HAT paleo-shoreline at 11 000 a BP compared to modern. Furthermore, estimates are made assuming the modern tidal range, as this complex geography of the area means a localised paleotidal correction is unavailable, though it is most likely the tidal range was greater at 11 000 a BP, such that the elevation of the HAT palaeo-shoreline may have been slightly above that estimated in our model (Ward et al., 2016; Scourse et al., 2024). However, due to uncertainties caused by the paleotidal model grid resolution, we chose to not apply a paleo tidal correction for this site.

In addition to our bathymetry-RSL model (Fig. 8), geomorphological evidence helps further constrain the period in which the stone circular alignments likely formed, with moraines mapped offshore between Skye and nearby Scalpay, suggesting that glacial extents during the LLS in nearby Loch Ainort reached almost the opposite coast of Scalpay. Bickerdike et al. (2018) also reconstruct the maximum extent of the Younger Dryas advance in Loch Sligachan seaward of the field site at Sconser (Fig. 9). No precise date is available for this advance, but it likely occurred within the LLS at 12 900–11 700 a BP the circular alignments must have been formed after this, given their *in-situ* preservation. Together with our bathymetry-RSL model (Fig. 8), this supports Hardy et al.'s (2021) hypothesis that they most likely date to between 11 700

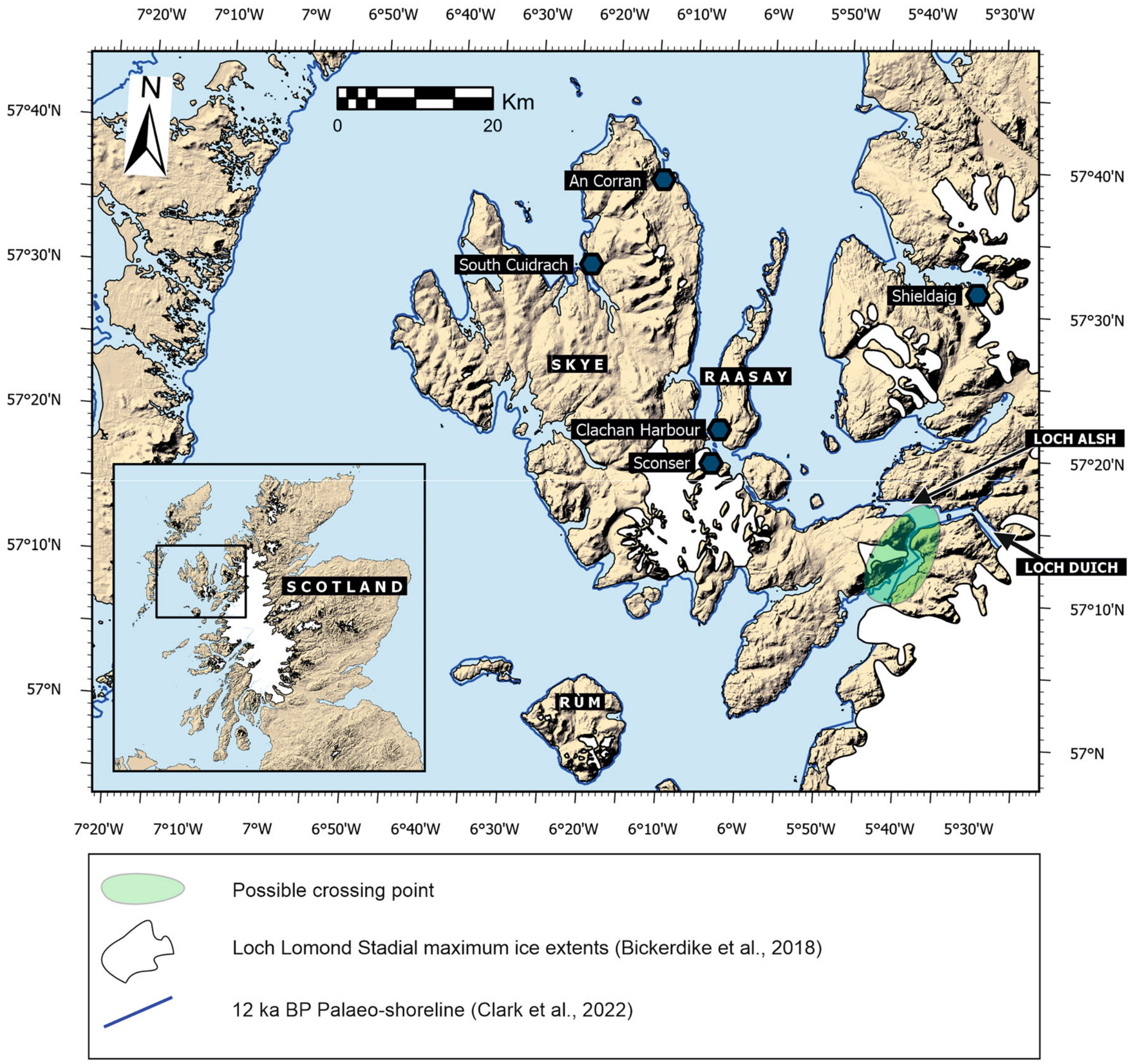

Figure 9. Map of Isle of Skye showing the Loch Lomond Stadial (LLS) ice extent (in white) during the Younger Dryas period (from Bickerdike et al., 2018) and the 12 000 a BP shoreline estimated using glacial isostatic adjustment modelling by Clark et al. (2022) (in blue), which highlights the exposed lowland terrestrial routes and the site of a potential land bridge during the lowest tides that likely existed at this time due to the relative sea level being lower than present. Topography hill-shaded to highlight relief. [Color figure can be viewed at wileyonlinelibrary.com]

and 10 000 a BP). However, with no diagnostic lithic artefacts found in association, there is no definitive way to link them directly to any of the other archaeological sites in the region, beyond this broad age range.

Discussion

Environmental and relative sea level context during the LUP in north-west Scotland

