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QUATERNARY NEWSLETTER

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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant issues are 5th January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue.**

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (800 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps, .tif or .jpg format (minimum resolution of 300 dpi is required for accurate reproduction). Quaternary Research Fund and New Researchers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. Ph.D. topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects.

NB: Updated guidelines on the formatting of contributions are available on the QRA website or from the editor.

COVER PHOTOGRAPH

A boulder in Tierra del Fuego, southernmost Patagonia, the inspiration for Harold Lovell's poem 'The Boulders of Bahía Inútil', included in this issue as QN's first piece of Creative Work.
Photograph taken by Will Christiansen.

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AN IGNEOUS ERRATIC AT LIMESLADE, GOWER, AND THE GLACIATION OF THE BRISTOL CHANNEL

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In January 2022 a large dolerite erratic boulder was discovered on the rocky foreshore of Limeslade, near Mumbles, by local resident Phil Holden. It is located between HWM and LWM in an area of southward-dipping Carboniferous Limestone beds, at grid reference SS624870 (Fig. 1). It rests in a deep gully or crevice, flanked by water-worn outcrops and pinnacles of bedrock with abundant solution pits and sharp-edged ridges (Fig. 2). It sits in a shallow rock pool, supported by boulders of mostly local origin. There are abundant beach gravels, cobbles and boulders in the vicinity, which contribute to the abrasion of bedrock outcrops and the surface of the erratic. The environment is affected by waves during the rise and fall of every tide, and it is possible that the erratic is occasionally buried by these mobile beach materials.

Figure 1. The rocky foreshore of Limeslade Bay, near the Mumbles. The erratic boulder is in a narrow crevice, top right. Most of this area is submerged at high tide. *(Photo: courtesy TheDeacon1323)*

The boulder cannot have been derived from anywhere in the vicinity, since the Gower Peninsula is made up almost entirely of Carboniferous and Devonian sedimentary rocks (Fig. 3) on the southern edge of the South Wales Coalfield. Carboniferous limestones crop out extensively across southern Gower, but to the north of the Mumbles Peninsula and Limeslade Bay there are exposures of mudstones and sandstones belonging to the Marros Group and also mudstones, coal seams and sandstones of Lower Coal Measures age, in Swansea Bay. Pennant Sandstones crop out extensively to the north of Swansea and Penclawdd in the core of the coalfield syncline. The nearest igneous rocks are found in central and northern Pembrokeshire, about 65 km away.

Figure 2. The erratic boulder resting in its crevice between the tide marks on the rocky limestone foreshore. At one end it has a more or less triangular cross section. The shape of the underside is not known.

In Limeslade Bay the newly discovered boulder is invisible from a distance, and from a few metres away it may appear to be just another detached mass of limestone bedrock; but on close examination it is seen to have a distinct greenish hue and a coarse surface texture. It measures c. 2.2m x 1.3m x 1m and has an irregular shape, with a somewhat triangular cross section. It has a twisted bulbous feature at one end and a flattened surface at the other, with a number of approximately parallel fractures from which thin slabs of rock have broken off, probably as a result of pounding during storm conditions. The ridge or top edge is smoothed, and on one flank there are signs

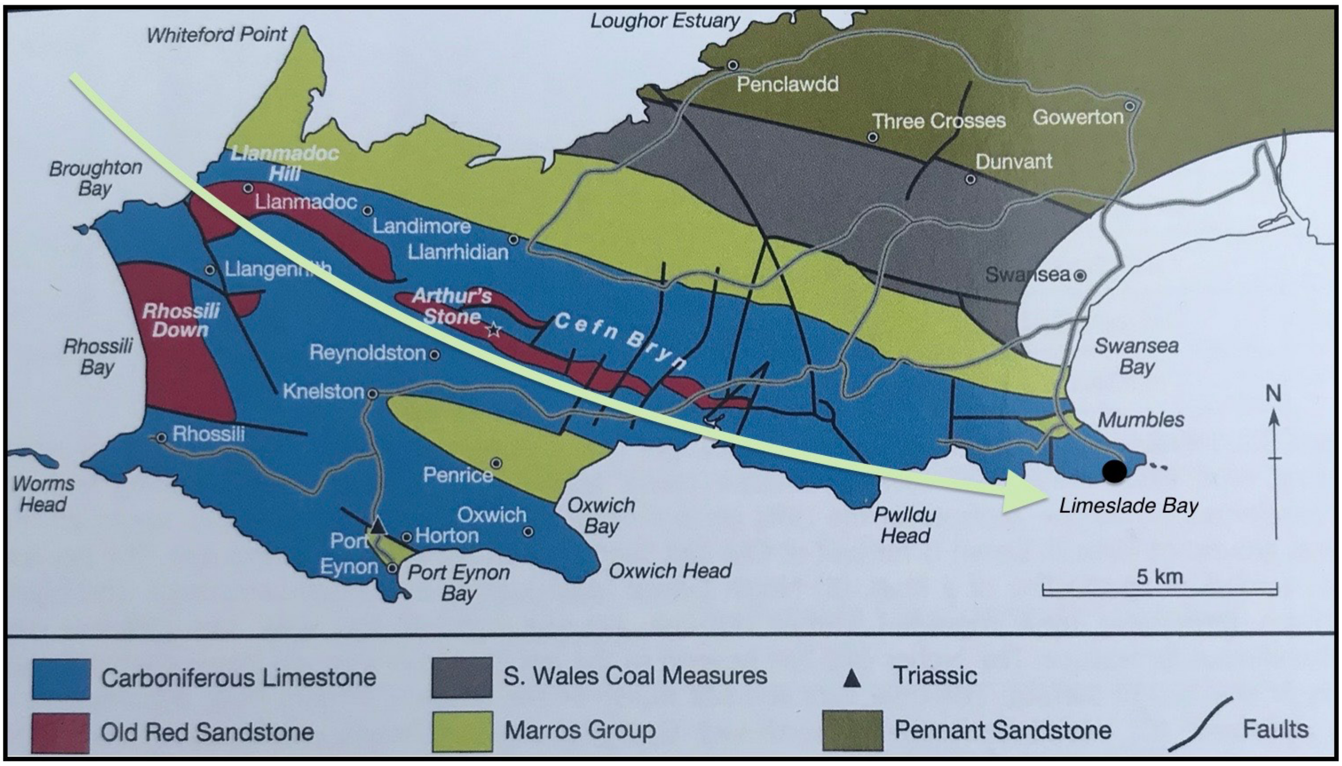

Figure 3. Simplified bedrock geology map of the Gower, showing the extent of the Carboniferous Limestone outcrop, the location of Limeslade Bay and the postulated direction of erratic transport. *(Source: G.Owen and QRA, Gower Field Guide, 2015.)*

of facets (now heavily abraded) which are suggestive of damage during transport. The weight is estimated as c 5 tonnes, but in the neighbourhood there are small boulders of the same rock type (Fig. 4), so it is possible that at one time the erratic was substantially larger.

The boulder surface is remarkably fresh; if there ever was a weathering crust, it has been removed by constant pounding and abrasion by waves. On close examination the crystal structure is quite visible. The rock's colour is very similar to that of fresh unspotted

Figure 4. Some of the small "matching" igneous cobbles found in the vicinity of the larger Limeslade boulder.

dolerite surfaces in the western part of Mynydd Preseli in Pembrokeshire. A small flake from the bottom surface of the boulder was examined by igneous geologist Dr Katie Preece at Swansea University. She reported that the rock is made of greenish unspotted dolerite or micro-gabbro with crystals of feldspar and pyroxene, similar to another rock sample from Foel Eryr on Mynydd Preseli but with slightly larger crystals. Crystal size is linked to cooling rate - so the same intrusion can have a coarser (slower cooled) interior portion and finer (quicker cooled) exterior. When the surface texture is compared visually with that of unspotted dolerites in Cilgwyn, near Newport, there is a remarkable similarity.

Professor Peter Kokelaar, who has extensive knowledge of the igneous rocks of north and west Pembrokeshire, has visited the boulder and has said this on the basis of an initial visual assessment: "It is a metamorphosed coarse dolerite (not quite gabbro), sparsely porphyritic with oscillatory- zoned euhedral and subhedral plagioclase phenocrysts mostly ~0.5 cm and up to 1 cm; dark patches could be (altered) ophitic pyroxenes. The rock shows sub-parallel feldspathic banding roughly perpendicular to the long axis (2.2m) of the boulder. The banding perpendicular to the 'columnar' length is fairly typical of some coarsely jointed sills I have mapped between Fishguard and St David's Head." One such sill occurs at Ogof Golchfa, near Porthclais (SM740236), and the similarities in hand specimens are again striking. However, visual comparisons (especially for weathered surfaces) can cause confusion, and no further precision in provenancing has been possible until now.

Geological Analyses

Two fragments taken from the underside of the boulder have kindly been analysed by Prof Tim Darvill (TD) and by Dr Steve Parry using pXRF and thin section analysis. The results (Table 1) are instructive, but they highlight the need for more intensive analyses, preferably using non-invasive methods.

The Limeslade study was undertaken in order to test the hypothesis that the boulder might have come from one of the dolerite outcrops at the eastern end of Mynydd Preseli. All figures represent ppm measurements, which means that direct comparisons are not possible with much of the past geochemistry work on Preseli which presented oxide percentage weights for the major elements and ppm measurements for the trace elements. However, comparisons are possible with some of the figures published by Thorpe et al (1991), Pearce et al (2022) and Bevins et al (2022) in which element concentrations are given in ppm.

The most striking feature of the 3 columns of Carn Meini figures is the disparity between the TD readings (average 99.1 ppm for Ni) and those of Pearce et al (2022) where the average across 165 readings is 42.5 ppm. Not one of the 165 readings was over 90 ppm, raising the possibility of calibration or instrumental

Table 1: Average compositions (ppm) for elements, from pXRF analyses

Element	Limeslade erratic	Carn Meini	Carn Meini	Carn Meini	Carn Goedog	Carn Goedog	Cerrig Marchogion	Cerrig Lladron	Carn Ddu Fach	Carn Ddafad-las
Mo				5.4		5.1	5.4	4.9	4.85	4.7
Zr	111	68	70.6	64.5	69	59.2	65.1	73.9	61.4	78.5
Sr	223	276	231	241	228	217	245	216	319	278
Rb	8.8	19	5.7	9.7	9	5.9	6.9	7.4	5.4	6.3
Pb			15.8	48.8		46.4	56.9	40.3	49.7	54.0
As	5.6		12.6	46.9		26.6	71.2	22.3	63.0	33.8
Zn	88	68	79.6	29.6	75	42.3	45.5	58.4	54.2	50.4
Cu	64	60	78	26.6	41	29.6	26.6	26.0	26.3	25.9
Ni	96.2	29	99	42.5	43	49.6	62.4	83.5	94.2	83.0
Co				206		202	250	236	227	206
Fe	58478		62746	30165		44374	47127	56986	50784	53586
Mn	1007		1725.0	504		731	772	932	891	946
Cr	141	213	221	101	523	148	136	141	116	116
V	172	190	157	107	205	123	155	168	156	170
Ti	5342		2720	2310		3315	3166	3923	3664	5288
Ca	58871		39755	37175		43957	44731	41457	43185	41895
K	3240		2253.4	4131		3420	4377	4576	4582	4005
S			783.4	2081		1973	2058	2124	2214	1558
Ba	544	326	452	313	113	493	458	298	566	529
Nb		3		3.6	4	3.8	3.9	4.5	4.2	4.3
Al	17139		12533.0	21248		25520	22988	32329	32771	31940
P			1040.0	549		565	506	806	567	489
Si	103691		73379	81237		96108	91556	114913	114247	128119
Cl				757		343	658	673	646	430
Mg	2410		1502.4	9616		10366	11803	14457	12968	13549
All in ppm	TD	RT et al	TD	NP et al	RT net al	NP et al	NP et al	NP et al	NP et al	NP et al

Table 1. The geochemical compositions of three "control samples" of spotted dolerite from Carn Meini and the average of three analyses of the same sample from the Limeslade boulder, with other columns providing data from the unspotted dolerites in other Preseli tors. Yellow highlights: noteworthy "high" readings. Blue highlights: noteworthy "low" readings. *Data courtesy Prof Tim Darvill. Sources are acknowledged on the bottom line: TD = Tim Darvill, RT = Richard Thorpe, NP = Nick Pearce.*

error. On the other hand the Rb readings reported by Pearce et al for Carn Meini averaged at 9.7 ppm, with a very wide scatter, whereas the TD readings were lower, averaging at 5.7 ppm. For Ba, the TD figure is 452 ppm and the Pearce et al figure is 313 ppm. The discrepancies are even wider for Fe: 62,746 ppm for the TD readings and 30,165 ppm for Pearce et al. There are similar wide discrepancies for the elements Pb, As, Zn, Cu, Mn, Cr, V, K, S, Al, P, and Mg. Again it is possible that these anomalies are related to instrumental, environmental, procedural and human errors. But perhaps the greatest reason for these discrepancies (and the wide scatter of plotted points on bivariate graphs) is that Carn Meini is not a single tor but an association of tors, with at least ten prominent craggy outcrops across 250,000 sq m of terrain. Samples have been taken by researchers from many different locations in this assemblage of tors, revealing great heterogeneity within the parent igneous mass. This contradicts the claim made by Pearce et al (2022) that there is homogeneity in the Carn Meini intrusion, based on the fact that there are near constant concentrations of Ni, Zr and Ba over 12m of stratigraphic height (see their Figure 6). That takes no account of substantial lateral variations across the intrusion which are visible to the naked eye.

When the readings for the Limeslade boulder are compared with those for Carn Meini and selected unspotted dolerite outcrops on Preseli, a number of differences are apparent. Zr exists in the Limeslade sample at 111 ppm, far in excess of any of the readings for the dolerite tors and outside the "scatter field" as drawn by Thorpe et al (1991). Zn (88 ppm) is also substantially higher, as are Ti (5342 ppm) and Ca (58871 ppm). On the other hand the following have very low comparative readings: As (5.6 ppm), Al (17139 ppm) and Mg (2410 ppm).

There is inadequate data for the creation of scatter diagrams or bivariate graphs involving the Limeslade boulder ppm readings. So it is not possible at present to say that the pXRF readings occupy a different visualised "compositional space" for trace elements than the readings for the Preseli tors.

However, following an investigation of thin sections taken from a boulder sample (Fig 5), Dr Steve Parry characterises the rock as an ophitic microgabbro. He states that in terms of its state of alteration, the constituent feldspar is argillized and some of the pyroxene appears to be uralitized, but he concludes that this is by no means a pervasively altered rock.

He reports as follows: *In detail, it can be stated that medium- to coarse-crystalline (clino-)pyroxene (the relatively strongly coloured, high relief mineral seen in PPL or plane-polarised light) is intergrown with, and commonly ophitically encloses, variably elongate, chiefly medium-crystalline, prisms of plagioclase. The pyroxene shows evidence of incipient uralitization (giving rise to a fibrous appearance and lower order interference colours seen in cross-polarized light images), while the feldspar is argillized to a greater or lesser extent (reflected in its variably turbid appearance in PPL). Localized remobilisation and overprinting by opaque material (presumably oxides of Fe and/or Ti) provides further evidence of alteration. Inferably late, interstitial, developments of*

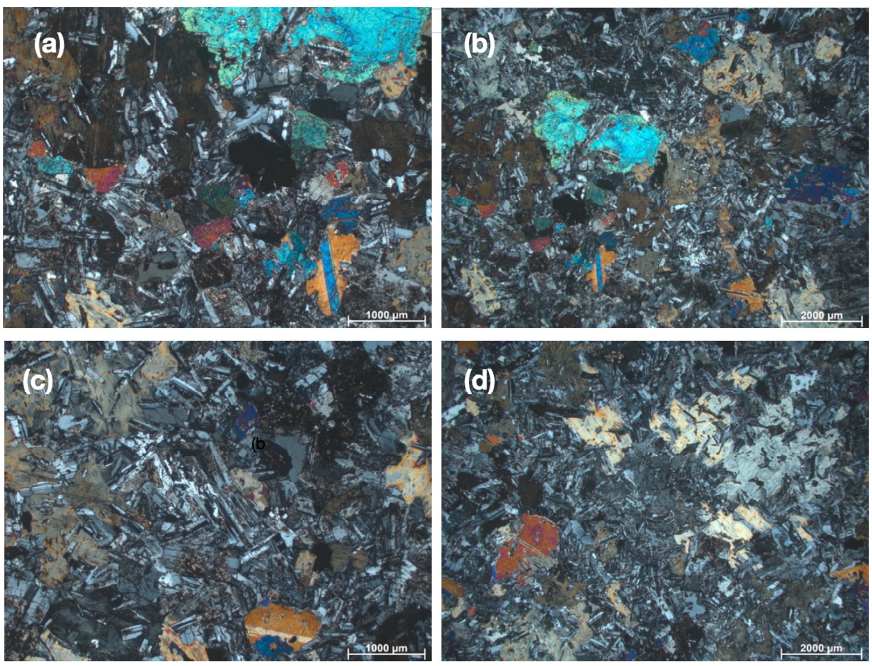

Figure 5. Thin sections (photomicrographs) from the Limeslade samples, showing general textural characteristics, courtesy Dr Steve Parry. Note the different scales. Image (a) is an enlargement of part of image (b).

