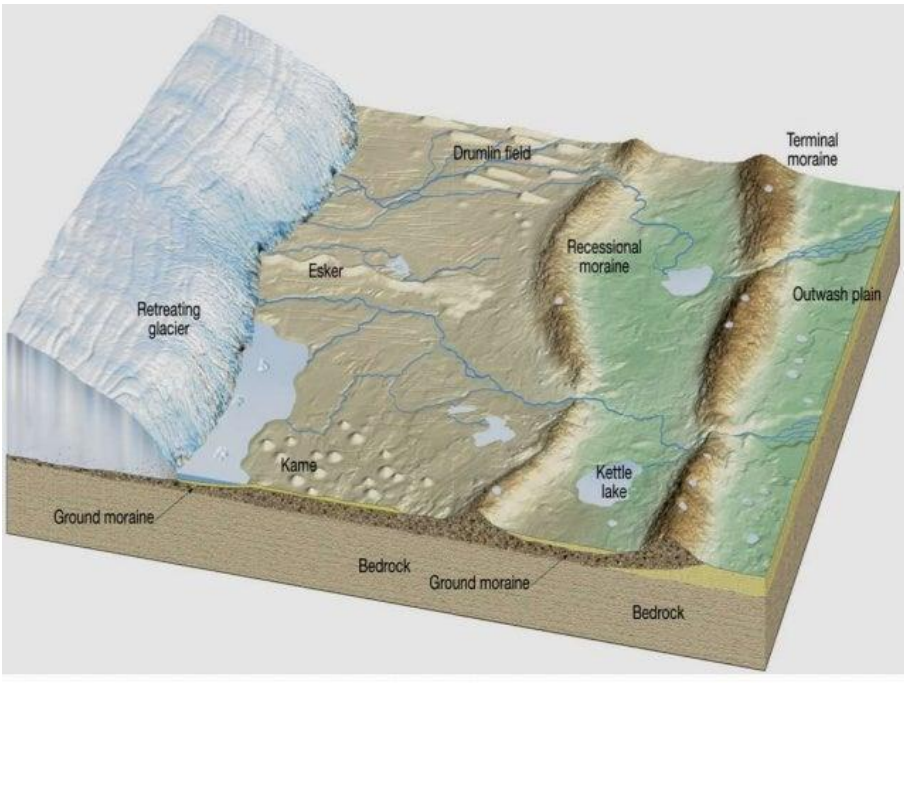
The Glaciation of Deeside

AGS Field Trip to Dinnet and Cambus o' May
- Sept 2023

Led by Dr Stuart Archer



Palaeo Lake Outflow Channel (channel 2) at Dinnet with Morven in the background

List of Localities:

1. **The Dinnet Outflow Channels**
    a. **St James (distal)**
    b. **Clearfield (proximal)**