The Late Glacial and Early Holocene periods, following the maximum extent of the British-Irish Ice Sheet, were marked by significant changes in ice extent, climate and RSL (Clark et al., 2022), which provide a critical framing for the LUP finds on Skye. Limited empirical evidence suggests that the Skye ice cap separated from mainland ice by 16,000 BP (Small et al. 2016); though ice sheet modelling suggests that the majority of Skye may not have been ice-free until c.15 000 a BP (c. 13 000 BC) (Clark et al., 2022) (Fig. 1). From 16 700 to 14 700 a BP, the topography of the Sound of Raasay means ice retreat was likely slow (Bradwell et al., 2019, 2021) with a small increase in the ice front associated with the Wester Ross Readvance (c. 15 300 a BP; Ballantyne and Small, 2019). Glaciers on Skye (e.g., Loch Ainort, Loch Sligachan) were likely also constrained to fjord mouth settings during this time (Small et al., 2016).

Abrupt warming was instigated from c. 14 700 a BP at the onset of the Bølling-Allerød Interstadial. During this time, ice-front margins retreated rapidly, in most cases to within their LLS readvance limits (meaning there is little preserved empirical evidence of ice extent) and, though debated, it is largely thought that ice did not entirely disappear from the upland areas of western Scotland (Ballantyne & Small, 2019). During the subsequent cold Younger Dryas (LLS) period (12 900–11 700 a BP), ice in the upland areas of the British Isles readvanced (Bickerdike et al., 2018), resulting in a significant ice barrier (termed the Western Highlands glacier complex) to animal and human migration over much of mainland western Scotland (Fig. 1). On the Isle of Skye, there is extensive geomorphological evidence for an LLS readvance over the Cullin Hills (Fig. 9), with a smaller ice cap also forming to the southeast over the Kyleakin Hills (Bickerdike et al., 2018). There are limited chronological constraints on the timing of the LLS ice advance on Skye, with reappraisal of a sole ^{10}Be age on a glacial erratic at Coire Fearchair suggesting glaciation within this cirque occurred at the start of the Younger Dryas, around 12 900 a BP (Bromley et al., 2023). Though debate continues around the exact timing of the LLS and forcings associated with the Younger Dryas cooling, it is widely accepted that local ice advances occurred at least over several centuries at the end of the Late Glacial over large parts of western Scotland (Bickerdike et al., 2018). Mapping of the LLS ice extent on Skye shows that the ice extent reached the modern coastline around the Cullin Mountains (Bickerdike et al., 2018), with offshore data from Loch Ainort, suggesting that local ice positions could reach into the sound between Skye and the island of Scalpay (Dix and Duck, 2000) though the area was very likely exposed land at the time due to lower RSL (Fig. 9).