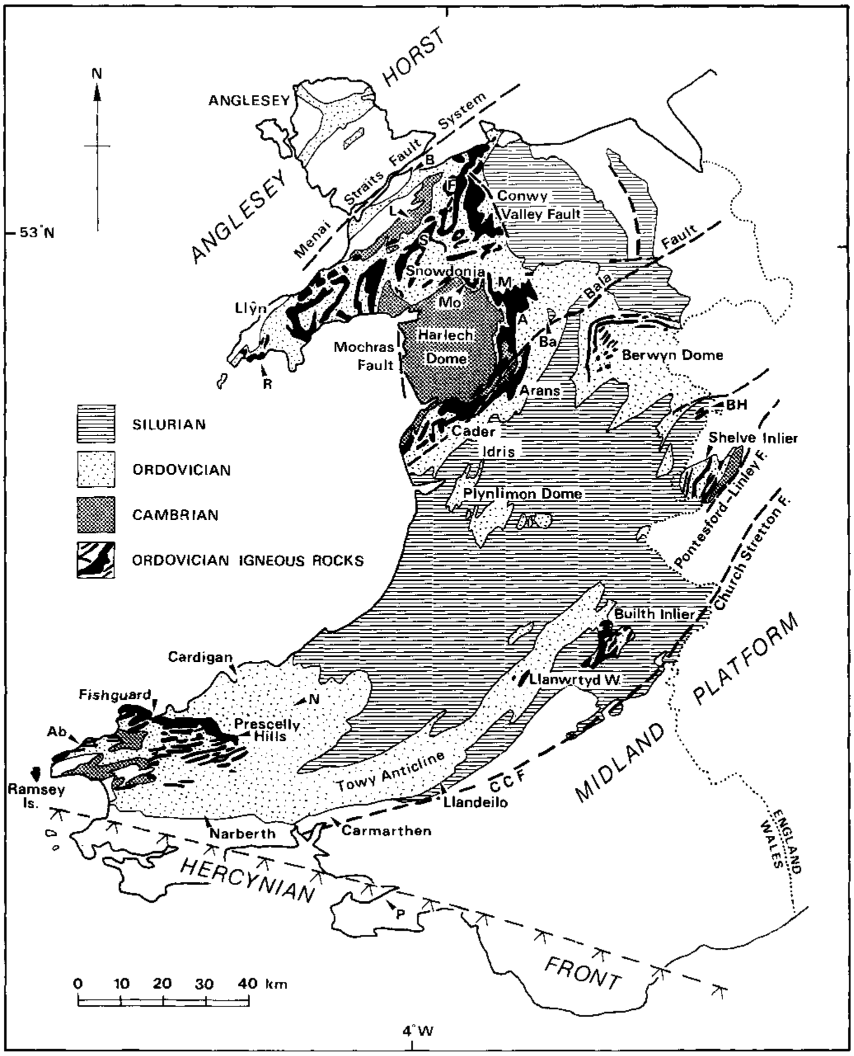

Figure 6. Ordovician igneous rocks: outcrops in Wales shown in black. *(Source: Kokelaar et al, 1984)*

quartz occur sporadically, and their occurrence is typically marked by more intense alteration of the neighbouring pyroxene and feldspar.

In summary, Dr Parry suggests that there is nothing about the petrology or geochemistry which is exceptional or particularly noteworthy. Micro-gabbro intrusions of this general type are not unusual in the Lower Palaeozoic successions of Wales (Fig. 6), but at present it would be unwise to suggest a specific age or provenance. Material of this general type does occur at Stonehenge, but further studies are needed to determine whether the erratic is a possible match for any of the bluestones or debitage.

It is already well established through detailed petrological and geochemical research that almost all of the known spotted and unspotted dolerites in the Stonehenge bluestone assemblage have come from Preseli, although there is still doubt about the precise provenances of analysed samples (Thomas, 1923; Ixer & Bevins, 2017; Bevins et al, 2014; Bevins, Pearce & Ixer, 2021). There is also an important association with rhyolite standing stones and debitage at Stonehenge, apparently having come from the northern flanks of Mynydd Preseli. Preseli unspotted dolerite is also found in hand axes, and the Implement Petrology Group has classified it as "group XIIIb", assuming that at least some of the axes were made in Neolithic or Bronze Age times from destroyed bluestones or "knock-offs" at Stonehenge. "The group comprises altered sub-ophitic dolerite, originally with clinopyroxene-plagioclase-titanomagnetite-ilmenite-apatite intergrowths. Alteration is widespread and secondary minerals include albite, muscovite, chlorite, epidote, clinozoisite, actinolite, quartz, pyrite, titanite, pumpellyite and prehnite" (Ixer and Bevins, 2018). However, there are substantial differences between samples, probably precluding a common source. Again, more detailed petrological and geochemical analyses are needed.

On the basis of this research it can be tentatively suggested that the Limeslade boulder has not come from a Mynydd Preseli outcrop. It remains to be seen whether there is a closer compositional match with either Precambrian or Ordovician dolerite outcrops in other parts of NW Pembrokeshire. There are scores

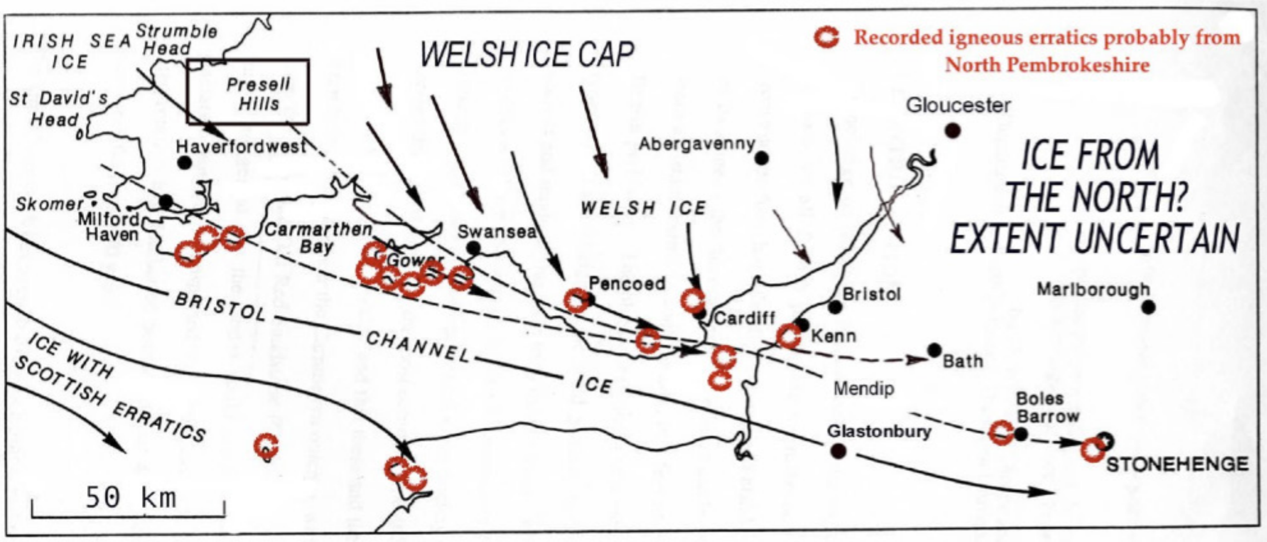

Figure 7. Ice movement directions for the Anglian Glacial episode, c 450,000 years ago. Igneous erratic distributions suggest a concentration along the contact zone between Welsh ice and Bristol Channel ice (as part of the Irish Sea Ice Stream). (Base map adapted from Kellaway 1971 with data from Mitchell 1960, Gilbertson and Hawkins 1978, Thorpe and Williams-Thorpe 1991, Williams-Thorpe et al 1991, Boulton and Hagdorn 2006, and Patton et al 2012.)

of outcrops in NW Pembrokeshire (including the St Davids Peninsula, Pen Caer and the Eastern Cleddau catchment) where narrow strips of microgabbro or coarse dolerite with a greenish tinge are exposed at the surface; as noted above, one such occurs at Ogof Golchfa, near Porth Clais (Downes, 2011), and there is another "candidate outcrop" on the prominent summit of Garn Fawr, near Pwllderi. There are other possible sources in mid Wales and in the Welsh borders (Fig. 6). The more distant sources of dolerite, for example in the Cader Idris region, in Llyn, and in Snowdonia, have in the past been considered as possible sources for the Stonehenge unspotted dolerite assemblage, but dismissed on the grounds that they are physically not well matched (Kokelaar et al, 1984; Williams-Thorpe et al, 2006; Bevins et al, 2014).

The History of the Boulder

As for the mode of transport and deposition of the Limeslade boulder, it might be claimed that it is a bluestone monolith transported by human beings and then dropped accidentally or as a result of a shipwreck in this exposed and dangerous coastal location. Atkinson (1979), Green (1997) and many others have suggested that stone-bearing seafarers passed this way, *en route* for Stonehenge. However, the boulder is an irregularly shaped lump of rock rather than an elegant pillar, and it is considerably larger and heavier than most of the Stonehenge bluestones. No evidence has ever been produced to show that in the Neolithic tribesmen from West Wales had either the technical ability or the vessels capable of transporting rocks of this size and in this environment (John, 2018).

Could the erratic be a "drop stone" transported by floating ice and then dumped on the shore at a time of relatively high sea-level? This mechanism has been discussed at great length with respect to the giant erratics on the coasts of Devon and Cornwall (Lewis (ed), 1970). The biggest problem with this "IRD" (ice rafted debris) hypothesis is that when conditions are cold enough for the presence of floating dirty icebergs in the Bristol Channel, sea level must inevitably be more than 100m lower than its present position, with a coastline far out on the Celtic Shelf. The only mechanism, at such a time, for the establishment of an active coastline in more or less its present position is isostatic depression of an equivalent value, associated with an ice cover at least 300m thick. Nothing on this scale has yet been discovered or modelled in studies of isostatic adjustments in the Bristol Channel region (Massey et al, 2008; Shennan et al, 2018). Bradley et al (2023), in a study of Devensian palaeo-shoreline positions around the British and Irish coasts, using BRITICE-CHRONO data, demonstrated that the Bristol Channel coasts were far offshore at times of possible ice rafting of debris. This is supported by the study of debris inputs and ice rafting episodes by Fabian et al (2023). However, Scourse (2024) has suggested that there was a substantial glaciation in Early or Middle Devensian time, possibly around 50,000 years ago, with ice from the Irish Sea Ice Stream crossing Pembrokeshire, extending into the

Bristol Channel, and sufficiently thick to depress the crust by around 80 m. This is not supported by the field evidence, since on the southern coast of Cardigan Bay the Quaternary sediment sequence shows only one glacial episode following the Ipswichian Interglacial — namely the Late Devensian LGM (26,000 years ago). The deposits beneath the LGM Irish Sea till are probably periglacial but do not incorporate any other glacial sediments (John, 1970; McCarroll & Rijsdijk, 2003; Scourse et al, 2021).

The IRD hypothesis is also incapable of explaining the presence of "high level erratics" in Devon and Cornwall (Madgett & Inglis, 1987). Paul Berry (2021) has described igneous erratic boulders near Baggy Point at 46 m, 60 m and 80 m altitude, and the famous Shebbear erratic lies at 150 m altitude. Prof Nick Stephens (1998) recorded erratic material in the Ilfracombe - Berrynarbour area, up to an altitude of 150 m - 175 m. High-level erratics were also plotted in the Ilfracombe area by Harmer in his famous "erratic map" published in 1928. The "apparent concentration" of big erratics between the present-day high and low tide marks arises simply because that is where large stones are washed clean by wave action and are exposed to view. Large erratics on the coasts of Devon and Cornwall are not restricted to the intertidal zone, and it is a mystery why glacial transport should be questioned, given that glacial deposits are known on the Isles of Scilly, on Lundy Island (at an altitude of c 105 m) and south of Barnstaple up to an altitude of 60m.

Could the Limeslade erratic boulder have come from the north? This is unlikely (Fig. 7), since the glacial deposits carried by southward-flowing Welsh Ice appear to have contained sandstones, grits, shales, conglomerates, limestones, quartzites and other sedimentary rocks associated with the Carboniferous sequence of the South Wales Coalfield and the Silurian and Ordovician sediments of mid-Wales. There are very few igneous rocks cropping out in a vast area affected by the south-flowing ice of the Welsh Ice Cap — and the only igneous erratics found in the "Welsh" glacial deposits of the Gower are assumed to have been picked up from pre-existing deposits carried in from the west and then laid down by the Irish Sea Glacier (Shakesby and Hiemstra, 2015; Kokelaar, 2021). The directions of ice movement in the Builth Wells and Llanwrtyd Wells area were broadly eastwards and south-eastwards, but there is a chance that igneous erratics from the Llanwrtyd Wells area might have travelled south-westwards along the Tywi trough during some glacial episodes. There is also a slight possibility that the Limeslade erratic has come from Ireland, since it is widely recognised that ice from the Irish Ice Cap fed into the Irish Sea Ice Stream as it flowed towards the Celtic Sea shelf edge. This option cannot be completely dismissed until further studies are complete.

On balance, the Limeslade boulder is most likely a glacially transported erratic, carried south-eastwards by the ice of the Irish Sea Glacier during one of the Quaternary glacial episodes. It is already known from abundant studies of glacial erratic transport that igneous rocks from North Pembrokeshire were transported southeastwards and then up the Bristol Channel during at least one glacial episode, generally referred to as the Anglian or MIS-12 glaciation. Transport and emplacement might also have occurred during the Late Devensian glacial episode (John, 2023). Dolerites are prominent in the erratic assemblages (Griffiths, 1940; Kellaway, 1971; Thorpe et al, 1991: Lewis (ed), 1970; Lewis and Richards (eds), 2005; John, 2018). This may be because dolerites are more "massive" and are less liable to comminution during transport than other rock types.

Implications

The discovery of this erratic in the SE corner of the Gower Peninsula has a profound bearing on the debate concerning the entrainment and transport of Preseli "bluestones" from West Wales towards Stonehenge. Following the assertion, a century ago, that glacial entrainment and transport would have been impossible (Thomas, 1923), it has been widely accepted by archaeologists that bluestone monoliths were either collected or quarried by tribal groups in Neolithic times and then transported eastwards to Salisbury Plain either by sea or overland. This idea has been supported by some geologists and geomorphologists (Scourse, 1997; Green, 1997; Ixer & Bevins, 2017), although many other earth scientists have been quite prepared to accept that glacial entrainment, transport and emplacement would have been perfectly possible (Judd, 1902; Kellaway, 1970; Thorpe and Williams-Thorpe, 1991; Patton et al, 2012; Elis-Gruffydd, 2017; John, 2018, 2023). In recent years Bevins and Ixer have been part of a research team led by Prof Mike Parker Pearson which has developed a narrative of Neolithic bluestone quarrying at Rhosyfelin and Carn Goedog, the establishment of a "lost circle" of bluestones at Waun Mawn, the transport of bluestones to Stonehenge as part of a ritual featuring ancestor worship and political unification, and finally the creation of specifically bluestone settings at Stonehenge.