2. **Cambus o'May Esker Complex**

3. **Burn o' Vat – glacio-fluvial mega pothole**

4. **Loch Kinord overlook – kettlehole lake**

5. **Glen Davan – esker**

6. **Raebush – Dinnet readvance moraine or esker?**

7. **Groddie – bifurcating esker? And Culblean drumlin field from a distance**

8. **Auchnerran – or "Loch Nerran" palaeo-lake**

9. **Kieselghur – Old Diatomite Works**

Localities

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2. Cambus o' May Esker Complex
3. Burn o' Vat – glacio-fluvial mega pothole
4. Loch Kinord – kettle hole lake
5. Glen Davan – esker
6. Raebush – Dinnet readvance moraine
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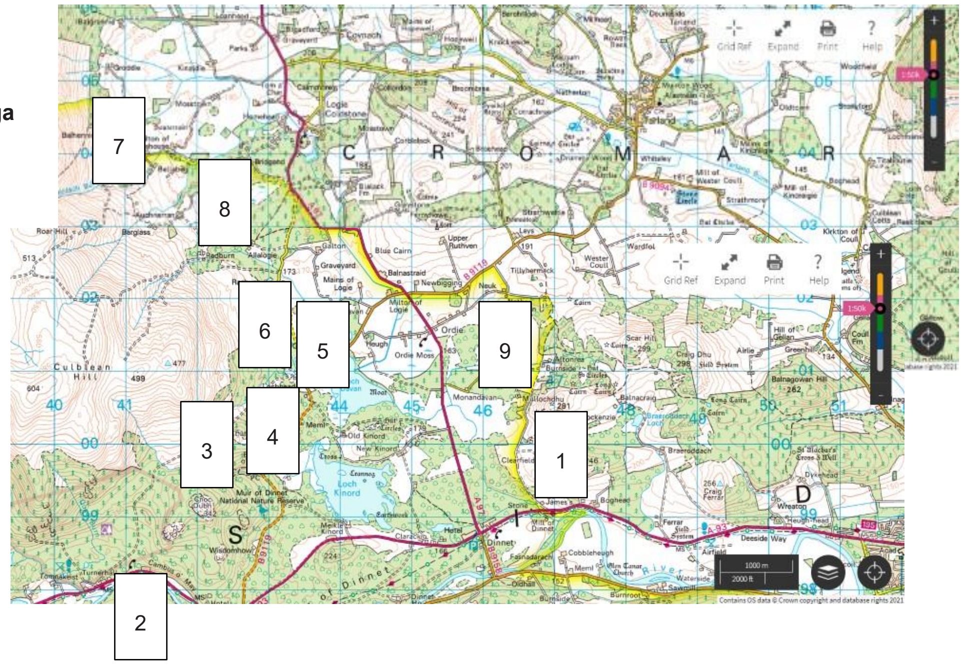
8. Auchnerran – "Loch Nerran" palaeo-lake
9. Kieselghur – Old Diatomite Works



Three main roads cross the field area, providing access to the localities:

- The North Deeside Road (A93), E-W, from Aboyne to Ballater,
- the N-S A97 from Dinnet to Logie Coldstone
- and SW-NE B9119 Burn o' Vat to Tarland.

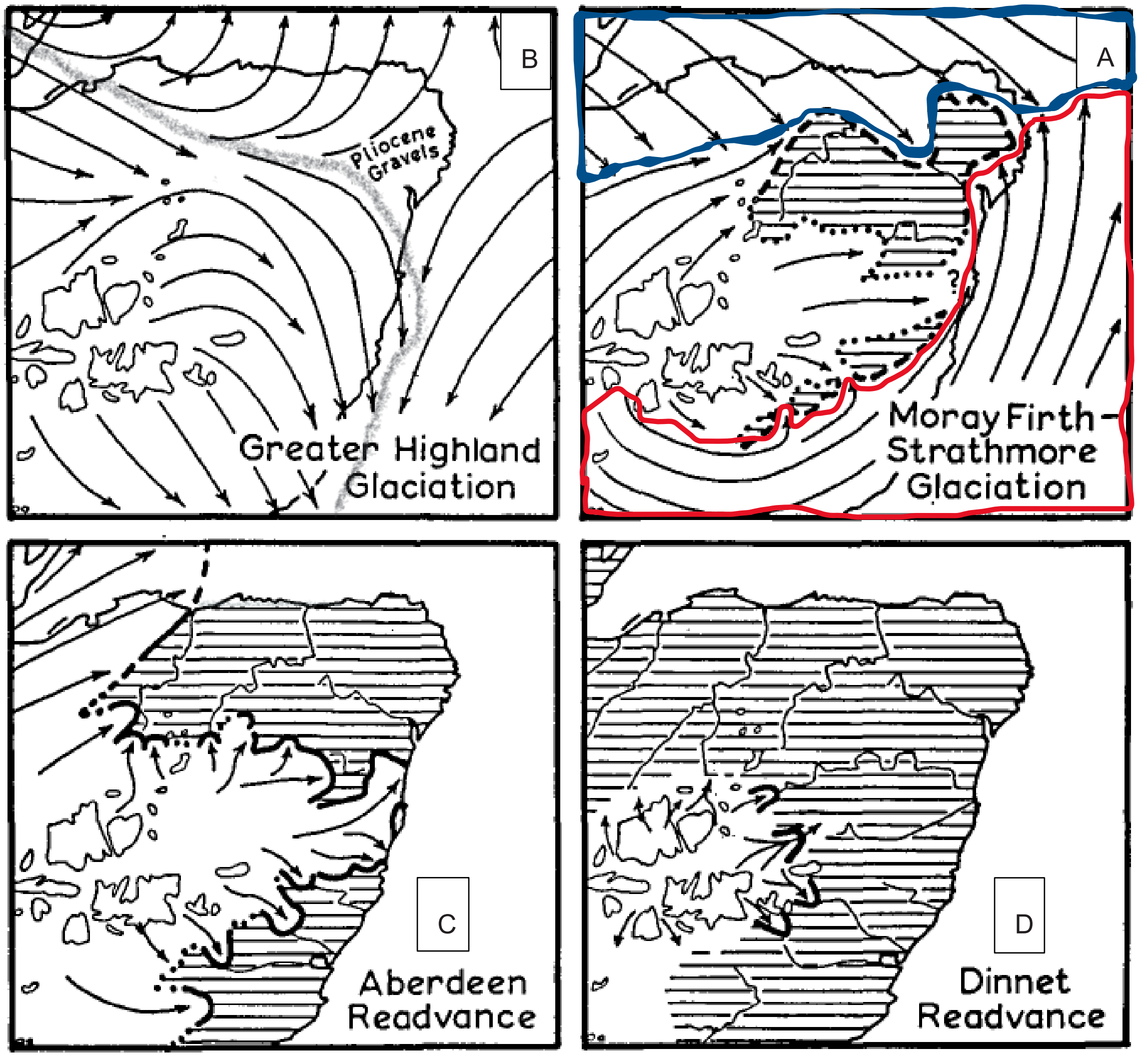
Geomorphological Themes:

1. **Palaeo Loch "Kinavan" and the Dinnet Outflow Channels**
2. **The Dinnet Readvance or stagnation deposits during deglaciation?**
3. **Glacial geomorphology and industry**
    - **Dinnet Diatomite Works**
    - **Quaternary Shallow Gas in the North Sea – from geohazard to energy resource (Aviat, Paso, Peon etc.)**
    - **Site surveys for wind turbine foundations and the "Quaternary offshore re-awakening"**
    - **Sand and gravel quarrying – versus geological conservation?**
    - **The value of new onshore LiDaR data (Scottish Govt)**
        - **Laser imaging Detection and Ranging**

Introduction

Historically, the previous theories of glaciation of the Northeast of Scotland were proposed by Jamieson, Bremner and Read. T.F. Jamieson of Ellon, in particular, broke new ground in the field of Quaternary Science, suggesting that Scotland had been glaciated just around the time of the famous visit to Scotland of Louis Agassiz from Switzerland in 1840.

In early models of glaciation, there was believed to be a stratigraphic succession of three tills. The oldest deposits were considered to be the "shelly indigo till" or Moray Firth Till (A) that were then followed by the "non-shelly lower grey till" of the Greater Highland Glaciation (B) and then superimposed by the "red boulder clay" of the Strathmore Glaciation (A) where ice swung back to the NW once round the mouth.



The glacial sequence in North-East Scotland.

Historical regional models for the 4 main ice ages. According to F.M. Synge (1956)

The Aberdeen Readvance (C) and the later Dinnet Readvance (D) made the glacial stratigraphy more complex by eroding some of the older deposits in places.

The basic colours of the deposits relate well to the provenance areas as they were governed by the entrained bedrock materials. This was integrated with evidence for glacial transport directions from striations and other classic indicators.

Charlesworth (1956) and Synge (1956) both concluded that a substantial portion of Buchan had not been glaciated during the last glaciation. This resulted in the concept of 'Moraine-less Buchan'. This concept was hotly debated and later rejected by Clapperton and Sugden (1975, 1977), who simply viewed Buchan as an area of rapid deglaciation and of complex paleo-environments. Arguments around the preservation of the Pliocene age Buchan Gravels and cold based versus warm based ice sheet interpretationsin the north-east also polarised this debate.

More modern reinterpretations suggested that the shelly indigo till and the red boulder clay were time equivalents (see A above) – a mix of Moray Firth and Strathmore provenances meeting around Peterhead, and in addition to the two readvance tills then the succession became four-fold rather than three (see above, Synge, 1956).