The pattern of Late Glacial ice retreat over Skye (as summarised above) means the rate and magnitude of RSL change differ from the north to south of the island (Best et al., 2022; Scourse et al., 2024). Empirical data from south Skye suggests a trend of falling RSL from 16 000 to 12 000 a BP (Shennan et al., 2018), with the elevation sea level at c.15 100 a BP ~ 20 m above present, falling rapidly to 11.59 m above present by c.14 200 a BP (Best et al., 2022). RSL is then thought to fall to around, or just below, present-day levels c.12 000–11 000 a BP (c. 10 000–9000 BC) (though this is unconstrained by field data), then rising to ~4 m above present during the early and mid-Holocene (Selby and Smith, 2006, 2015; Shennan et al., 2018). By comparison, little data constrains the absolute elevation of the Late Glacial sea level in northern Skye (Selby and Smith, 2006; Shennan et al., 2018); however, recent glacial isostatic adjustment modelling suggests the elevation of the sea level in northern Skye from c.15 000 to 7000 a BP was always below or at modern, rising up to 3 m above present during the mid-Holocene (Bradley et al., 2011; Clark et al., 2022; Scourse et al., 2024). This means that areas of the now-submerged foreshore around Skye were likely exposed for much of the Late Glacial and Early Holocene, providing an environmental context for some of the lithics at South Cuidrach, as well as the stone circular alignments at Sconser. Lower RSL also resulted in land bridges in central Skye between now-separated islands, most notably Skye, Raasay and Scalpay, and provided a terrestrial corridor from c.12 000 a BP outside the Younger Dryas (LLS) ice extent (Fig. 9). There may have been a land bridge (or very narrow crossing, <300 m wide and likely walkable during the lowest Spring tides) c.12 000–10 000 a BP between mainland Scotland and south Skye at the Kylerhea Narrows (Fig. 9) although the range of possible ice histories and changes in coastal geomorphology means that there is some uncertainty in the exact topography and the duration of these land crossings (Clark et al., 2022).

Timing of the Ahrensburgian

Crombé et al. (2024) suggest timing for the Ahrensburgian towards the later part of the Younger Dryas and into the Early Holocene, from around 12 200 cal a BP. There are several sites in central and southern England with lithic evidence that has been identified as Ahrensburgian, including Three Ways Wharf, which has radiocarbon dates that cluster around 12 400–10 500 cal a BP (Lewis and Rackham, 2011). Ahrensburgian artefacts were also found at Killerby Quarry, in Yorkshire (Waddington et al., 2020; Hudson et al., 2023). The lithic technology from many other sites of this period in England suggests a southerly influence most likely coming from what is today, France. This has not currently been identified in Scotland.

The exact timing of the Ahrensburgian occupation of Scotland is unknown as no radiocarbon datable material has been recovered; however, occupation in and around the Isle of Skye and Inner Sound as well as other sites on or near the western margins of Scotland are likely to have been constrained by the Younger Dryas (LLS) expansion. Yet, even towards the later part of the Younger Dryas, access to the west of Scotland was likely challenging due to the extensive LLS glaciers (Fig. 1); these did not begin to melt until around 11 600 a BP, although sea levels were relatively low at this time, and not all ice maxima would have been synchronous, therefore access to western Scotland cannot be ruled out. To the north of the main LLS ice mass, there was an ice-free corridor to Lochalsh (Fig. 1) that passed through Shieldaig (where an Ahrensburgian point was found), although reaching Skye itself would have likely required a short sea crossing at Loch Alsh to Skye directly or across the land bridge at Kylerhea Narrows (Fig. 9). Lower RSL means Raasay was connected to Skye, and it is notable that two of the sites, Clachan Harbour (Raasay) and Sconser (Skye), would have been intervisible and located at some distance from the coast at the time. Marine travel to north east Skye and An Corran would therefor have required travel up the eastern coast of Raasay.