This new narrative has been disputed (for example, by Elis-Gruffydd, 2017 and John et al, 2015) on the grounds that "bluestones" of rhyolite or dolerite were not preferentially used — and were therefore not greatly revered — in West Wales Neolithic stone settings; that the presence of bluestone quarries has not been adequately demonstrated; that the Waun Mawn stone circle (deemed to be a place where bluestone monoliths were "parked up" for several centuries) never actually existed; that no evidence has ever been found to support long-distance bluestone transport across sea or overland; and that the bulk of Stonehenge bluestones are not elegant pillars but heavily weathered and abraded boulders that would not be out of place at any present-day glacier snout (Fig. 8). Nonetheless, the narrative has been repeated multiple times by Parker Pearson and his team (e.g. Parker Pearson et al, 2021), and has been made more complex in spite of a paucity of hard field evidence.

Following Phil Holden's discovery in January 2022, the assertion that "glacial transport of the bluestones was impossible" (Parker Pearson, 2012) is now unsustainable. The narrative developed by archaeologists over the last decade is based upon questionable assertions. Indeed, there is already a substantial retreat from key components in the story in recent publications (Parker Pearson et al, 2022; Bevins et al, 2022; Pearce et al, 2022; Parker Pearson, 2023).

We still do not know when this erratic might have been entrained by glacier ice, or what route it might have followed. It may have been moved several times, over several glacial episodes, following a zig-zag course. It may have been much larger to start with. And it will be interesting to see whether the provenancing work on fresh samples from the boulder will produce clear results.

A further point of some significance is that the erratic now found on the Gower south coast demonstrates that at some stage the ice of the Irish Sea Glacier or Ice Stream was powerful enough to affect the Gower, resisting the force of Welsh ice coming off the western Coalfield and the Black Mountains (Shakesby & Hiemstra, 1995; Kokelaar, 2021). We do not know precisely where the junction between these two ice streams might have been at the time; but this new evidence confirms that the ice coming from the W and the NW must have been powerful enough to reach Somerset and quite possibly Wiltshire. (This is already established from the evidence summarised in Figure 7.)

Further work is required. Cosmogenic dating of the boulder surface will be distorted by the fact that it is subject to constant surface abrasion in this high energy wave-lashed environment. However, there are exposures of a cemented raised beach in Limeslade Bay, now widely assumed to be of Ipswichian age (Kokelaar, 2021; Shakesby & Hiemstra, 2015). If it can be established that the raised beach contains boulders and cobbles of the same dolerite rock type as the Limeslade erratic boulder, that would indicate entrainment, transport and emplacement during a pre-Ipswichian glacial episode.

Finally, what are the implications for the interpretation of Stonehenge as a national icon and as one of the wonders of the world? It is indeed a spectacular monument to the aspirations of the Neolithic and Bronze Age tribes who inhabited Salisbury Plain. But once the glacial transport hypothesis is taken seriously, Stonehenge loses much of its aura and marketing potential! It is still enigmatic, but it is now appears that it was built of a wide variety of stones, large and small, from many different provenances, and used more or less where they were found. As noted above, many of the stones have the characteristics of long-abandoned glacial erratics (Fig. 8). Further, since there are only about half as many stones as there should have been in an "immaculate" or completed monument, a reasonable assumption is that it was never completed, having been abandoned by the builders when they simply ran out of stones (John, 2018). There appears to be no convincing evidence to counter that interpretation of the romantic old ruin.

Acknowledgements

Phil Holden (the finder of the boulder) is thanked for the use of his samples and for other cooperation. I acknowledge the kind advice of Dr Katie Preece, Prof John Hiemstra and Prof Danny McCarroll (all of Swansea University Geography Department), Prof Peter Kokelaar, Dr Olwen Williams-Thorpe and the late Dr Dyfed Elis-Gruffydd for their advice and practical help. Prof Tim Darvill and Dr Steve Parry are thanked for the sample analyses and for their interpretive notes.

Figure 8. Bluestone SH45, made of spotted dolerite. This was sampled by the OU research team in 1987. *(Photo: courtesy Simon Banton)* Like most of the other Stonehenge bluestones, this has many of the characteristics of a glacially transported erratic boulder.

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QN Quaternary Newsletter
Article
QRA Quaternary Research Association

LAST THOUGHTS ON THE GLACIATED LINCOLNSHIRE CLAY VALES AND THE TRENT

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Two responses to my article on the Trent 'trench' and Lincoln gap (Straw, 2022a) were published in Quaternary Newsletter, Number 157 (Baker, 2022; Bridgland, 2022) and are welcome additions to the debate. While Colin Baker's response consists largely of an account of ice-wedge polygonization across the Vale of Belvoir with only part reference to the main issue, that by David Bridgland includes a defence of the 'uplift paradigm' and discussion of events and features that relate to the courses of the Trent since the Anglian Glaciation. Both responses include consideration of the Vale of Belvoir and differ clearly from the writer's views concerning its present form. Issues relating to tills and fluvial gravels have been considered in Quaternary Newsletter, Number 157 (Straw, 2022b), and in this note circumstances relating to the two Lincolnshire vales and the Cropwell Butler and Ancaster gaps are discussed.

Baker quotes from Howard et al (2009) where it is stated that "there is no reason to suppose that either the River Trent or glacial ice have occupied this lowland area since it was excavated, the latter process being attributable to the streams of the Smite-Devon system". This view is referred to also by Bridgland. To quote from his response, he considers: " … this low country to have arisen from quite recent erosion and lowering of the landscape, these fairly minor tributaries having kept pace with downcutting by the Trent. A key point is that the latter was entrenched and laterally restricted in the relative hard bedrock of its 'Trench' whereas the Smite and Devon achieved rampant denudation in the less resistant rocks underlying the 'low country', including the Vale of Belvoir".

But can this really be the case? The Vale of Belvoir is very wide (some 15 to 20 km), the streams have always been of low gradient and could rarely have had sufficient discharge and energy to achieve the requisite amount of lateral erosion and sediment transport.

The history of the Vale of Belvoir is far longer than these views imply. If it is agreed that a proto-Trent initiated the Ancaster gap across the Lincolnshire Limestone cuesta, as indicated by the Rauceby gravels surviving on the northern edge of the gap, then country to the west of the gap must have been higher and drained by that river and any tributaries. As the gap floor was lowered, so was some of the ground west of an emerging escarpment, and a strike-oriented vale would surely have come into being. By the time of the Anglian Glaciation, when all of Lincolnshire was glacierized, the land surface on the weaker rocks was probably near 70-80 m OD and a Lias-based vale existed which, if there were no Lincoln River (Swinnerton, 1937), was drained partly north to the Humber and partly south to the proto-Trent (the Smite-Devon system did not then exist). During this glaciation, as witnessed by the composition of the widespread Lowestoft Till and chalk-free Oadby Till (Straw, 2021), selective erosion of the relatively soft Lower and Upper Jurassic clays in the vales occurred, lowering their outcrop surfaces. With deglaciation, the Trent could well have regained its course through the Ancaster gap, probably as successor to Anglian meltwaters that had lowered it to the height of the new subglacial surface. It can then be claimed (Straw, 1963, 2022a) that the Trent held this course through MIS 11, 10 and 9, receiving left-hand tributaries from the north such as the Erewash, Leen, Dover Beck and Greet plus the bulk of Midland drainage which had become focussed on Long Eaton (Westaway, 2021). This situation was interrupted when Lincolnshire was again glacierized during MIS 8 and ice sculpted the present macro-forms of both the Vale of Belvoir and the central Lincolnshire vale.

Coastal ice entered north Lincolnshire (becoming part of the western ice-stream (Straw, 1983)) and the central Lincolnshire vale, and inundated the Chalk Wolds (Straw, 2021). Chalk-bearing, Lias-rich till (Upper Oadby Till) covers the western half of the Kesteven plateau and parts of Leicestershire south of the Vale of Belvoir, the Lias component undoubtedly being derived from its outcrop (Straw, 2021). Widening and lowering can plausibly be attributed to glacial erosion, even though till does not survive except east of Gainsborough, which can however be regarded as a relic of a wider sheet that formerly extended south. Deglaciation involved stagnation and down-wasting, with dispersal of vast quantities of meltwater from the vale that excavated the ‘trench’ and its possible extension north of Newark to Gainsborough (Straw, 1963), passed through the Ancaster gap depositing some of the Belton Gravels (Berridge et al, 1999), and utilised the newly created Lincoln gap. Only when the ice had disappeared could the Smite-Devon streams begin to add the details that we see today.

The clay vale of central Lincolnshire also has a long history. When the Ancaster gap was initiated, clay ground to the east must have been somewhat lower than the crest of the Lincolnshire Limestone cuesta and a strike vale on Upper Jurassic clays would develop between the cuesta and the Chalk Wolds to the east, with some drainage north to the Humber (cf. the present river Ancholme), and some south. Both Anglian and Wragby ice took advantage of this depression, eroding the Upper Jurassic clays and converting large quantities of bedrock into the tills now spread over Cambridgeshire, Northamptonshire and Bedfordshire. In the clay vale itself, Wragby and contemporaneous tills veneer a wide, low, glacially-moulded, symmetrical depression (Straw, 1958, 2022b; Westaway et al, 2015), which does not merit consideration as a pre-MIS 8 Trent paleovalley if the river entered it at Lincoln for the first time during deglaciation.

A final point relates to the Cropwell Butler gap. Baker, in his response, refers to the circumstance of gypsum dissolution, and this had been acknowledged as an influence on the floor of the gap (Straw, 2022a), but it cannot have affected the course of the Trent. Likewise, the spread of ice-wedge polygonization across the Vale of Belvoir only emphasises that it post-dates the MIS 8 glaciation and confirms multiple phases of periglaciation.

As with the Vale of Belvoir, there is confusion concerning the Cropwell Butler gap. Bridgland notes that Baker identifies channels in the floor of the gap, through which the Trent “might have escaped from its Trench into the Vale of Belvoir”. This is unrealistic and I endorse Baker’s view that the Trent has never passed from the gap to the Vale. The gap is a much-modified feature. Apart from any effects of gypsum dissolution, it can be observed that during MIS 8 it must have been filled with slow-moving ice (relative to that in the Vale and surmounting the Marlstone scarp not far to the east) at least 100 m thick, as also the valleys of its left-hand tributaries. The subsequent movement of meltwaters around, through and beneath it, and associated with excavation of the Long Eaton to Newark ‘trench’, could have remodelled some of its side-slopes and produced the channels noted by Baker. Since the landscape stabilised, the gap has undergone some 200,000 years, including several intense periglacial phases, of subaerial soil and slope development, floor disruption by gypsum dissolution and stream erosion. It is not surprising that it looks shabby and, to some, unconvincing, but sufficient of its macro-form survives for its former function as a major river valley to be perceived.

I have two related conclusions – the Lincolnshire clay vales have a long history and too little credence has been given to date of the impact and consequences of substantial glacial soft-rock erosion during both MIS 12 and MIS 8, the latter being responsible for the present macro-forms of the vales, and these vales have a long pre-MIS 8 history that should be re-assessed in terms of a drainage evolution that does not involve a Trent ‘trench’ and Lincoln gap.

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GLACIAL LAKE TERRACES IN THE VALE OF PICKERING

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Introduction

Lewis (1894) proposed, that during an ice age, a North Sea glacier advanced down the east coast of England blocking drainage exits of easterly flowing rivers. This glacier, now referred to as the North Sea Lobe (NSL) of the British-Irish Ice Sheet (BIIS) reached North Norfolk by 25.8 – 24.6 ka (Evans et al. 2021). Marginal oscillations of this ice sheet that caused the river blockages are dated to 24.1 – 22.3 ka (Evans et al., 2021) Eventual uncoupling of onshore and offshore ice, resulted in the impoundment of pro-glacial lakes such as Lake Pickering, Lake Wear and Lake Tees (Fig.1). This southerly surge of the glacier and the onshore encroachments are attributed to the Last Glacial Maximum (LGM).

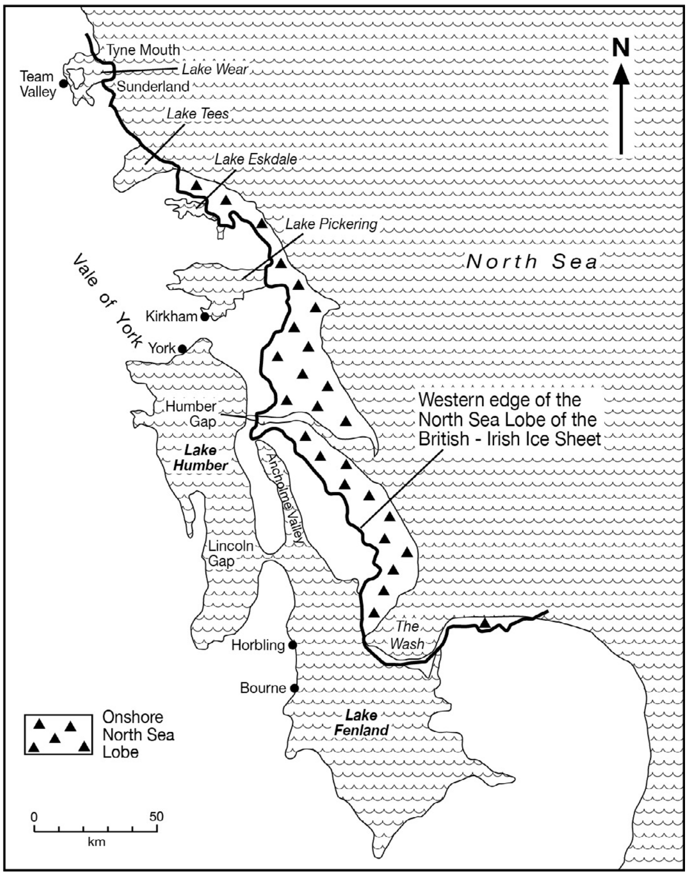

Figure 1. Map of the east coast of England showing pro-glacial lakes impounded by the North Sea Lobe of the British and Irish Ice Sheet that extends to The Wash and north Norfolk. *From Fairburn, 2014.*

A distinctive feature of the geological mapping, in the Vale of Pickering (Fairburn, 2019) has been the recognition of two sets of alluvial fans. One set, to the north of the Chalk escarpment, comprises the Chalk gravel alluvial fans and the Sherburn Sands (Fig 2; Fairburn and Bateman; 2021, fig.4), while the other set, on the northern side of the Vale, is comprised of sediments forming the Hutton Buscel Terrace and equivalents of the Sherburn Sands (Fig.3: Fairburn and Bateman, 2021, fig.3). In both areas, the top of the Sherburn Sands is imprinted by the 45 m shoreline of Glacial Lake Pickering (see Figs 2 and 3), while the top of the Chalk gravel alluvial fans and the sediments of the Hutton Buscel Terrace terminate below the 70 m O.D. strandline (Figs 2 and 3).

Note also that Smith (1994) records terracing in Glacial Lake Wear at 70 m, 45 m and 43 m O.D. The map of Lake Wear (Fig.1) has been drawn at the lowest level (i.e. 43 m O.D.).

Luminescence dating of the alluvial fans indicate that there have been two glacial incursions into the Vale of Pickering: one set of fans dated to the LGM (Evans et al., 2017) and an older set dated to the Drenthe Stage (MIS 4) of the Saalian Glaciation (Fairburn and Bateman, 2021). A penultimate glaciation of possible MIS 8 age, in the Vale of Pickering, was also suggested by Powell et al. (2017) from a series of diamictons investigated by cored boreholes.