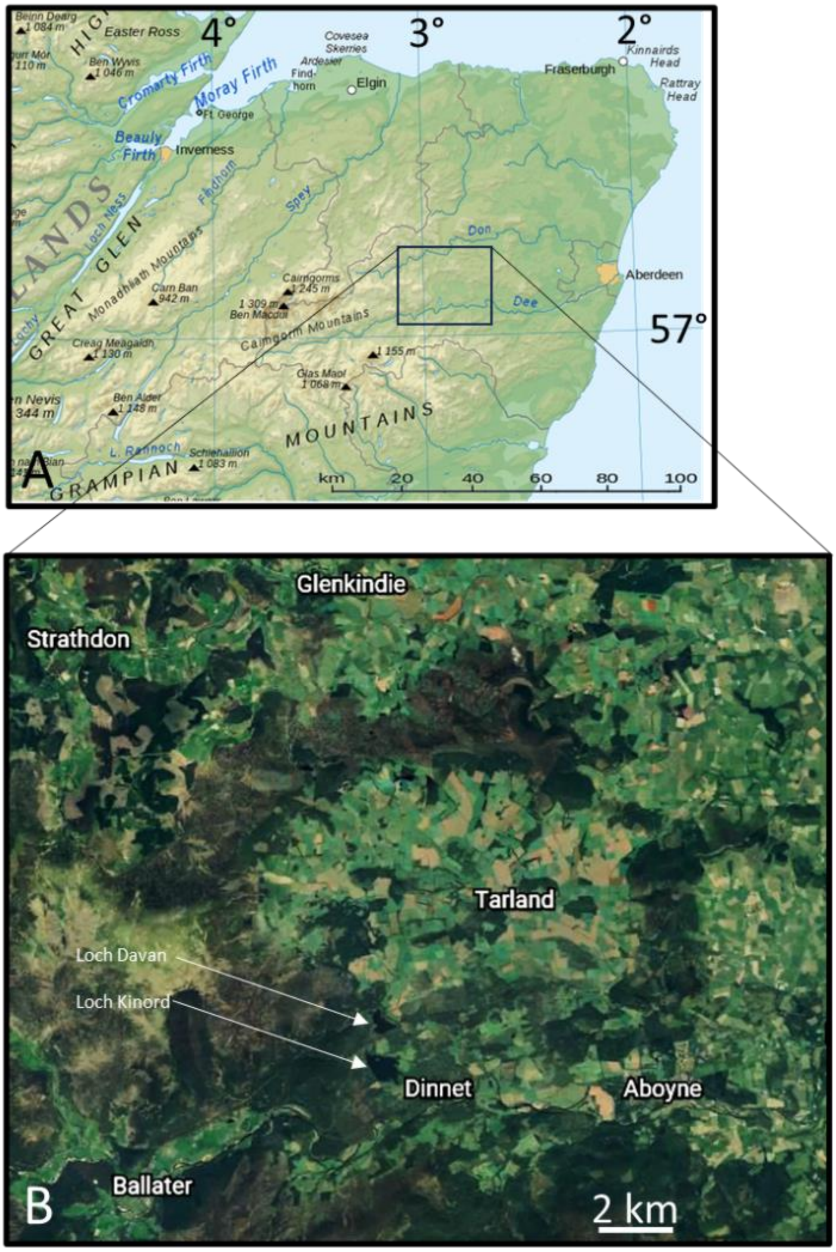
The Aberdeen Readvance persisted as a concept in the literature for 100 years between Jamieson's 1874 and Sisson's 1974 paper and the Dinnet Readvance is now considered more of a stagnation event (e.g. Simpson, 1955 and Brown, 1993).

General physiography of the Howe of Cromar

with the Morven hills to the west being viewed (topographically rather than geological) as the start of the Highlands.

This picture was taken at the opening of this new marker stone near Dinnet Mill. It was erected by the Deeside Field Club in 1965 using granite from Dunecht quarries.

This event is a reminder of the debate that has existed in Scotland for centuries – namely, the definition of 'The Highland Line'. This is relatively straightforward in the west of Scotland, but not so in the east, where the geological definition (Highland Boundary Fault) and altitude-based definitions (e.g. ~600' or 200 m) are not coincident.