Other Ahrensburgian findspots in Scotland occur on the islands of Tiree, and two islands in Orkney (Fig. 1) and in Islay south-west Scotland where Mithen et al. (2015) suggest a Younger Dryas—Pre-Boreal age for a possible Ahrensburgian presence. All these remained islands throughout the period (Clark et al., 2022) and would have required sea/land hopping. This is not considered a hindrance; maritime transport may have been a faster way to travel around these complicated lands and seascapes. In Fennoscandia, radiocarbon data suggest a human presence along the north and west coastlines while ice sheets were still in place. This is thought to have been made possible by the use of maritime transport by highly mobile groups who were accustomed to variable environments and likely possessed strong adaptive abilities (Kleppe, 2017). However, extensive maritime movement northwards along the western seaboard of Scotland does not appear to have occurred. Bloodstone is a high-quality raw material that outcrops on the island of Rum, where it is highly visible as a large hill on the island's west coast, 12 miles off the south-west corner of Skye. However, it does not appear at South Cuidrach until the Late Mesolithic and does not occur in any of the LUP assemblages in Scotland.

Since deglaciation did not begin in Scotland until shortly after the start of the Holocene, around 11 600 a BP, conditions would have been volatile as the glaciers rapidly melted. This date is towards the later part of the continental timing for the Ahrensburgian. Consequently, either groups of Ahrensburgians reached Scotland while the LLS glaciers were in place, or they represent a late survival, reaching Scotland after the ice sheets had begun to recede. However, so far, no Ahrensburgian artefacts have been recovered from areas that were covered by ice sheets during the Younger Dryas (LLS), which would confirm an LUP presence following the disappearance of the ice.

Mobility. How did they reach Skye?

Bell (2020) suggests that migratory routes can be predicted based on landscape features such as bodies of water and 'dramatic topography'. In the Late Glacial period, any reconstruction of routes in Scotland necessarily begins with a consideration of ice cover and RSL change since these have such large spatial and temporal variations. At a broad scale, the southern half of the North Sea (Doggerland) was dry land during the Bølling Allerød (Late Glacial) Interstadial following the retreat of the ice from c. 21 000 a BP until its full submergence by c. 8000 a BP (Gaffney & Fitch, 2022; Clark et al., 2022, Walker et al., 2022). At its peak, Doggerland covered the southern North Sea up to approximately the middle of England and then stretched in a northeasterly direction to northern Denmark where there is extensive evidence for an LUP presence from the Hamburgian onwards (Pedersen et al., 2022). Where the Ahrensburgian people first reached Britain is not known, but based on the lithic evidence, it is likely that LUP populations travelled in a northwesterly direction across Doggerland from what is now, Germany and Belgium, rather than passing through southern England (Ballin, 2016) (Fig. 10).

The Ahrensburgian is known primarily from the lowlands of north Germany, southern Scandinavia, the southern Baltic, England and Poland, all part of the North European Plain. The evidence for a LUP presence along Scotland's north-east coast (Ballin 2017, 2019, 2021) is unsurprising; these low-lying landscapes would have been familiar to the north European LUP populations. To reach north-west Scotland would have involved complex travel across unfamiliar terrain, comprising steep mountains and large bodies of water in the form of lochs (lakes) that begin in south central Scotland and continue to its north coast, through the central and western half of the country.

Scotland's topography is a limiting factor in cross-country movement. By combining this with the state-of-the-art ice sheets and sea level reconstructions (Bickerdike et al., 2018; Clark et al., 2022; Scourse et al., 2024) and the distribution of known sites and findspots, it is possible to identify 'hot spots' where these pioneer populations would have likely had to pass through, thus providing a focus for future research. There were large rivers in Doggerland, and the Tyne and Tees in northern England would also have needed to be navigated or circumvented. To move into north Scotland, humans would first have had to navigate or cross the Tweed or Clyde rivers. Both rivers begin in the Lowther Hills, where the Hamburgian site of Howburn (Fig. 1) is situated, while the other major river, the Forth (31 km wide at its mouth), begins further north at Ben Lomond, a location that was beneath the ice sheets at 11 600 cal a BP. The Great Glen, a geological fault that runs in a north-easterly–south-westerly direction along the length of Scotland, also had to be crossed or circumvented to reach north-west Scotland. Until there was a significant up-valley ice retreat in the early Holocene, direct east-west travel to Skye would have been impossible, and even then, there is a constrained number of valleys (glens). Migration could only have occurred either before or well after the Younger Dryas, or around the ice sheets. Even then, it would have involved coastal hopping and some sea travel from both the north and south (see Fig. 1). The single tanged point from Shieldaig, on the mainland north-east of the Isle of Skye, perhaps indicates a northern route. In Skye, the glaciated Cuillin Mountains also formed a barrier to terrestrial movement northwards until the ice melted, although low RSL provided lowland coastal routes between the (modern) islands of Skye, Scalpay and Raasay.