The purpose of this article is to clarify the validity of glacial lake terraces (or strandlines) in the Vale of Pickering and to respond to comments by Straw (2023) who casts doubt on, or negates, conclusive glacial data derived from geomorphological mapping and luminescence dating (Fairburn 2019, 2022; Fairburn and Bateman, 2021). Straw's comments lack credibility as they are made without supportive mapping or dating and would appear to have been

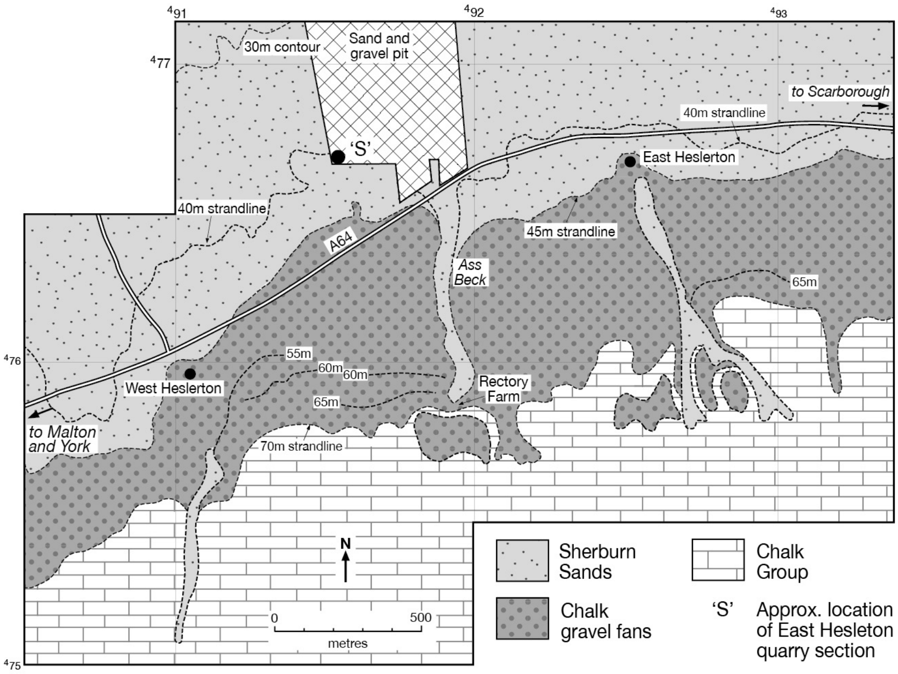

Figure 2. Geological map of the Vale of Pickering between east and west Heslerton, showing the 45 m O.D. and 70 m O.D. strandlines and Ass Beck draining into the East Heslerton sand pit. Note that the drainage channels south of East and West Heslerton are probably MIS 6 meltwater channels *(modified from Fairburn, 2023).*

made solely on the basis that such data is contrary to his views (i.e. Straw, 2014; 2023).

The 70 m O.D. Lake

Fox-Strangways (1892) and Kendall (1902) believed that there was a 70 m O.D. glacial lake in the Vale of Pickering, however more recent evidence rejects this idea. Fairburn (2019), for example, considered that entrapment of a 70 m O.D. lake and the presence of laminated clays at 65 m O.D., near Crambe, are anomalous on the current landscape. Mapping suggested that many aspects of the morphology and geology of the Vale of Pickering, could only be explained by regional uplift as a result of glacioisostatic rebound. Mapping of this rebound surface, rising from c. 40 or 45 m O.D. to 70 m O.D. was illustrated by Fairburn (2022, fig.8).

Fairburn (2019) interpreted the origin of the Hutton Buscel Terrace as a rebound feature, so for Straw (2023) to suggest that Fairburn (2019) interpreted the origin of the feature as resulting from streams from the Jurassic dipslope, flowing into a 70 m O.D. lake is erroneous.

The 70 m O.D. shoreline

Although a precedent for the continued usage of the term was created by Fairburn (2019, fig.2), it has been decided, in this text, to replace '70 m O.D. shoreline' with '70 m O.D. strandline' to avoid confusion. The

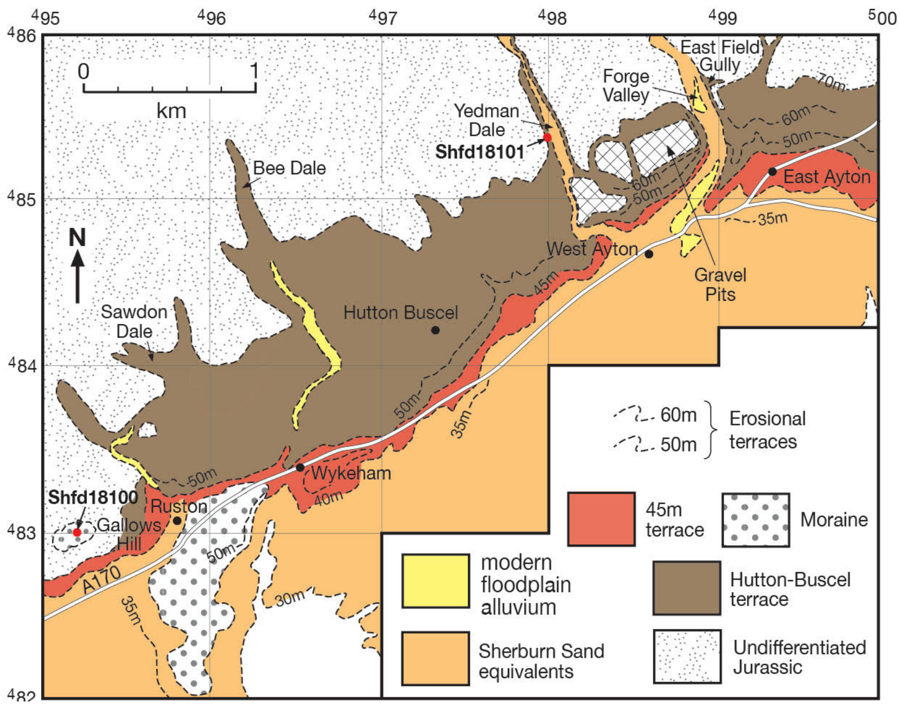

Figure 3. Landform map of the Hutton Buscel Terrace between Ruston and Forge Valley bounded along the northern edge by the 70 m O.D. strandline. Note IRSL locations Shfd18101 and Shfd18100. *Modified after Fairburn and Bateman, 2021.*

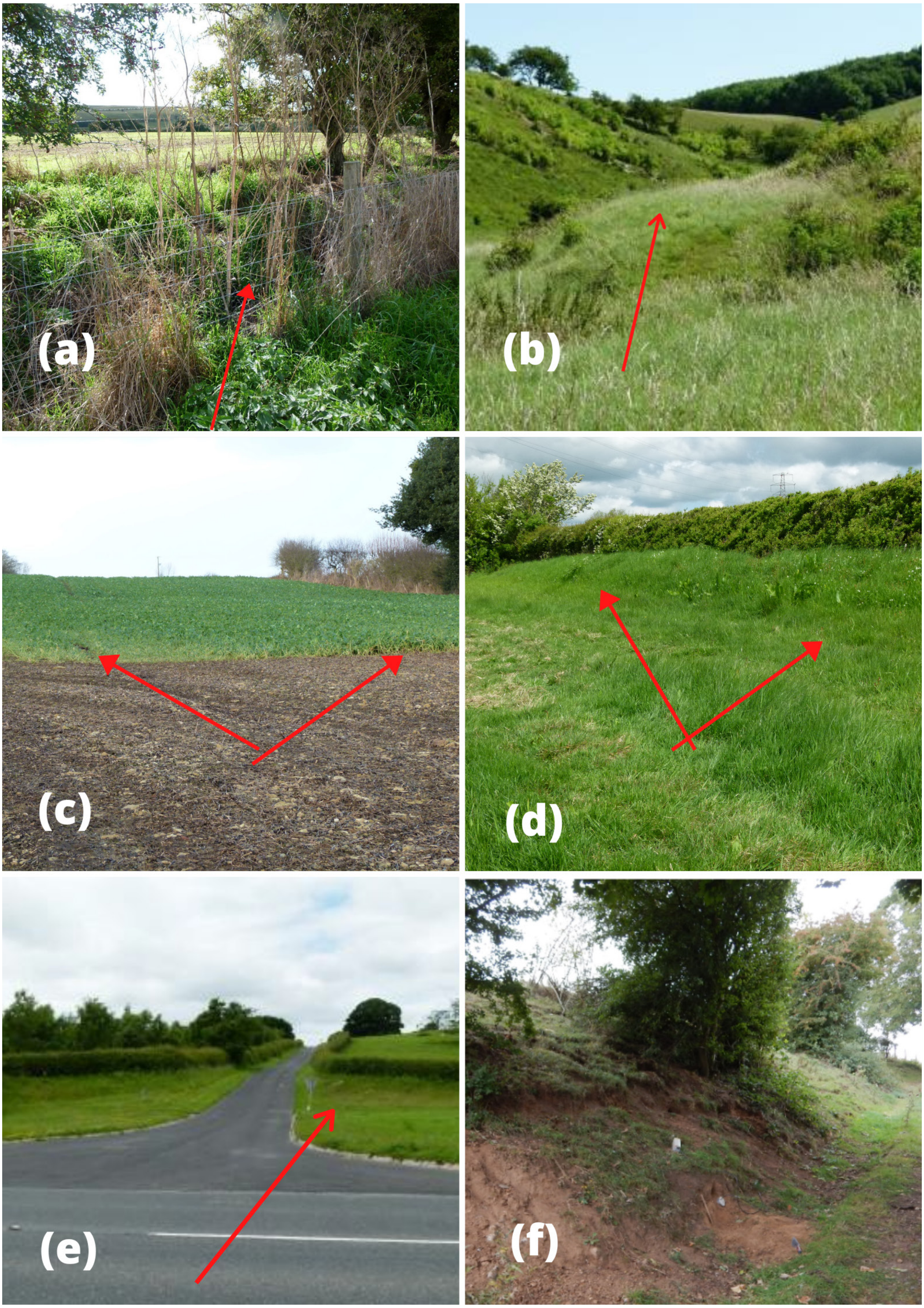

Figure 4. Landforms in the Vale of Pickering referenced in the text: (a) The 45 m O.D. strandline near East Heslerton. Note the Yorkshire Wolds in the background. From Fairburn, 2023. (b) Remnant of the 70 m O.D. terrace near East Heslerton at the northern edge of the Wolds. From Fairburn, 2019. (c) 70 m O.D. strandline in Yedman Dale. From Fairburn and Bateman, 2021. (d) 70 m O.D. washing line bordering till near Crambe. From Fairburn and Bateman, 2021. (e) The 45 m O.D. strandline defining the base of the Hutton Buscel Terrace. From Fairburn, 2019. (f) Location of the IRSL sample in Yedman Dale. From Fairburn and Bateman, 2021.

70 m O.D. strandline is therefore a significant landform in the Vale of Pickering as it marks the northern edge of the Yorkshire Wolds and the northern edge of the Hutton Buscel Terrace (Figs 2 and 3).

The Wolds

The 70 m O.D. strandline forms the prominent erosional edge of the Chalk Group escarpment (Fig. 4a) where it separates outcropping chalk from chalk-gravel alluvial fans (Fig.2). Only remnants of the original extended terrace have been preserved (Fig. 4b) due to the instability of such a feature flanking the chalk aquifer.

The Hutton Buscel Terrace

Here (Fig.3), the 70 m O.D. strandline not only provides a lithological boundary between the sand and gravel of the Hutton Buscel Terrace and Jurassic limestone, but it also forms a distinct land usage boundary between grassland on the Jurassic limestone and the ploughed surface on the sand and gravel (Fig. 4c). The strandline also delineates the feeder channels (e.g. Bee Dale and Yedman Dale) that drain south-westward from the Jurassic dipslope, (Fig.3).

Eroded Till

Near Crambe the back-wall of the 70 m O.D. strandline forms a 'washing line' of silt between older glacial till (possibly MIS 6) and Jurassic bedrock. (Fairburn and Bateman 2021, fig.5b; Fig.4d).

The Hutton Buscel Terrace

The origin of the Hutton Buscel Terrace has been a controversial issue since the pioneer work of Fox-Strangways (1892) and Kendall (1902): Fox-Strangways suggested the feature originated as a shoreline terrace, while Kendall preferred an origin marginal to a glacier (i.e. a kame terrace). On the Scarborough 1:50 000 geological sheet (British Geological Survey, 1998), the Hutton Buscel Terrace, along with the Wykeham Moraine, form a package of sediment referred to as 'sand and gravel of uncertain origin.' Since the early work, Straw (1979) has also regarded the landform as a kame terrace with the bulk of the material forming it originating from and through Forge Valley; while Eddey et al., (2017), in also referring its origins to a kame terrace, suggested it also supported a 70 m O.D. lake in the valley.

Relevant to the origin of the Hutton Buscel Terrace is its occupancy in the landscape. Accepting a base of 45 m O.D. (Fig. 4e) and a width of about 1.0 km, any river diverted to flow across the Jurassic dipslope, as suggested by Straw (2023), would have to be bigger than the River Ouse currently flowing through York. Such a river would need to be held in place by a wall of ice rising to over 70 m O.D. Such a circumstance would seem unlikely.

52 m Strandline

Near Goodmanham, on the edge of the Yorkshire Wolds, de Boer et al. (1958) mapped a terrace at about 200 ft (61 m O.D.). More recent mapping by Fairburn and Bateman (2016, fig.5) and Fairburn (2022, fig.8) located the terrace to nearer 55 m O.D. De Boer et al. (1958) were able to extend mapping southwards as far as South Cave at an elevation of 45 m O.D. (Fairburn, 2022, fig.8). In a later publication, Penny (1974), changed the description of the terrace to that of a 52 m strandline.

The prime significance of the 52 m strandline, between Goodmanham and South Cave, is that the strandline terrace overlies the 'older alluvial fans' (Fairburn and Bateman, 2016, fig.5), which had been dated to late MIS 7 or earliest MIS 6 (Fairburn, 2022, fig. 20). Mapping to the north of Goodmanham confirms that the 52 m strandline rises to 60 m O.D. at Meltonby and 65 m O.D. at North Cliff (Fairburn, 2022, fig.8). It is also likely that the strandline extends to 70 m O.D. at Nearfield Farm (Fairburn 2022, fig.14) and west of Crambe (Fairburn, 2022, fig.13a; Fairburn and Bateman 2021, fig.5b).

The importance of the 52 m strandline in understanding post-MIS 6 glacial rebound was overlooked by Eddey et al. (2022) and Straw (2023).

In challenging the validity of uplift of the 40 m O.D. shoreline to '70 m lake strandline', Straw (2023) challenges the mapping of De Boer et al. (1958), Penny (1974) and Fairburn and Bateman (2016). Straw (2023) is also in error in his reference to a 70 m O.D. lake.

MIS 4 – MIS 6

In selecting two locations for luminescence dating (IRSL), that would provide confirmation of a penultimate glaciation in the Vale of Pickering, the main targets were Gallows Hill at the northern end of the Wykeham Moraine and a section of the Hutton Buscel Terrace in Yedman Dale (Fig.3, Fig.4f). The dating results provided a minimum age for the Wykeham Moraine of 176 ± 16 ka and impoundment of a glacial lake in the Vale with a minimum age of 156 ± 12 ka (Fairburn and Bateman, 2021).

These dates then precisely define the Drenthe Stage of the Saalian glaciation in Europe (Lang et al., 2018) in the early or middle part of an MIS 6 glaciation (Fairburn and Bateman, 2021, Fig.5). Recognition of an MIS 6 glaciation, in the Vale of Pickering, tends to confirm MIS 6 as a major glaciation in the UK, as the event has also been identified in the West Midlands by Gibson et al., (2022), from the Moreton Stadial of the Late Wolstonian Substage and by Evans et al. (2019) from the Stiffkey Moraine in Norfolk.