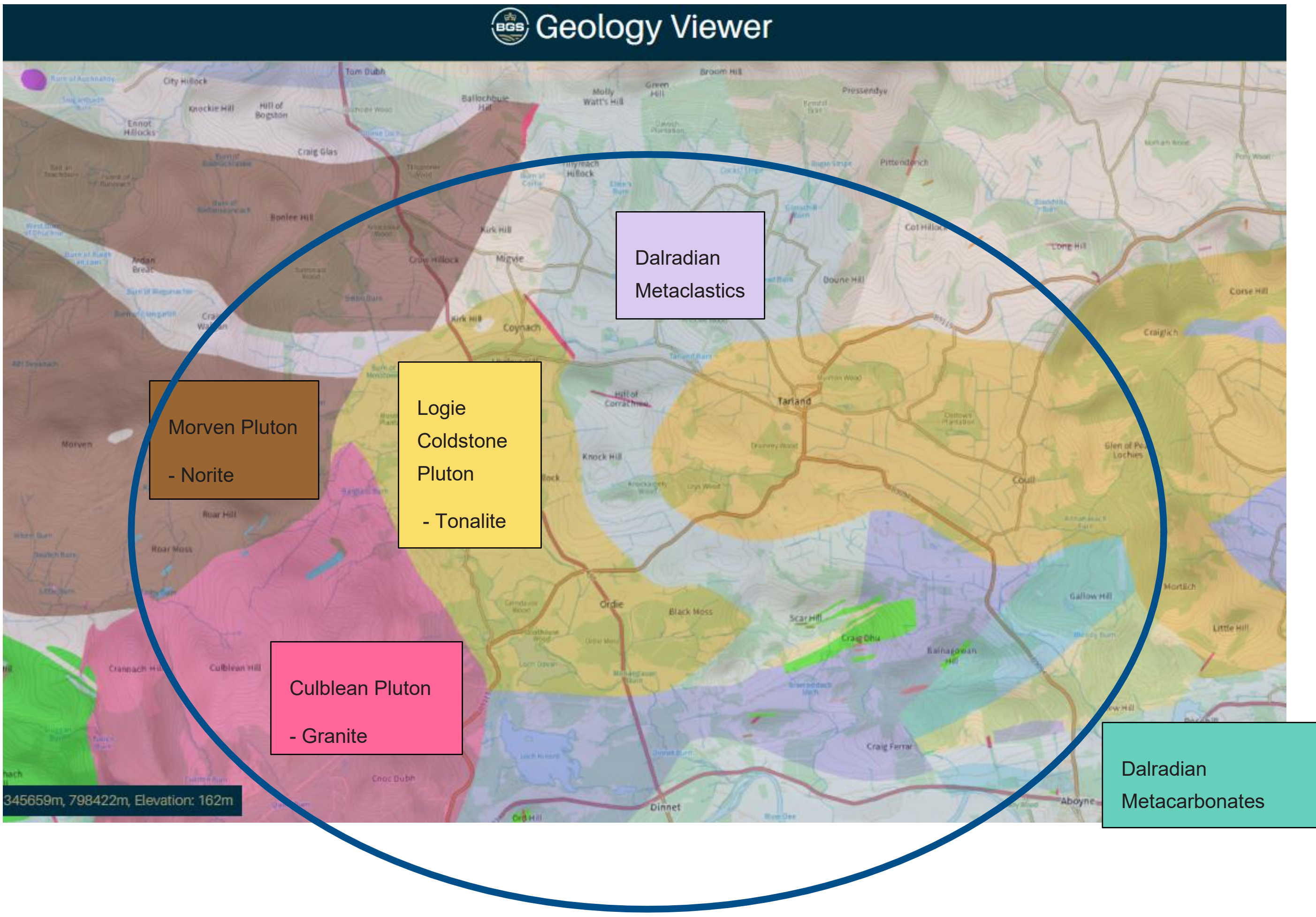
The Howe of Cromar is a bowl shaped topographic low on the eastern edge of the Grampian mountains. It is elliptical in shape and is 10 km x 7 km. It represents the last of the large, low lying, easily farmable areas in the foothills of the Cairngorms.