Subsistence and adaptation

The Ahrensburgian culture was first identified at the site of Stellmoor in north Germany where hundreds of reindeer bones were recovered, leading to a perception that subsistence was focused exclusively on animal hunting (Price, et al., 2017). Since this early work, a broader picture of Ahrensburgian life and subsistence has developed and become more nuanced with evidence from a wide range of different locations. Lithics still form the major part of Ahrensburgian cultural information because these survive well, but piecing together small amounts of other available evidence helps to develop a wider perspective.

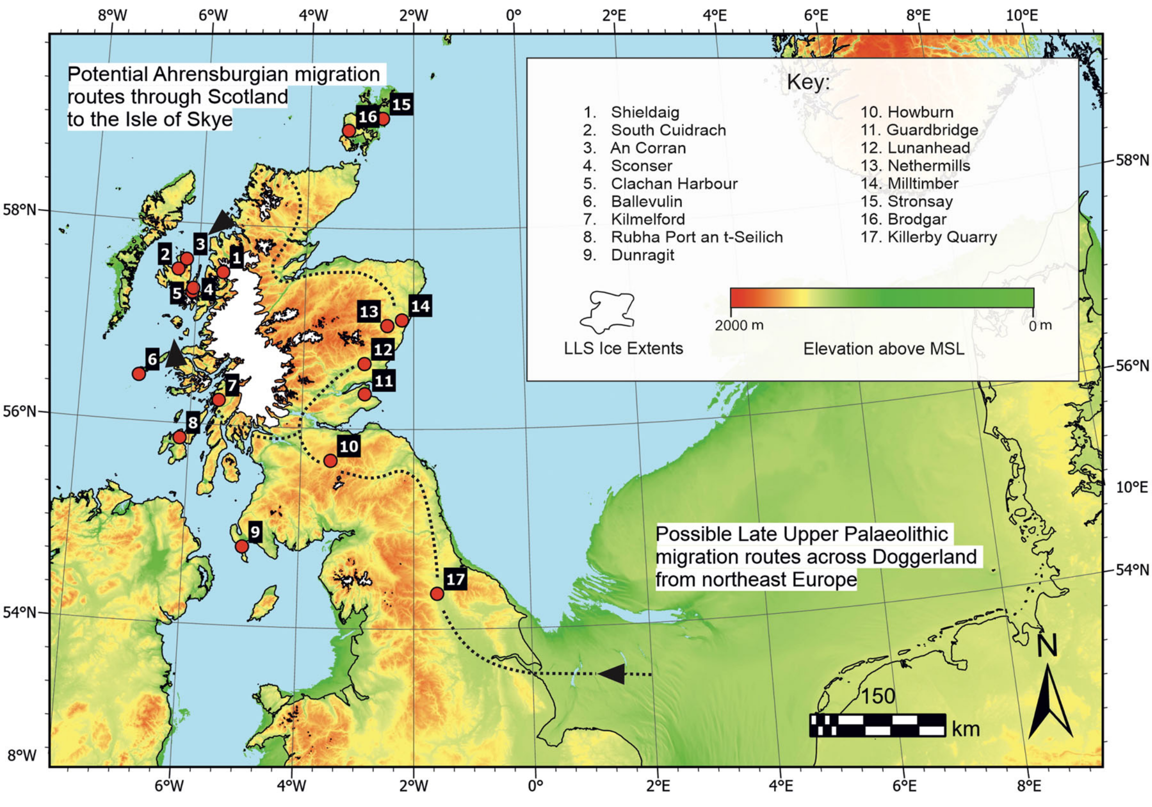

Figure 10. Paleogeography of Doggerland (modern southern and central North Sea) and British Isles at 12 000 a BP based upon glacial isostatic adjustment modelling by Clark et al. (2022) and the Loch Lomond Stadial (LLS) ice extent (in white) from Bickerdike et al. (2018). Lower relative sea levels at this time provided a terrestrial migration route for the Ahrensburgian people from northwest Europe. The exact route across Scotland to the Isle of Skye, north or south of the LLS ice mass, cannot be constrained by the existing data. However, the presence of exposed coastal routes, fluctuating valley glacier margins, and relatively short sea crossings—due to the sea level and ice sheet conditions during the Younger Dryas—means that neither possibility can currently be ruled out. [Color figure can be viewed at wileyonlinelibrary.com]