In his criticism of an MIS 6 age for a penultimate glaciation in the Vale of Pickering, Straw (2023) has suggested that a single luminescence date (in fact there are two dates) are inadequate to confirm such an event, but decided an MIS 4 date is more likely, even though he has not provided any luminescence dating. Such an assertion is refuted, notably as MIS 4 does not have a strong signature on the O18 chart (Fig.5) and was of limited time duration compared to MIS 6, Fig.5. Straw (2023) also suggests that the Hutton Buscel sample taken from poorly-sorted gravels from a section in a farm cutting, may not be suitable for analysis, but does not explicitly say why. In reality, the sample taken from the top of the Hutton Buscel Terrace (Fig 4f) was taken from the best location noted during mapping for Fig.3.

MIS 8

John Powell (personal communication) has suggested that a more probable age for a diamicton in the west of the Vale of Pickering and on the flanks of the Jurassic dip-slope could be MIS 6, comparable to IRSL dating by Fairburn and Bateman (2021), rather than preferred MIS 8 for the deposit (Powell et al., 2017).

MIS 3

Dating by both Evans et al. (2016) from fluvioperiglacial fans near North Cave in the Vale of York and Eddey et al. (2018), from fluvial deposits in the Vale of Pickering, have recorded ages ranging from MIS 2 and MIS 3 (Fig.5). However, these dates fail to provide any evidence for an MIS 4 glaciation. Note also that most of the Eddey et al. (2018) O.S.L. data from Yedingham and High Marishes provide MIS 2 ages of fluvial sediments deposited in the Vale prior to the flooding of the 45 m O.D. lake.

Conclusions

As the chronology for the major landforms and

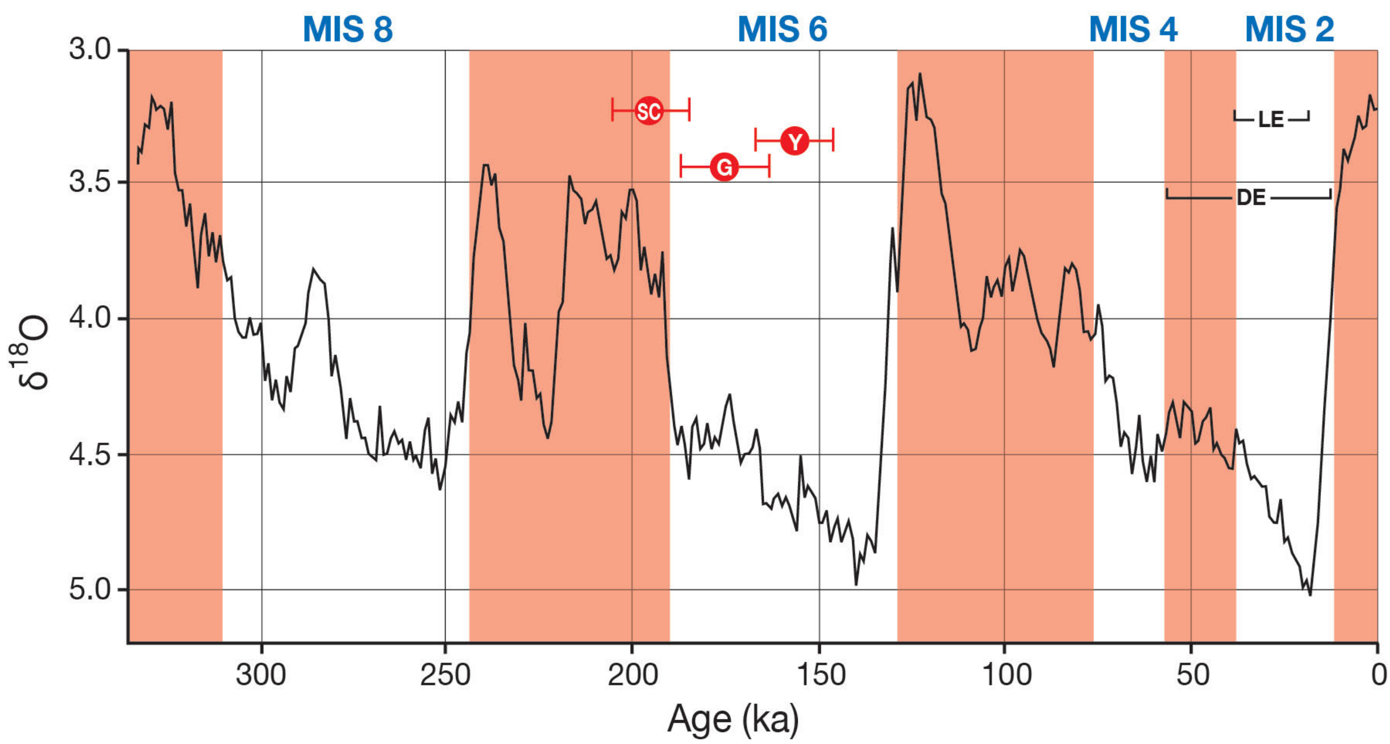

Figure 4. Luminescence dating. Gallows Hill (G) and Yedmandale (Y) from Fairburn and Bateman, 2021; South Cave (SC) from Fairburn and Bateman, 2016; DE from Evans et al., 2018; LE from Eddey, 2018. Adapted from Fairburn and Bateman, 2021.

terracing in the Vale of Pickering has been derived from detailed field mapping and meticulous luminescence dating, any criticism of the data would need to be soundly based on revised mapping and dating. This, however, is not the case in the recent criticism of the glacial history of the Vale by Straw (2023) as he has not provided any new evidence to support his arguments. This is particularly applicable to Straw's claims that the penultimate glaciation, in the Vale, was MIS 4 in age and not MIS 6.

It is also hard to accept that the most conspicuous linear landform, delineated at c. 70 m in the Vale, whatever title it is given, could be 'weak and contested' as claimed by Eddey et al. (2022) and Straw (2023).

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QRA ADM EDI PANEL DISCUSSION, SOME PERSONAL REFLECTIONS

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The first EDI panel discussion took place at the 60th Anniversary of the QRA, following some presentations on "Inclusivity in Quaternary Science". To mark the occasion, we have added some personal reflections about the event.

The QRA has made amazing progress towards inclusivity in the last few years. The EDI Working Group was initiated in 2022, led by Professor Jane Hart, with Dr Kathryn Adamson, Dr James Lea and Dr Rob Storrar, along with Dr Becky Briant co-opted to advise. We were able to put forward the EDI statement, produce a survey template for meetings, a Code of Conduct for meetings, and enable caring costs to be included in all QRA grants.

This initial work was continued by a new EDI Sub-committee, with Jane Hart, Laura Boyall, Dr Katherine Roucoux and Professor Sarah Woodroffe, with Dr Della Murton taking over as the new EDI Officer in 2024.

From the beginning, the group acknowledged that cultural changes take a while, but small steps can be made towards progress. Positive actions include the naming of QRA grants and medals to reflect a better gender balance (see QRA Awards and Medals, this issue) and the changing of grants and medals details to be more inclusive. At this ADM we were delighted that women made up 49% of attendees, gave 59% of the talks, 48% of the posters, gave both Keynote speeches and felt able to ask questions in the lecture theatre, as well as being recognised via medals and awards. There was an excellent turnout to the discussion session and EDI talks. Delegates were very forthcoming in their positive responses.

We are aware that there is still a long way to go, with excellent examples provided by the presentations from the Inclusivity in Quaternary Science session. We are also aware that many of the 'steps' towards progress have concerned binary gender, whilst issues of disability, race, gender identity, sexual orientation and others still need to be addressed and we are actively discussing ways in which the QRA is able to be more welcome to everyone.

Discussion panel

The members of the discussion panel introduced themselves and discussed some steps they thought the QRA should be making, before opening the session to the floor via spoken and anonymous online questions. These included:

1. What might we learn from our teaching practices? Institutions, in the UK and elsewhere, often implement EDI initiatives that we might draw on to inspire change within the QRA.
2. With regards to decolonisation, how might we develop our community and build representation, by inviting keynote speakers from underrepresented communities?
3. Are there insights that we can glean from allied industries (such as consultancies) to share best practice?
4. How might we ensure that Quaternary science is accessible for those with disabilities - including hidden disabilities - that make certain activities such as fieldwork, difficult?
5. For Jane: Do we have information on what proportion of women at the ADM are on insecure contracts? The balance is great, let's work to reduce leaks in the pipeline!

6. What does ‘celebrating and increasing diversity’ look like for you/QRA? How will you know if things are changing?
7. Are women’s experiences from the QRA different to those in other aspects of Geology?
8. What does ‘addressing’ the colonial history & post-colonial legacy mean and how do you see it involving in a practical way
9. How can we navigate the contrasting viewpoints on inclusion efforts, especially when some participants perceive the earlier talk as understated while others find it rather disheartening?
10. Is there a commitment for there to be an EDI panel discussion and session next year and each year following?

Other questions that there was not time for:

11. Geosciences is predominately white. This conference reflects that. What can/should the QRA do to increase diversity in this respect?
12. What do you think are the best ways to challenge discriminatory behaviour and/or practices?
13. What steps have/can be taken for further inclusion for transgender or gender non-conforming people within the QRA and at events?
14. Could QRA Exec think about responding to articles such as this for QRA using QN? https://www.nature.com/articles/s41561-021-00737-w
15. The QRA could support development and sharing of resources (e.g. drone imagery) for field trips / key Quaternary sites?
16. Many QRA members are not here. Are there any barriers that might prevent people from attending QRA meetings. Can we make sure that their voices are heard and we are working on removing barriers
17. It is clear that there is an appetite for this type of panel discussion at the ADM and the need to address all the issues suggested above. In response to question 10, we definitely need to continue these debates into the future, and we are looking forward to continuing discussion with the QRA membership in making the association ever more inclusive.

Figure 1. The panel *(photograph courtesy of Abi Stone.)*.

PANEL ON CO-DESIGN AND CO-PRODUCTION OF PHYSICAL GEOGRAPHY RESEARCH 19TH MARCH 2024, ONLINE

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Jane K. Hart, School of Geography and Environmental Science, University of Southampton, Southampton, SO17 1BJ
Katy Roucoux, School of Geography and Sustainable Development, University of St Andrews, St Andrews, KY16 9AL

With the growth of decolonising geography initiatives across the country, it is increasingly clear that we as physical geographers of various types must engage more directly with the ethical implications of our research. Thus, in a collaboration between the Quaternary Research Association, British Society for Geomorphology and the RGS-IBG, a webinar was held in March to kickstart a conversation. This was chaired by **Jane Hart (University of Southampton)**, President of the QRA. Three panel members shared their thoughts and then discussion took place in breakout groups. **Becky Briant (Birkbeck, University of London)** started by giving an overview of the concept of 'parachute science' and the implications for us as physical geographers. We saw that we need to view the data and understanding that we gain from landscapes as a resource. Extracting this resource without involving local communities and researchers mirrors the historical extraction of natural resources in unequal colonial and post-colonial economic systems and is unethical. All three organisations have started to address this issue and our aim was to increase the visibility of this work and move the conversation forward. **Louise Callard (Newcastle University)** then shared the work that she has been doing in Tuktoyaktuk, Inuvialuit, Canada, working alongside human geography colleagues as a science communicator on a project looking at the mental health of Inuit youth in the context of environmental challenges - https://www.cinuk.org/projects/cct/. This was funded by a targeted UKRI Canada, Inuit and UK focussed grant call which required co-investigators from both countries and the Inuit community. Louise reflected on the need for time, to understand local research priorities and to build relationships of trust, and the fact that even though this call was otherwise set up inclusively, the short timescales mitigated against doing this well before application. Other key reflections were the need to ensure that the project aligned with community priorities and the need to agree a communications strategy so that the community was represented as they would wish and retained ownership of their narrative. **Katy Roucoux (University of St Andrews)** then shared her journey researching ecological change in Amazonian peatlands. Whilst initially the research questions were scientifically focussed, looking at long-term ecological changes and carbon storage potential, more recently the focus of her research has shifted to working with local communities. When assessing threats to the peatlands, it became clear that local communities had very strong opinions about their land that were getting lost. This led to several interdisciplinary projects funded by the Scottish Funding Council/GCRF and the Leverhulme Trust which contributed to a REF2021 impact case study. In this they sought to understand community links with the peatlands, involving participatory mapping which the team later used to specify the location of ecological monitoring. Follow on work has remapped the peatland ecosystems in the area using the terminology of the local indigenous Urarina people, with the aim of making their perspectives visible to policy makers. Katy reflected on the need to work with local researchers who have long-term links and trusted relationships with communities, and who speak the necessary languages. By working together with human geographers and anthropologists to involve peatland communities in co-production of the research, our understanding of these ecosystems and their importance has improved and become multidimensional, in ways that would not have been possible through physical geography or (natural) science approaches alone.

This was followed up by a time for questions and comments in the large group and discussion in breakout groups. Participants were left with much to ponder and some ideas of best practice to disseminate - for example we need to address:

- culture, so that everyone is on board with being inclusive
- funding parameters - to fund the time needed to understand the priorities of local communities
- communication and translation - both due to language and cultural differences and to avoid misrepresentation
- capacity building in lower resource communities

Please do join the conversation so that together we can do more ethical research and change the culture.

Useful resources

The British Society for Geomorphology have set up a £5000 grant for Decolonising Geomorphology - https://www.geomorphology.org.uk/funding-and-grants/grants/

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QRA AWARDS AND MEDALS

The QRA has a range of Awards and Medals. Until recently only some of these were named. The Executive committee decided to name all the single winner awards and medals for two reasons. Firstly, a named award is much more prestigious for the awardee; and secondly, the Executive wanted the awards to celebrate a greater number and a more diverse range of our past Quaternary Scientists and reflect the inclusive nature of the QRA. These new names were launched at the QRA 60th Year ADM celebrations, and the details are shown below.

The Winifred Pennington-Tutin Award

The QRA awards the Winifred Pennington-Tutin Award annually to the best British or Irish undergraduate dissertation.

Winifred Pennington-Tutin (1915-2007) was born in Barrow-in-Furness and studied for her degree and PhD at the University of Reading, specialising in the study of algae and mosses. She worked at the University of Leicester from 1947, being made Honorary Professor in 1980. Her research focused on the lake ecosystems and vegetation of northern Britain, and she was the first to spot the late-glacial oscillation there. Work with the Freshwater Biology Association at Lake Windermere led to a landmark Nature paper in 1941, the same year as her PhD was completed. In 1979, her work on palaeolimnology and palynology earned her the Fellowship of the Royal Society, recognising the correlations she had found between climate, vegetation and human activity.

Key References

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The Richard West Grant

Supporting outstanding field expeditions or innovative laboratory projects.

Richard Gilbert West (1926-2020) studied at the University of Cambridge, supervised for his PhD by Harry Godwin. He was a botanist, geologist and palaeontologist, using pollen and macrofossils to distinguish climate stages, and vegetation successions during interglacial periods. During a long and successful career, he led the Subdepartment of Quaternary Research at Cambridge (1966-87) and was Head of Department of Botany (1977-91).

He was elected FRS in 1968, was awarded the Bigsby Medal of the Geological Society in 1969, was president of the QRA from 1969-71, and was awarded the Lyell Medal from the Geological Society in 1988.

Key References

West, R.G. 1968. Pleistocene Geology and Biology. Longmans

The Lewis Penny Medal

The Lewis Penny Medal is awarded to an Early Career Researcher (normally less than 35 years old and/or less than 7 years post-PhD, who has been a member of the QRA for at least 3 years) who has made a significant contribution to any area of Quaternary research.

Lewis F. Penny (1920-2000) came from a family of geologists. After studying Natural Sciences at Cambridge, he worked at Hull University for his entire career, where he prioritised educating new generations of geologists and developing the geology degree. He contributed to many societies; he was the first Secretary/Treasurer of the Quaternary Field Study Group and the second QRA president.

Lewis's detailed field research led him to re-interpret the Holderness glacial deposits as last glacial in age, rather than formed over multiple glaciations.