Bedrock Geology

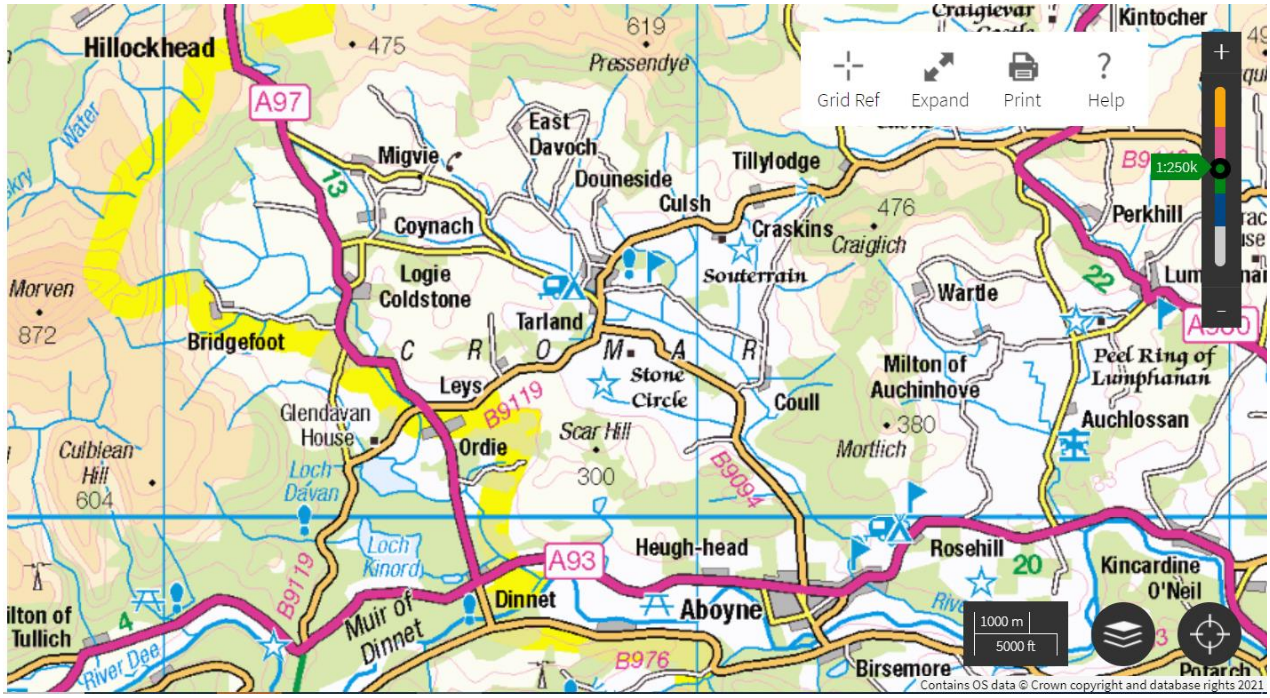
In 2009, while working at Aberdeen University, a friend and colleague (Dr Scott Thackery) and I tested the concept that because of the near perfectly elliptical shape of the Howe of Cromar, that this large, topographic low could have been a meteorite impact crater. Despite numerous discussions, excursions and sampling, including the making of thin sections, no shocked quartz or iridium was ever found.

The geological origin of the Cromar is likely related to the relative hardness of the basement rocks. Gabbro and Granite to the west at Morven and Culblean, respectively, with the centre of the Howe represented by softer metamorphic rocks of the Dalradian and a highly weathered and weak Tonalite around Logie Coldstone. The weakest lithotype of the area appears to be the Deeside Limestone Formation, which is a meta-carbonate. This outcrop belt is the location, that the River Dee occupies.

However, the geological map and relative hardness might not tell the whole story of the Cromar because there is a possibility that an ancient Old Red Sandstone (Devonian age) river occupied the bowl of the Cromar – no deposits of this age remain to support this theory.



This elliptical topographic low (in blue approx.) facilitated the formation of glacial lakes by providing natural topographic confinement. Its western edge is defined by a line of hills including Culblean (604 m) and Morven (872 m) and its northern edge by a line of hills that include Baderonach (475 m), Pressendye (619 m) and Pittenderich (508 m). The eastern edge of the Cromar is defined by the lower hills of Craiglich (476 m) and Mortlich (381 m) both of which lie just north of Aboyne.



Of more relevance to palaeo-lake Kinavan is a line of low hills that exist in between the villages of Dinnet and Tarland (Scar Hill at 300 m, Mulloch at 281 m and Tomachallich at 246 m) that provided the eastern confinement for the lake. This line of low hills, in the centre of the Cromar, provide an important topographic barrier to the east side of the lake, allowing the "Kinavan bowl" to be described as the western third of the Howe of Cromar.

These physiographic barriers provided the perfect setting to host a palaeo-lake on three sides (west, north and east) whilst to the south it's envisaged that the Dee valley glacier created an ice dam. Immediately prior to the spill to the south-east through the Dinnet channels, the lake possibly spilled eastwards into the Tarland bowl using the Leys and the Wester Coull gaps at 186 m and 189 m. respectively. To the north, the Howe of Coynach gap may have represented the highest lake spill at 193 m but the evidence for this is less obvious, meaning that how long the lake existed at this highest level, is unknown. Between Mulloch and Tomachallich, the Knockenzie gap sits with a sill height of 200 m and may have provided an overflow channel to the Braeroddach Loch to the east and ultimately past the west flank of Craig Ferrar.

This eastern topographic sill termed the "Mulloch - Tomachallich Sill" may have provided some control over ice edge positioning also, encouraging a pause or still stand – either as the main "late glacial" Dee Valley glacier retreated or as ice readvanced. Alternatively, the "Culblean – Cnoc Dhu Sill" to the west could have provided the buttress for ice to pause on, leaving the ice dam to the south of palaeo Loch Kinavan to be simply dead ice.