The possibility that the Ahrensburgian people may have also exploited coastal resources has been suggested before (Schmitt et al., 2009; Glørstad, 2016). Lewis & Rackham (2011) detected the use wear evidence that suggested cutting fish, whittling wood, boring antlers and possibly scraping hide, from a site in southern England. From the southern Baltic, Adamczyk (2021) has identified the use of harpoons and probable exploitation of water resources, such as fish, waterfowl, mammals and molluscs and suggests that while there is no concrete evidence as yet, there would have been ample opportunity to exploit the many edible plants including berries and *Cyperaceae*. While the amount of *Betula* (birch) diminished in the region during the Younger Dryas, pollen suggests that, while Scotland was largely treeless at this time (Edwards et al., 2019), birch continued to be present in low amounts (Walker and Lowe, 2019) and then increased significantly during the early Holocene (Edwards et al., 2019). Some parts of birch trees, such as the inner bark (cambium), can be eaten, while the trees offer wonderful raw materials for the construction of material items. Cziesla (2018) suggests exploitation of different fish species and freshwater seals based on particular harpoon shapes, while Winkler (2019) suggests that in continental Europe, animal species exploited include reindeer, elk (*Alces alces*), roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) with species of fish and fowl also evident from bone assemblages. Several authors have also identified antler axes, and Mevel et al. (2019) have identified the use of uniserial and biserial barbed points and a fishhook. The location of South Cuidrach reinforces the maritime perspective suggested by Schmitt et al. (2009). While there is direct access to upland areas and abundant environments for terrestrial animals at South Cuidrach, it is situated on the shoreline. It is unlikely that the inhabitants would have crossed this geographically complex island from the raw material source on the east coast at An Corran unless they specifically aimed to reach a location suitable for the coastal and riverine exploitation offered by South Cuidrach's west coast position.

More broadly, South Cuidrach raises new questions about the nature of the Ahrensburgian culture, its distribution, mobility and the way people evidently adapted to the rapid climatic and environmental changes. Whether the Ahrensburgians were in Skye before, during or immediately after the Younger Dryas (LLS), the environment is likely to have been mostly periglacial tundra. A combination of evidence suggests that the area may have had its coldest temperatures during the latter part of the Younger Dryas (Walker and Lowe, 2019). Environmental reconstruction based on a pollen core from Loch Ashik in south Skye indicates a low amount of *Betula* and *Rumex*, a decrease in *Gramineae* (grasses), consistent amounts of *Salix* and an increase in *Empetrum* (crowberry) and *Cyperaceae* during the Younger Dryas, with this pattern gradually reversing as the climate warms up in the Early Holocene (Pre-Boreal) (Walker and Lowe, 2019). Localised areas of pine, whose inner bark is also edible, may have been present in parts of north-west Scotland throughout this time, potentially representing a survival that extended even through the Late Glacial (Edwards et al., 2019).

The lithic raw material used at South Cuidrach during the LUP is baked mudstone. This is only present as an accessible outcrop of knappable raw material in north-east Skye, at An Corran (approximately 16 km north-east of South Cuidrach). Here, it is present within the local igneous rocks as rafted sediments altered by contact metamorphism (Saville et al., 2012). It is a fine-grained, black (monochrome), flint-like lithic raw material with excellent flaking properties. When weathered, its outer surfaces disintegrate and become powdery and this changes to light grey or fawn.

No extraneous raw materials have been encountered, suggesting that the inhabitants of South Cuidrach were not new to the region. Other locally available raw materials include quartz, small flint nodules found on the beach to the west of An Corran and bloodstone, which is common in regional Late Mesolithic assemblages. But none of these has been detected in the LUP assemblage.