He was awarded the University of Helsinki Quaternary Research Medal (1973) and the Yorkshire Geological Society Sorby Medal (1979).

Key References

Penny, L.F. (1959) The Last Glaciation in East

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The Dorothea Bate Award

Formerly the Journal of Quaternary Science Outstanding ECR Paper award, the Dorothea Bate Award is presented to recognise the outstanding work of an Early Career Researcher (ECR). To be eligible for this award, a paper must be first-authored by an ECR who completed their PhD no more than 7 years ago, taking into account any career interruptions.

Dorothea Bate (1878-1951) first became fascinated with Quaternary fossils exploring Wye valley caves in 1898, shortly after persuading what is now the Natural History Museum to let her become the first woman to work there. She worked at the NHM most of her life and was appointed curator of Aves and Pleistocene Mammals in 1924, but was only salaried from 1948.

Alone, Dorothea undertook excavations in the Mediterranean from 1903, discovering many new species including dwarf elephants and hippos. She understood, long before most, that fossil bones could reveal much about climate and environmental history.

Her immense contribution included 80 papers and many notes. She was awarded the Geological Society Wollaston Fund and then elected Fellow of the Society in 1940.

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Bate, DMA (1907) On elephant remains from Crete, with description of *Elaphas creticus*[1]. *Proc. Zoo. Soc.* Lond. 77, 238-250

The Mabel Tomlinson Outreach Grant

To promote and foster engagement between Quaternary Science and a wide and diverse audience, the QRA offers an annual outreach fund, named in honour of Mabel Tomlinson.

Mabel Tomlinson (1893-1978) first encountered the Quaternary through her school-teacher parents. She studied Geology at Birmingham University, researching the river terraces of the Lower Avon and Arrow Valleys for her M.Sc.(1923) and Ph.D. (1929). Despite working as a teacher from 1917. She was awarded a D.Sc. (1936) for her continued work on river terraces in the midlands.

Mabel inspired many students to become professional geologists. In 1961 she was awarded the Henry Stopes Memorial Fund and Medal of the Geologists' Association and the R.G.H. Worth prize of the Geological Society, London.

Key References
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The Dick and Jean Grove Conservation Grant

The Dick and Jean Grove Conservation Grant is awarded to promote and deliver conservation of our Quaternary geoheritage.

As an undergraduate, Jean Clark (1927-2001) was encouraged to take part and organise glaciological expeditions to Jotunheimen, Norway. On one expedition she met a new staff member, Dick (Alfred Thomas) Grove (1924-2023), who had interrupted his Geography degree to serve as an RAF pilot during the war. They married in 1954 and had six children.

Initially a glaciologist and a soil scientist, the Groves increasingly focussed on environmental history. Jean's research used natural proxies and archival material to reconstruct climate fluctuations in the last millennium, culminating in her seminal work "The Little Ice Age" (1988).

Working in Africa, Dick's interest in flying and aerial photography led to his focus on the impact of long-term climate change on landscapes. His work on desertification highlighted the complexity of environmental history in desert margins. After Jean's death, he completed the revision of "The Little Ice Age".

Key References
Grove, J.M., 1988. *The Little Ice Age.* Routledge (2nd Edition, 2012)

1 now *Elephas creticus* Bate

USING SEDIMENTOLOGY & GROUND PENETRATING RADAR TO INVESTIGATE THE INTERNAL ARCHITECTURE OF DE GEER MORAINES

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Abstract

Spatiotemporal resolution of palaeo-ice sheet terrain is critical to the quality ofice sheet reconstructions. De Geer moraines (DGMs), may be a candidate landform that can increase such resolutions to a potentially unprecedented (e.g. annual) rate of retreat, however, prior to reconstruction development, accurate formational properties must be established.

The aim of this project/fieldwork campaign is to investigate the internal architecture of DGMs and establish a more accurate mode of formation. Fieldwork involved investigating DGMs at four key sites across southwest Finland employing a combination of sedimentological and ground penetrating radar (GPR) methods.

We present preliminary findings describing the internal architecture of one DGM from southwest Finland. Key findings include: a vertical variability in lithological units indicating diachronous formation, thrusting structures located within the proximal parts of the ridge suggesting unidirectional pushing processes, and evidence of shearing stresses within upper units of the ridge indicating movement from overriding ice.

We suggest that, whilst deposits situated at the base of the ridge may have been deposited behind the grounding line, possibly in shallow subglacial canals and/or crevasse cavities, the main DGM ridge was formed via push processes at the grounding line of a water terminating ice margin. The preliminary findings provide merit to support the idea that DGMs may be used to refine ice marginal reconstructions, however, further work must be undertaken to constrain the timescales at which they form.

Background and Rationale

Palaeo-ice sheet reconstructions provide valuable information regarding the extent and evolution of past ice sheets (Clark et al., 2022; Gowan et al., 2021; Hughes et al., 2016; Stroeven et al., 2016), thereby enabling us to better understand how the cryosphere responds to global climate and environmental change. Ice sheet reconstructions are typically produced by a 'glacial inversion model', allowing glaciological inferences to be made from the integration between geomorphological evidence and numerical dating (Clark, 1997; Dalton et al., 2023; Gowan et al., 2021; Pearce et al., 2017). Modern palaeo-ice sheet reconstructions provide time-slice resolutions of between 1,000 – 100 years (Clark et al., 2022; Hughes et al., 2016; Stroeven et al., 2016), however, as high-resolution digital elevation models (DEM), (derived from LiDAR, for example) become more widely available, it is possible that lower-relief geomorphology may be identified and used to refine these resolutions.

De Geer moraines (DGMs) are lower-relief ridges, typically elongated, narrow and orientated transverse to former ice flow direction. Since first observations, several models of formation have been conceptualised, with two overarching ideas commonly debated.

The first constitutes a sub-aqueous ice marginal environment whereby sediments are deposited at the grounding line of water terminating glaciers. This model infers that ridges are formed asynchronously, potentially annually, at the ice margin thereby illuminating DGMs as a good landform candidate for ice marginal reconstructions. The second model constitutes a crevasse infilling method whereby saturated and deformable sediments are squeezed up into basal crevasse cavities. This model suggests that ridges are formed synchronously, behind the ice margin, and do not pertain any temporal qualities that would be useful for ice marginal reconstructions (Rivers et al., 2023). The two opposing models present different spatiotemporal implications for ice marginal reconstructions and highlight the importance of establishing a more accurate understanding of genetic properties for ice-marginal and sub-marginal ridges.

Methods

Field investigations were undertaken at four key sites distributed across southwest Finland (FIGURE 1). Sedimentological and ground penetrating radar (GPR) methods were undertaken to investigate the internal architecture of DGMs.

1. Sedimentological Investigations

Sediment exposures across the mid-sections of one prominent *(UT1)* and one intermediate *(UT2)* DGM were excavated at right angles to the ridge crestlines to investigate the internal architecture of these DGMs (FIGURE 2). For each exposure: physical characteristics of sediment profiles were described and logged, lithological units were identified based on: grain size, degree of sorting, matrix composition and clast lithology (Benn & Evans, 2013; Evans, 2004).

2. Ground Penetrating Radar Investigations

GPR data were collected using 32-bit Mala GroundExplorer (GX) 160- and 450-MHz shielded antennas mounted on rough terrain skid plates and connected to a Mala GX controller. Multiple GPR datasets were acquired for each sampled DGM, acquiring both cross-sectional and along-crestline profiles where possible. Radar facies were determined by variations in reflector motif (e.g. reflector strength, length, shape, amplitude, and pattern). These were then corroborated with lithofacies identified from the excavated sediment exposures.

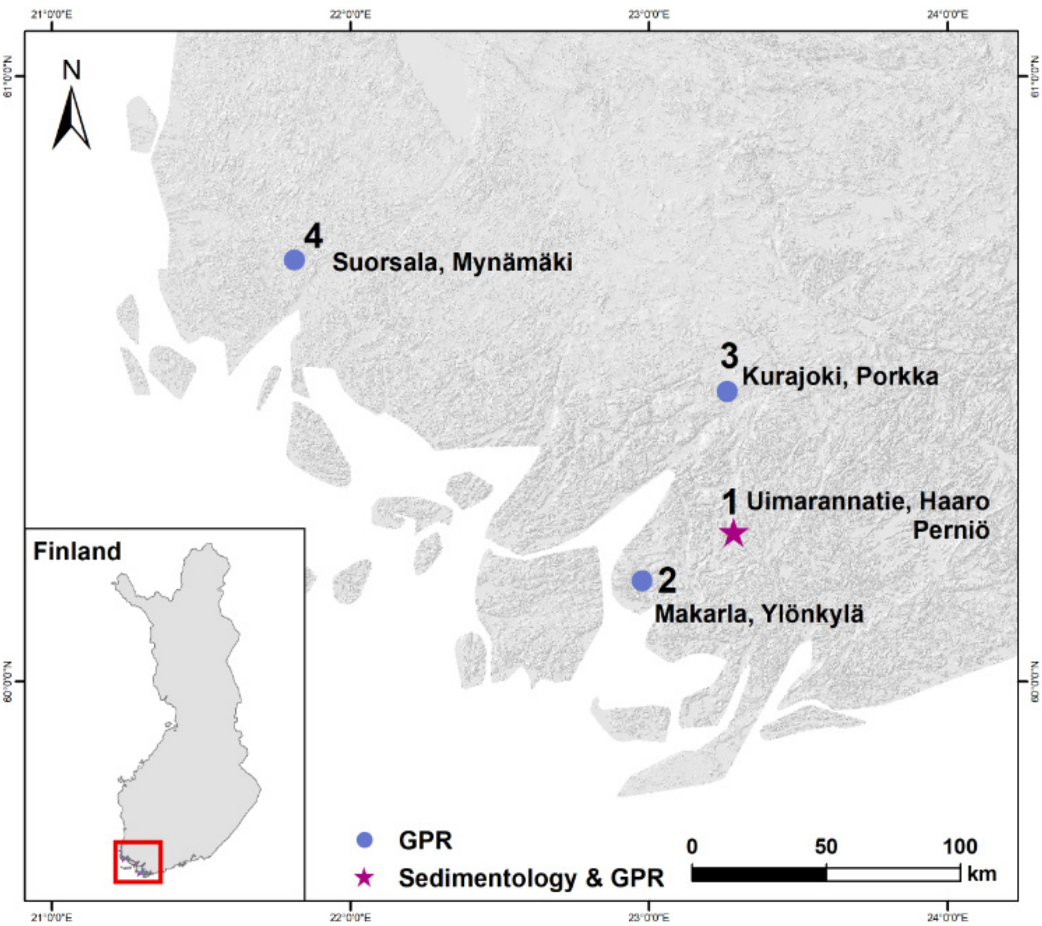

Figure 1: Location map indicating selected sites across SW Finland for data acquisition: 1) Uimarannatie, Haaro, Perniö – sedimentology & GPR; 2) Makarla, Salo – GPR; 3) Kurajoki, Salo – GPR; 4) Suorsala, Mynämäki - GPR.

Figure 2: Photos of UT1 excavated sediment exposure. A) drone captured aerial photograph showing plan view of excavated trench; B) oblique photograph (view toward distal side); C) oblique photograph (view toward proximal side; D) oblique photograph (view toward proximal side).

Results

Preliminary data from one investigated DGM *(UT1)* located at sample site 1 are presented. Sedimentological investigations revealed five different lithological units showing variable compositions of diamicton, interspersed in some locations with finer sands, silts and clays (FIGURE 3a). Evidence of thrust planes located proximally within the ridge indicate a unidirectional push movement involved during formation (Units 3a & 4). Shearing structures and stratification within the upper facies provide evidence of overriding ice (Unit 5). These are supported by evidence within the GPR radargrams showing long and continuous reflectors within the proximal parts of the ridge (RF2) (FIGURE 3b). These units are interpreted as being derived from an ice marginal push environment. Within the lower sectors of the ridge, however, sediments are more varied in grain size and interspersed with finer silts, sands, and gravel streaks. These units are interpreted as crevasse infill, possibly deposited behind the ice margin.

Significance

Differences in derivation between some of the units, particularly when assessing the ridges using litho- and seismostratigraphic approaches, infer diachronous formation. For example, it may be that lower sediment units were initially deposited in shallow subglacial canals and/or crevasse cavities situated behind the grounding line and then at a later stage these deposits were overridden, deformed, and aggregated by ice marginal push dynamics that formed more distinctive grounding line DGM ridges. This presents important implications for DGM utility within ice marginal reconstructions as it suggests that an annual ice marginal signal is likely, however, must be accurately distinguished within wider DGM fields. As such, the next steps of the project are to test this idea, attempting to develop a refined reconstruction of the Finnish sector of the Fennoscandian Ice Sheet margin using DGMs as geochronometric indicators.

Acknowledgements

Field investigations have been extremely important in the development of my PhD research and I would like to thank the QRA for the provision of the New Research Workers' Award in contribution to the funding of this research. In addition, I would like to thank the RGS for providing support via the Monica Cole Research Grant. I would also like to thank my supervisors Dr Robert Storrar and Dr Naomi Holmes, and my collaborators Dr Antti Ojala, Dr Joni Mäkinen and Camilla Holmroos for their guidance, efforts, and contributions to the project.

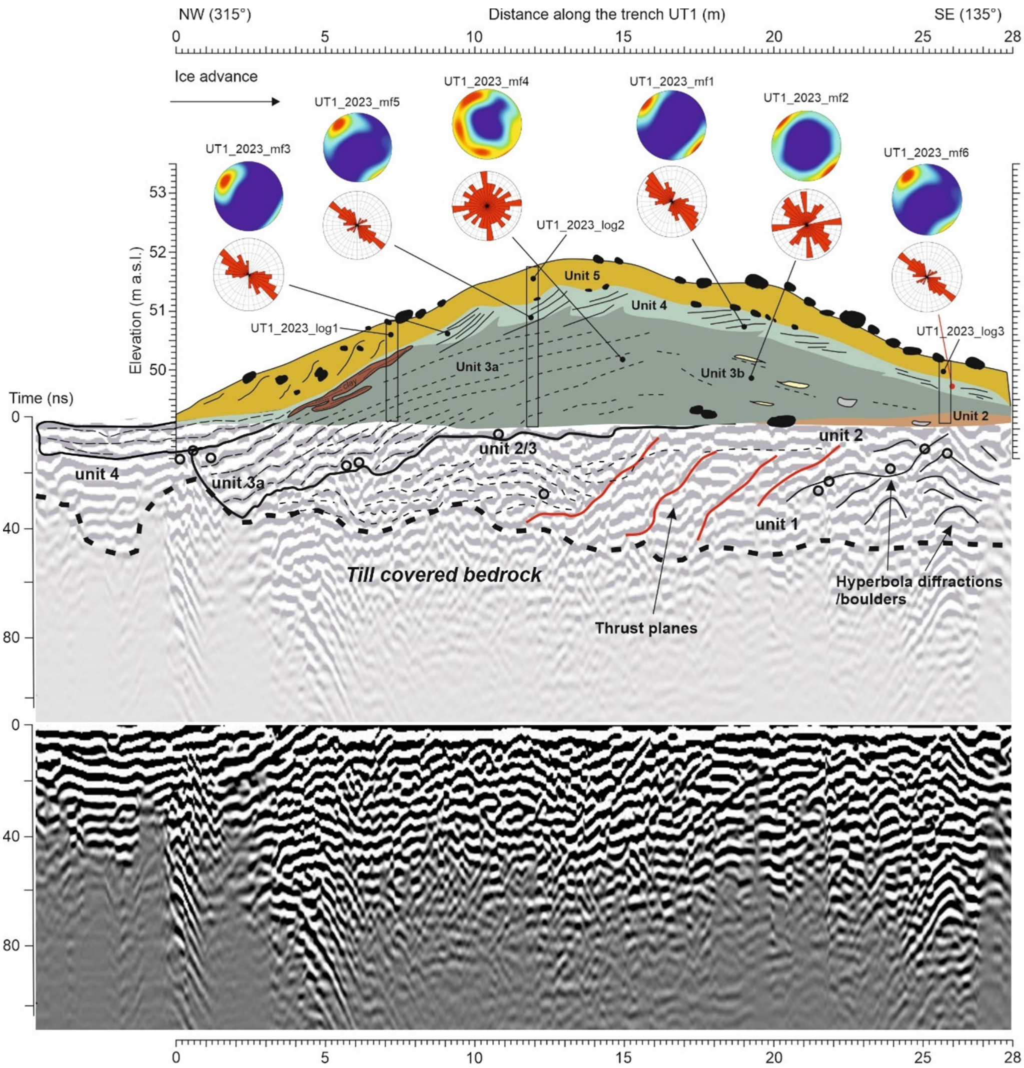

Figure 3a: Exposure sketch of UT1 with subsurface GPR data. GPR data was acquired along the excavation bottom to allow subsurface investigations.