Locality 1 – Dinnet Outflow Channels

In Aberdeenshire, north of the River Dee and to the east of the main Grampian massif, lie two kettle hole lakes called Loch Kinord and Loch Davan. Geomorphological and sedimentological evidence suggests that both lochs were once higher and linked, forming a large ice-dammed palaeo-lake that has been named here informally as palaeo-lake “Kinavan” (Kinord and Davan).

There are many lines of evidence to support the existence of palaeo-lake Kinavan:

- The existence of lacustrine deposits of Diatomaceous earth – well above the current lake levels
- Stable higher lake levels evidenced by shoreline “benches” and other topographic breaks in slope
- Perched deltas where the former lake level was sufficiently stable to be prograded into by rivers
- Outflow channels from the palaeo lake at heights well above the current lake and with no obvious catchment areas to drain.

Arguably, the most dramatic and spectacular of these is the series of palaeo outflow channels that are prevalent to the east of Dinnet at the southeast margin of the lake highstand outline. These channels are the focus of the initial part of the excursion.

Clearfield Channels – base map

The exact timing and evolution of lake level fall is complex to reconstruct and will require further work but is likely related to the gradual release of an ice dam to the south – the Dee Valley glacier. Several different options exist for the existence of ice in the palaeogeography at this time:

1. Ice retreating steadily westward up the Dee Valley at the end of the Devensian (Dimlington Stadial) – creating an ice dam as it wastes during its retreat.
2. Ice retreating in the Dee Valley then breaking off a large snout across the Cnoc Dubh – Culblean buttress (around Cambus o’May) and acting as an ice dam while being dead ice.

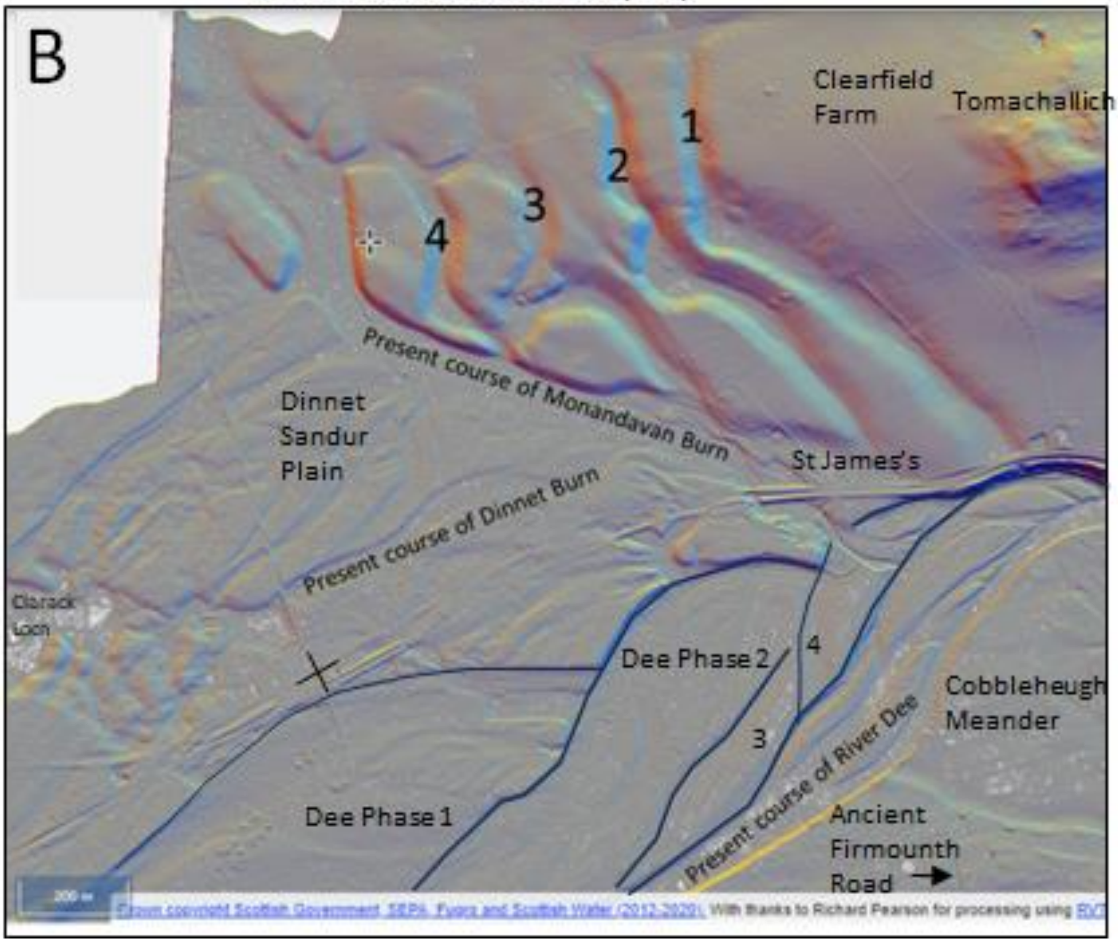
3. Ice readvancing during the ‘Dinnet Re-advance’ to create the ice dam then retreating.