The Trotternish peninsula in north-east Skye where the raw material source is located on the east coast, and South Cuidrach on the west coast, is split by an escarpment with few possible crossing points. A direct route between these two places is ~16 km, crosses an area of steep, high ground and requires navigation through the escarpment. Alternative land routes can be found to the north of the escarpment (approx. 23 km) and to the south (approx. 42 km). Travel by sea (approx. 36 km) is another alternative. The coastline to the north and south of An Corran comprises largely high cliffs; however, there is a large bay close to the raw material source where boats could land. Skye and the area around it will have offered an outstanding location for these LUP populations notwithstanding the highly volatile climatic and environmental conditions. The raw material source at An Corran provided local good quality materials, while this region is renowned still today, for being resource-rich. At South Cuidrach, the juxtaposition of the nearby uplands, likely home to deer and other large mammal populations, with the coastal and shoreline resources—including waterfowl, a wide range of marine mammals from seals to whales, fish, and shellfish—along with the adjacent freshwater lake and nearby river would have provided an abundant variety of plant and animal resources. Ochre is visible in a quarry cut to the north-east of the site and also appears as an outcrop to the south-west at Lyndale Point, around 1 km away. It is likely that these form part of a seam that crosses in front of the site across Loch Snizort as it is found readily on the beach in front of the site. This ochre was used here during the Late Mesolithic, and while its use in the Ahrensburgian is speculative, its presence may well have also been a reason for selecting this particular location. The site at Sconser is also notable in that the tidal flat where the circular alignments are located, is one of the few areas on this coastline with flat ground in a steeply mountainous area. It is adjacent to a paleo channel that would have flowed through what is now Loch Sligachan.

Conclusions

The confirmed presence of LUP, most probably Ahrensburgian, people in north-west Scotland offers a new perspective on this culture. Regardless of the route the LUP people took to reach Scotland, the wide geographical distribution of finds suggests they spread across much of the country. For these cultural groups, whose experience was likely rooted in the low-lying plains of their northern European homelands and Doggerland, moving into central Scotland and crossing its mountainous terrain—while potentially navigating fluctuating ice sheets and large bodies of water, both on the mainland and the Isle of Skye—would have presented an entirely new geographical context. Additionally, the suggested evidence from the islands of Tiree, Orkney and Islay implies significant sea journeys. In Skye, they discovered the extraordinary, yet very localised, baked mudstone raw material source, traversed this geographically complex island, and established themselves in a coastal setting on the west coast. Living in and around Skye required a combination of marine transport and the ability to adapt to a rapidly changing climate and environment, within a volatile, rebounding landscape dominated by mountains and seas and little low-lying land.

The reason they came to South Cuidrach is unknown; perhaps it was the ochre. However, this location suggests a focus on coastal and marine resources. The raw material source is some distance away, suggesting that, although few locations have surviving evidence today, the LUP inhabitants of Skye were likely familiar with their area and deliberately selected South Cuidrach. The abundant intertidal remains at Sconser indicate either a reasonably sized population or long-term occupation. Furthermore, the absence of lithic raw materials from outside Skye suggests the presence of an established population.

While the number of Ahrensburgian findspots is low, they are spread widely across Scotland, suggesting a larger population than the number of finds might imply. To date, all LUP sites in Scotland have been discovered by chance, and there is insufficient evidence to address further questions regarding their adaptations and lifestyles. By reconstructing the geographical limitations imposed by ice sheet evolution, changes in RSL and river courses, it may be possible to focus on likely locations—both onshore and offshore—and begin to uncover more evidence.

Recovering evidence for a LUP presence in Scotland presents challenges unmatched in continental Europe. However, despite being distant from its central area, the evidence from Skye reflects an Ahrensburgian presence, at the extreme north west continental limit, extending its distribution. The people who made these artefacts originated in the mainland of northwest Europe, crossed Doggerland into what is now Britain, and eventually reached the far north of the Isle of Skye. Here, they adapted to live in a fragmented, fluctuating, and volatile environment amid melting glaciers, mountains, and oceans—vastly different from the low-lying environments of their homelands on the northwestern edge of the Great European Plain.

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Data availability statement

The data that support the findings of this study are available from the corresponding author [K.H.], upon reasonable request.

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