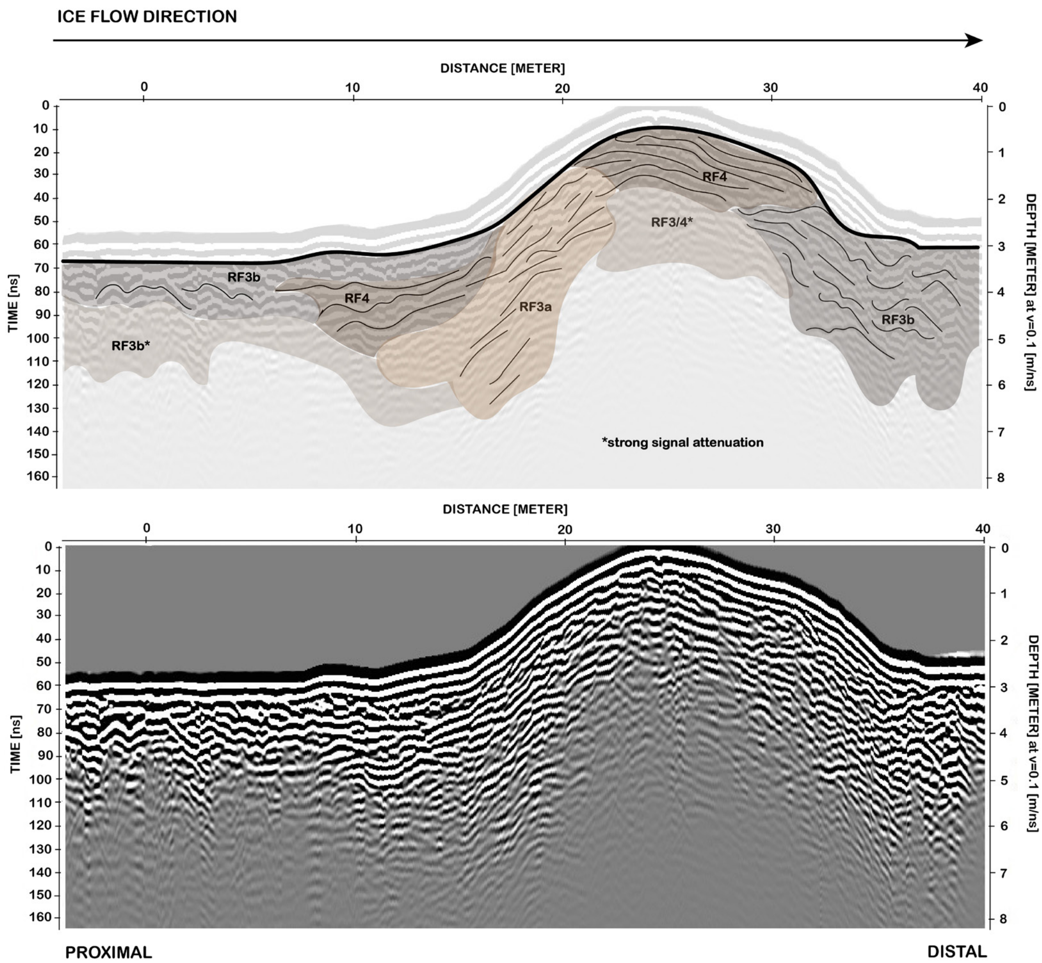

Figure 3b: Radargram for UT1 at sample site 1 (GPR #1), Uimarannatie, Haaro, Perniö.

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Quaternary Newsletter
Awards
Quaternary Research Association

RECORD OF MODERN-DAY PROCESSES AT RAPIDLY RETREATING GLACIERS: SNAPSHOTS FROM CENTRAL CHILEAN PATAGONIA

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Background and Rationale

Even within today's overarching context of rapid glacier mass loss and recession correlated to anthropogenic climate forcing (Zemp et al., 2015), glacial forefields host a wide array of processes and landforms which vary significantly. Detailed studies of the geomorphology of glacial forefields can provide insight regarding sediment transport, meltwater pathways, and the behaviour of ice itself. Regarding glaciers in Patagonia, they have been inventoried (Barcaza et al., 2017), there is vast knowledge of palaeoglacier extent (Davies et al., 2020), and remote sensing has focused mainly on calculating geometrical changes and velocities (Maas et al., 2013). However, there are few detailed geomorphological studies in the area centred on glacial forefields, and since sites such as ones in Central Chilean Patagonia have limited accessibility, there is scope for using uncrewed aerial vehicles (UAVs) for mapping them.

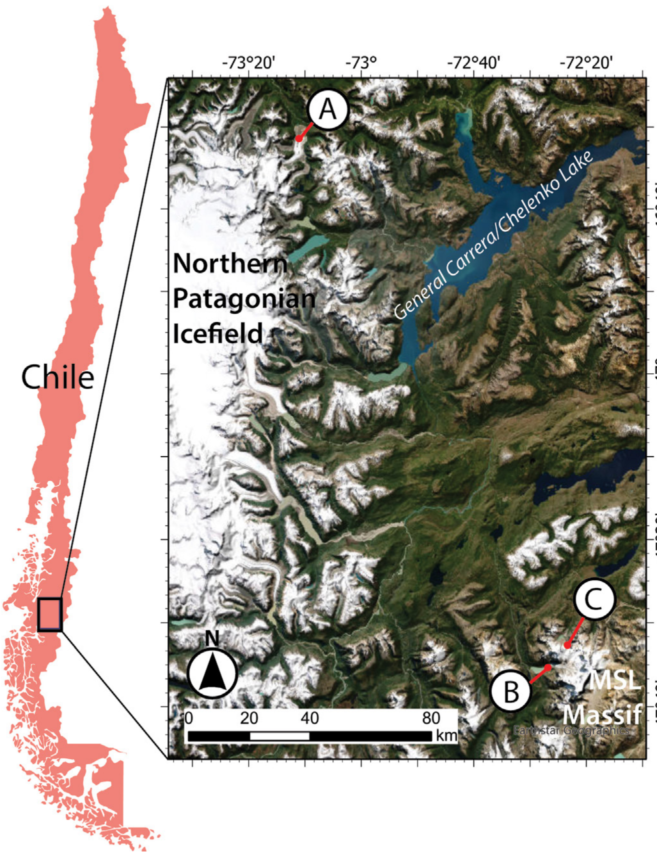

Figure 1: Location of studied glaciers within central Chilean Patagonia. A: El Cuarenta Glacier. B: Calluqueo Glacier. C: Río Tranquilo Glacier.

This work focuses on the geomorphology and processes that are occurring at modern glacial margins, specifically at selected sites in the Northern Patagonian Icefield and the neighbouring Monte San Lorenzo massif (Figure 1). By mapping the landforms at the margins of glaciers in and near the Northern Patagonian Icefield, we seek to work towards a better understanding of the dynamics of rapid deglaciation in this area.

Results

Photogrammetric data was obtained from UAV surveys carried out in January 2024. The resulting digital elevation models and orthomosaics range between 10-22 cm/pixel and 5-11 cm/pixel, respectively, and were used as the base for generating high resolution geomorphological maps (Figure 2) that exemplify features such as ice fragmentation, dead ice topography, and the rapid appearance and disappearance of flute fields.

El Cuarenta Glacier has completely disconnected from a debris-covered tongue, where there are no active sediment transport pathways other than rock falls. This debris-covered tongue calves into a proglacial lake that is contained by moraines. This lake has an

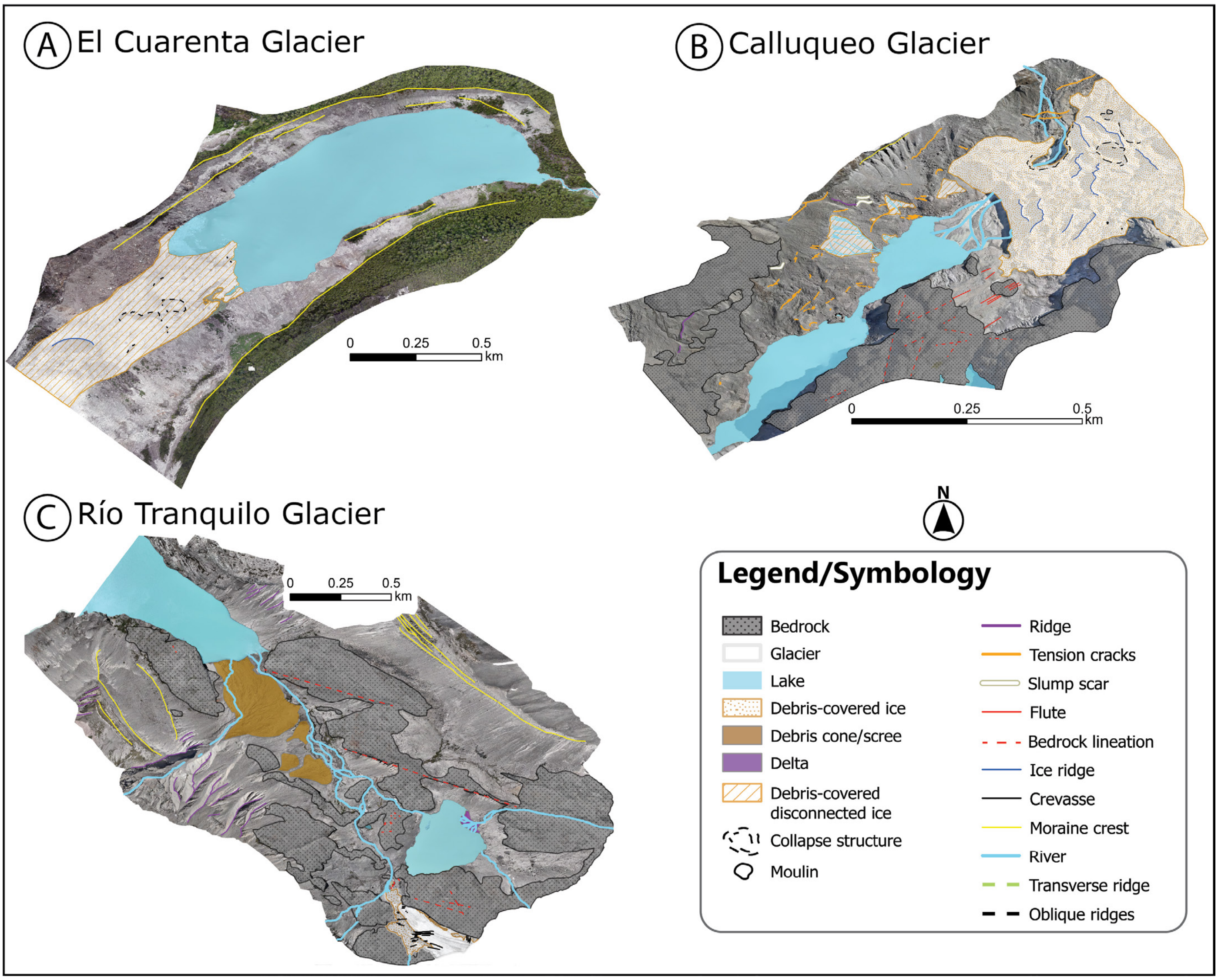

Figure 2: Mapped glaciers in Central Chilean Patagonia. For locations of each, refer to Figure 1.

outlet that feeds into the Norte River, approximately 177 m lower, in the main valley.

The Calluqueo forefield is dominated by the presence of tension cracks to the southwest of the active margin, and north of the river. There, it is also possible to find patches of debris-covered ice and collapse structures that, in conjunction with the tension cracks (Figure 3A), show the possible extent of the dead-ice, about 500 metres to the southwest of the active margin.

At Río Tranquilo Glacier, many processes have been overprinted by alluvial-fluvial activity, which quickly obliterates subglacial bedforms. Nevertheless, the forefield contains remnants of a flute field and some oblique and transverse ridges (Figure 3B), all of which were only revealed in the last two years and had not been previously mapped.

Significance

The high resolution of these maps and the scale at which the features have been identified are a starting point for the characterization of the current state of some of the glacial forefields found in the Northern Patagonian Icefield and Monte San Lorenzo Massif, and highlight the processes associated with rapid glacier recession in the area. The results can also have implications in hazard monitoring, since some of these glaciers are strongly connected to the local tourism industry: El Cuarenta Glacier and its associated proglacial lake are located directly above an important road (route X-728), which has historically already been affected by outburst floods (Iribarren Anacona et al., 2023); Calluqueo Glacier also receives many visitors, especially during the summer season, and establishing the location and extent of dead ice could be important information for the safety of the people who work in and visit the forefield.

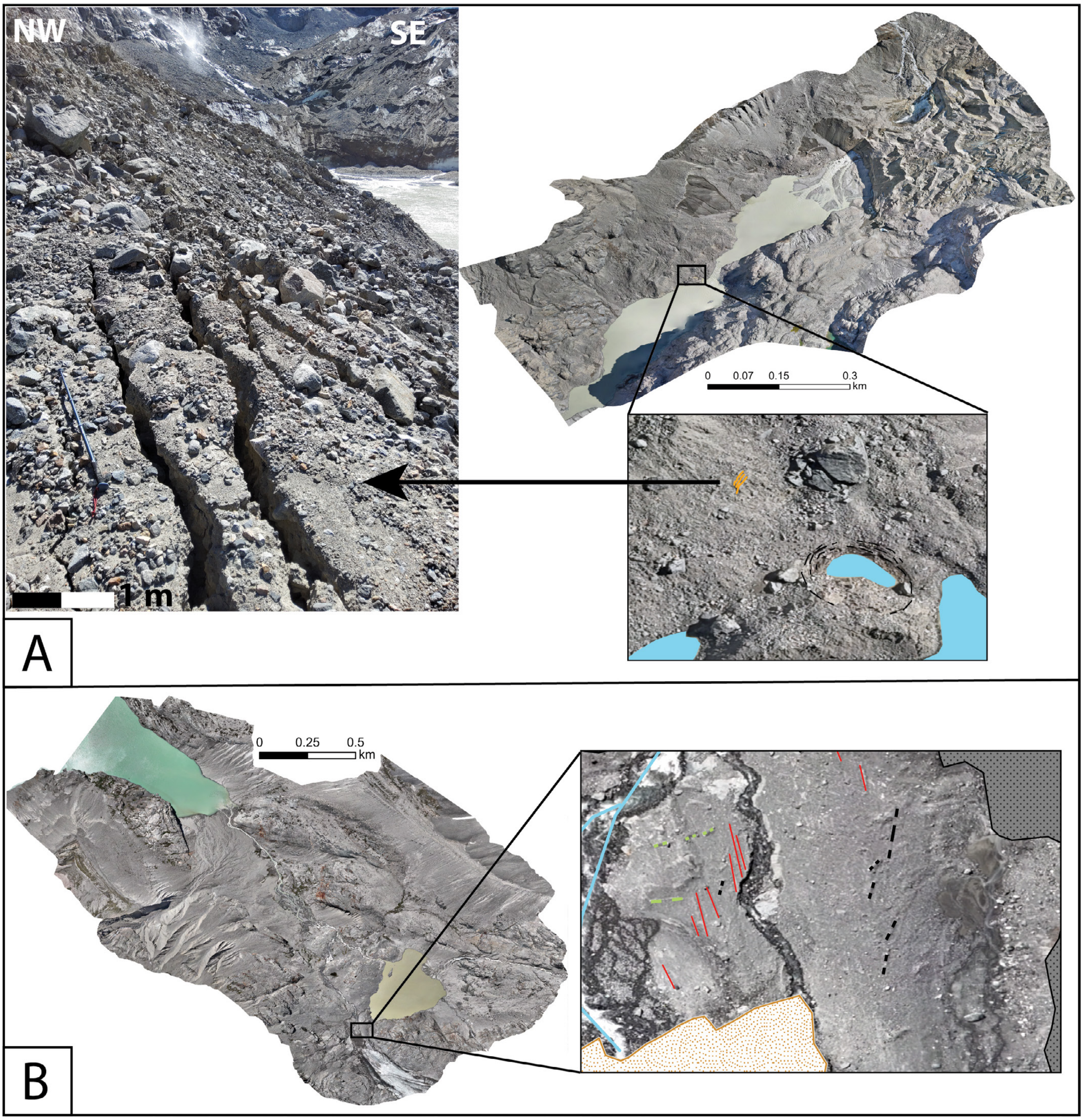

Figure 3: Figure 3. A: Calluqueo Glacier forefield exhibiting tension cracks and collapse structures that indicate the presence of dead ice. B: Remaining preserved flutes, transverse ridges and oblique ridges at Río Tranquilo Glacier forefield.

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Quaternary Newsletter
Awards

QUATERNARY MICROBIALITE FACIES OF EASTERN CAPE OF SOUTH AFRICA

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Background and Rationale

In the last 20 years, since their first description by Smith and Uken (2003), tufa microbialites and associated deposits, accreting in the supratidal rock coast environment and associated with carbonate-bearing groundwater springs, have been increasingly recognised globally (Cooper et al., 2022, 2013; Forbes et al., 2010; Perissinotto et al., 2014; Rishworth et al., 2020b; Smith et al., 2011). While modern accreting and inactive systems are being studied, their relevance as Quaternary palaeo-shoreline indicators requires investigation (Garner et al., 2024; Rishworth et al., 2020a). Following the discovery and recognition of such deposits defining a MIS 11 shoreline during the EPStromNet (Underwood et al., n.d.) Western Australia field campaign (Garner et al., 2024), further pre-Holocene deposits are sought.

The QRA New Researchers Award was used for field visits to map and sample living, Holocene and potentially Pleistocene, spring-fed peritidal tufa microbialites in the Eastern Cape of South Africa in October 2023, collaborating with researchers at Nelson Mandela University and University of KwaZulu-Natal. Fieldwork involved:

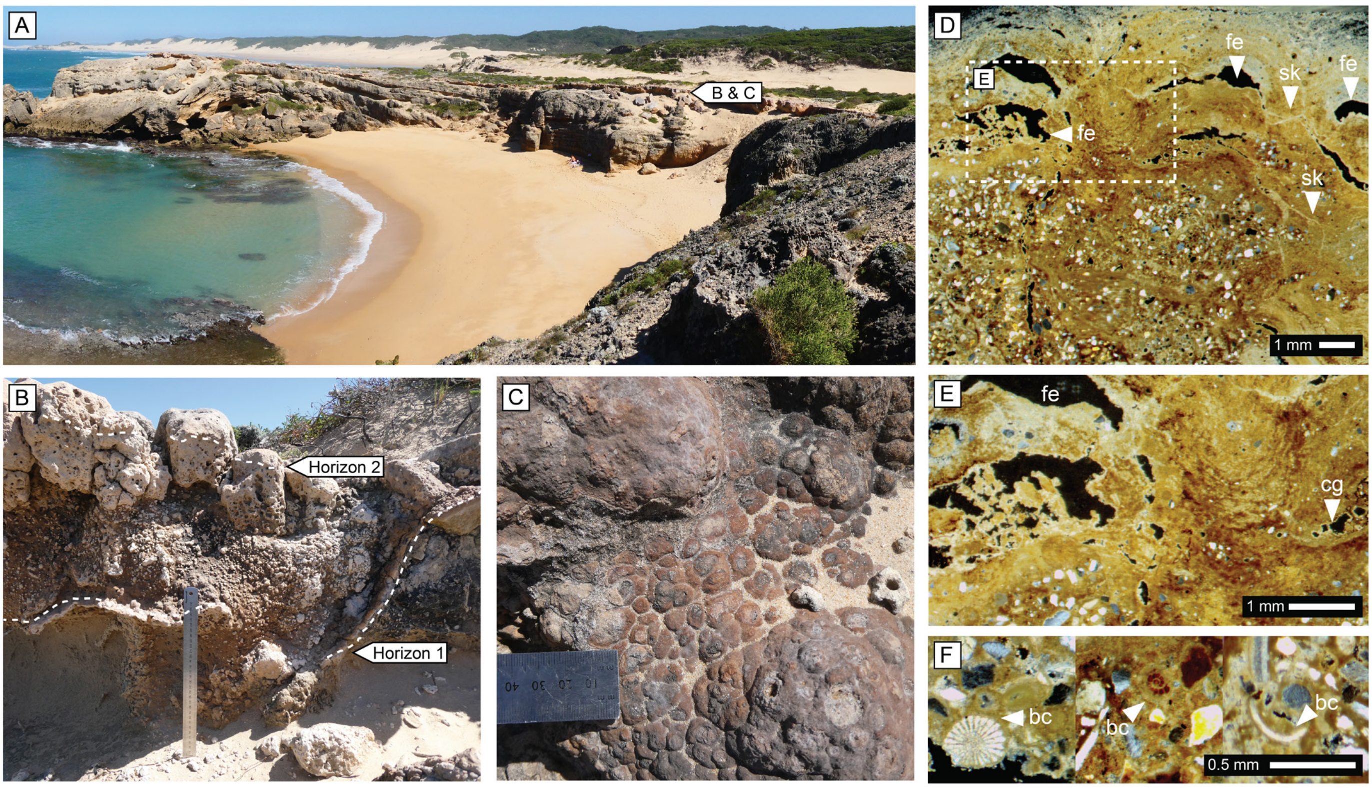

Figure 1. Laminar calcrete microbialite facies at Shelly Bay, Kenton-on-Sea. A: View of Shelly Bay looking SW; B: Profile of two horizons of laminar calcrete C: plan view of colloform surface topography; D-F: thin section of columnar-stacked hemispheroid mesostructure: E: development on calcarenite with fenestral (fe) and shrinkage (sk) porosity; F: inset detail of pores with circumgranular cements (cg) and intercolumn laminae; G: marine bioclasts (bc) within basal calcarenite (echinoid spine, formanifera test, and shell fragment).

Part I: the investigation of a potential Quaternary occurrence that had been reported (Smith and Anderson; pers. comm.) at Shelly Bay, Kenton-on-Sea.

Part II: the study of living and Holocene spring-fed peritidal microbialite system facies at St Francis Bay, east of Gqeberha (Port Elizabeth), South Africa, focused on facies description and preservation potential.

Part I: Shelly Bay, Kenton-on-Sea

Results

This site (Fig. 1A) is located in an aeolian calcarenite outcrop (Fig. 1F), with subfossil terrestrial gastropods (cf. *Achatina*) and calcretised rhizoliths. The reported microbialite deposit was investigated and found to consist of multiple horizons of laminar calcrete (Fig. 1B), occurring as laterally continuous, indurated sheets, visible in section, associated with undulatory karstified surfaces. Mesostructure is variable, comprising flat-laminar sheets with a planar surface topography to columnar-stacked hemispheroids with a colloform topography. Hemispheroids contain large fenestral cavities and shrinkage cracks with circumgranular and gravitational cements (Fig. 1D, E).

Interpretation and discussion

The potential microbialite facies at Shelly Bay, Kenton-on-Sea did not form in the same environment as contemporary rock coast spring-fed microbialites and is, instead, of vadose origin developing on palaeo-karst surfaces and cavities of the basal calcarenite. The discrimination of terrestrial stromatolites and laminar calcretes is problematic and multiple attempts have been made to identify distinguishing criteria (e.g., Read, 1976; Wright, 1989). Laminar calcretes vary from abiogenic to fully biogenic (Wright, 1989; Wright and Tucker, 1991), termed terrestrial and subaerial stromatolites (Riding, 2000)). Comparable facies have been reported from the mid-Late Pleistocene and Holocene of Australia, notably the Bridgewater and Tamala Limestone Formations as karstic cavities and solution pipe rims within aeolianites (Lipar et al., 2017, 2015). These comparable 'microbialites' are interpreted as being formed within karst voids through microbial vadose (subaerial) cementation in glacial conditions following aeolianite dissolution and karstification during interglacial-glacial transitions (Lipar et al., 2017).

Unlike rock coast tufa microbialites, this facies does not appear to have any reliable relationship with sea-level, with multiple profile development, due to prograding dune development (Read, 1976). This

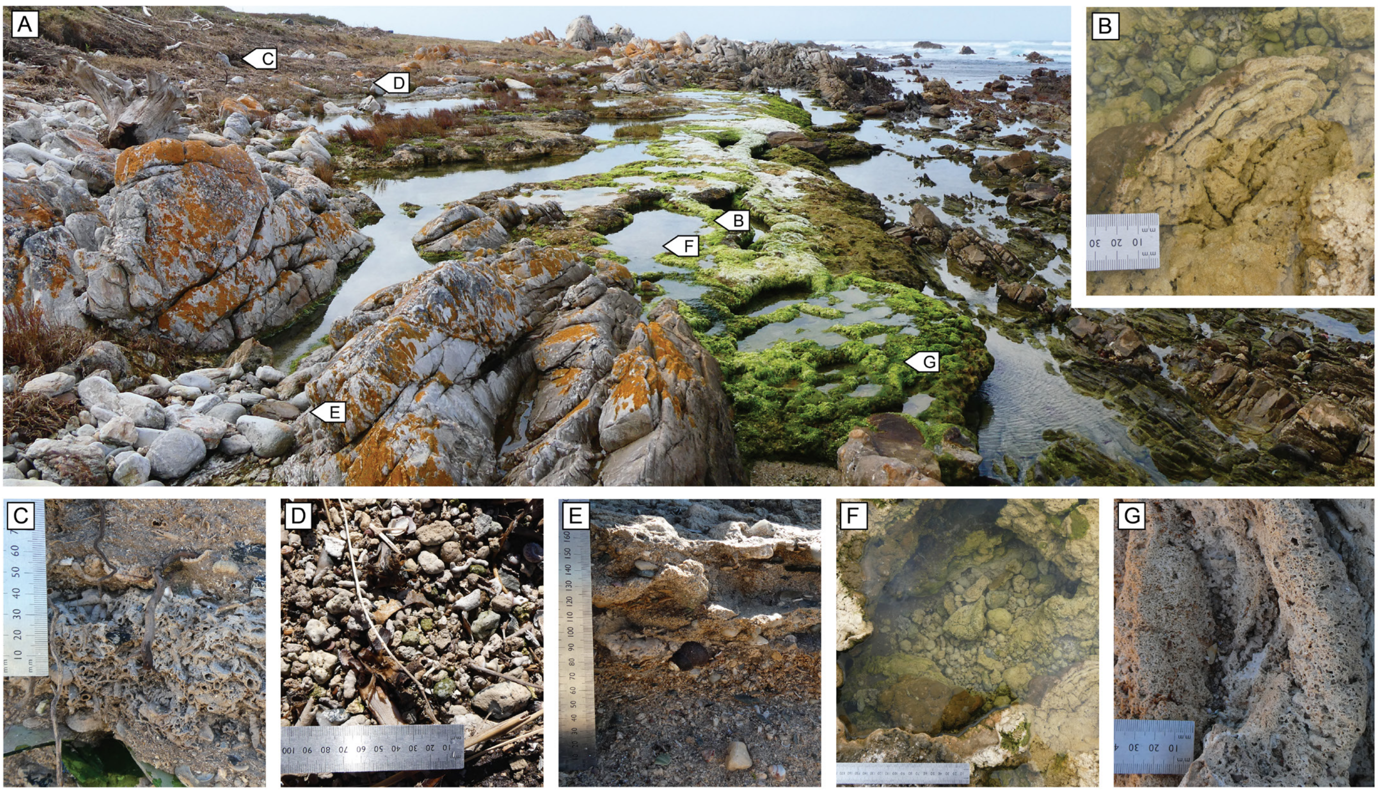

Figure 2. Figure 2. Tufa microbialite and associated marginal marine carbonate facies: A: example of tufa microbialite bearing groundwater-spring at Lauries Bay with inset B: stromatolite facies (in section); C: rhizoliths or root casts at the back of the beach; B: *Phragmites*-associated oncoids; E: beachrock; F: barrage-pool-associated oncoids; G: thrombolite (cm metal ruler for scale).

is also noted elsewhere, occurring at all elevations within the Tamala Limestone of Australia (Lipar et al., 2017).

Part II: St Francis Bay

Results

A large number of microbialite-bearing groundwater spring systems were observed, focused around four main areas in St Francis Bay (Fig. 2A). Stromatolite and thrombolite microbialite facies were common (Fig. 2B, G) forming a variety of macro-structures/morphologies, commonly barrage, as well as lacustrine crusts and cascades. Within some barrage pools, oncoids were also noted (Fig. 2F). While much attention has been given to microbialite facies in coastal groundwater springs, a variety of other terrestrial carbonate facies were also present. Rhizoliths were present proximal to the spring discharge point, within paludal deposits (Fig. 2C); oncoidal tufas were present within *Phragmites australis* beds (Fig. 2D). Distal to the discharge point was cemented 'beachrock', that formed where the groundwater flowed through unconsolidated beach sands and gravels (Fig. 2E).

Interpretation and discussion

The contemporary microbialites of St Francis Bay and the Eastern Cape are some of the most extensive and best developed microbialite systems globally. A variety of microbialite and associated marginal marine to terrestrial carbonate facies were present, comparable to those described in other global localities and those by Edwards et al., (2017). A spring high tide and high ocean swell event resulting in an 8 m storm surge 2 weeks prior to fieldwork lead to the discovery of previously undescribed *Phragmites*-associated oncoids in the backing beach and barrage pool-associated oncoids due to damage to the coastal vegetation and microbialite systems. This also provided some insight into long-term preservation potential.

Conclusions

In conclusion, while the laminar calcrete facies described from Shelly Bay, Kenton-on-Sea were formed in an environment that lies outside the wider PhD project focus, it is still worthy of further future study, especially given their relevance to Quaternary climate and environmental reconstruction as demonstrated by other global sites (Lipar et al., 2017, 2015; Lipar and Webb, 2014). Fieldwork producing description and sampling of living and Holocene spring-fed supratidal microbialites will facilitate greater global comparison, allow for greater understanding of their preservation potential and delimitation with associated facies in future research.

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The Boulders of Bahía Inútil

Large are the boulders of Bahía Inútil
Standing proud of the scrubland surround
For how long have Las Rocas Grises lain here, still?
And from where did their journey begin?
All jagged edge, and sandpaper hide
Oft covered in lichen's thick rug
With pockmarks and cracks worn as weather-beaten scars
By these sculptures of hornblende granodiorite

And so linearly strewn, not far, not wide
But aligned, like a quarry train frozen in time
For ice is the railway they've travelled
Though it's long derelict and abandoned now
Yet this is not the only train on the mainline
From Cordillera Darwin to the Argentine coast
And be they Darvill's, or Darwin's, or no-one's at all
They thrive in this landscape, do the old boulders of Bahía Inútil

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Written during fieldwork on Tierra del Fuego, southernmost Patagonia, in February 2013. Thanks to Chris Darvill and Will Christiansen for their company and feedback in the field. Those interested in finding out more about Darvill's/Darwin's boulders should read Darvill et al. (2015).

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Figure 1. The author stood on one of the Bahía Inútil boulders. *Photograph taken by Will Christiansen.*

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