Whatever the actual processes involved in the making of the ice dammed lake, four distinct palaeo outflow channels can be found 1km east of the village of Dinnet, in the vicinity of St James’s and Clearfield Farm.

The channels are smooth sided and trapezoidal in cross-section (upper-mid reaches) to pseudo-trapezoidal (lower reaches). Such fluvial cross-sections represent immaturity of development, suggesting the channels were not in existence for long enough to allow the formation of the most hydraulically efficient parabolic shape - associated most commonly with sinuous channels.

The length and gradient of the channels also suggest short-lived fluvial processes formed them. This supports the notion of outflow channels that were active for a time-limited period only, i.e. incremental drainage of a lake through channels that most likely discharged into a pro-glacial outwash or sandur, the course of which was similar to the modern River Dee but higher in terms of both present discharge and altitude.

Dinnet Outflow Channels (4-1)



Utilising the 2012 LiDAR Digital Elevation Model 1m - Scotland, Ph 1 – Acquired primarily for flood risk management but a paradigm shifting data set for geomorphology and archaeology. Open source Scottish Government.

Channel Morphometrics

The channels are 50-100 m wide, are 5-15 m deep and 400 – 1200 m in length. The channels have been named from east to west in order of occupancy (old – young). The four channels have different starting altitudes. The eastern most of the four (channel 1) has the highest at 185 m, channel 2 at 178 m, channel 3 at 171 m and channel 4 at 169 m. This gradual change in outflow altitude provides the distinct impression that their occupancy was sequential and ordered.

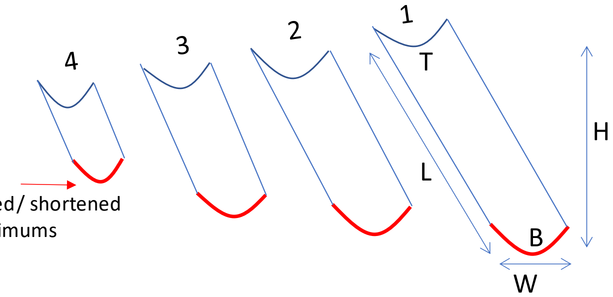
These heights were extracted crudely from OS maps (we'll change to altimetry eventually) and have been used as reconnaissance heights to test for correlation against other geomorphic features in the area such as shorelines and delta tops. In addition to the drop in altitude from east to west the channels also reduce in size, length and gradient.

Table 1

	Channel 4	Channel 3	Channel 2	Channel 1
Top height (T)	166	171	177	183
Bottom height (B)	160	152	155	158
Height loss (H)	6	19	22	25
Channel length (L)	600	900	1000	1200
Max channel width (W)	60	80	100	150
Gradient (H/L)	0.010	0.021	0.023	0.023
Lake area (km2)	7.6	9.9	11.6	13.1
Lake volume (m3)	10711029	54002261	118164367	192173209
Volume drained per channel (m3)	10711029	43291232	64162106	74008842
Peak outflow per channel (m3/s)	195	554	729	845
Minimum time to drain (hrs)	15.2	21.7	24.4	24.3

All measurements in m

Includes the area but not the volume of both existing lochs



Note that all channel terminations are eroded/ shortened and so these present day lengths (L) are minimums

Channel 1

- Looking NNW up channel from near the channel end point. Bullet shaped clast in the foreground suggests this has deflated down out of a till.

- Looking SE down channel from the high point between channels 1 and 2

Channel 2

- **Looking NNW up channel from near the channel end point**

- **Looking west across the channel with St James in the background**

Channel 3

- Looking NNW up channel towards the meander bend from Birchfield

- Looking SSE down channel towards the meander bend

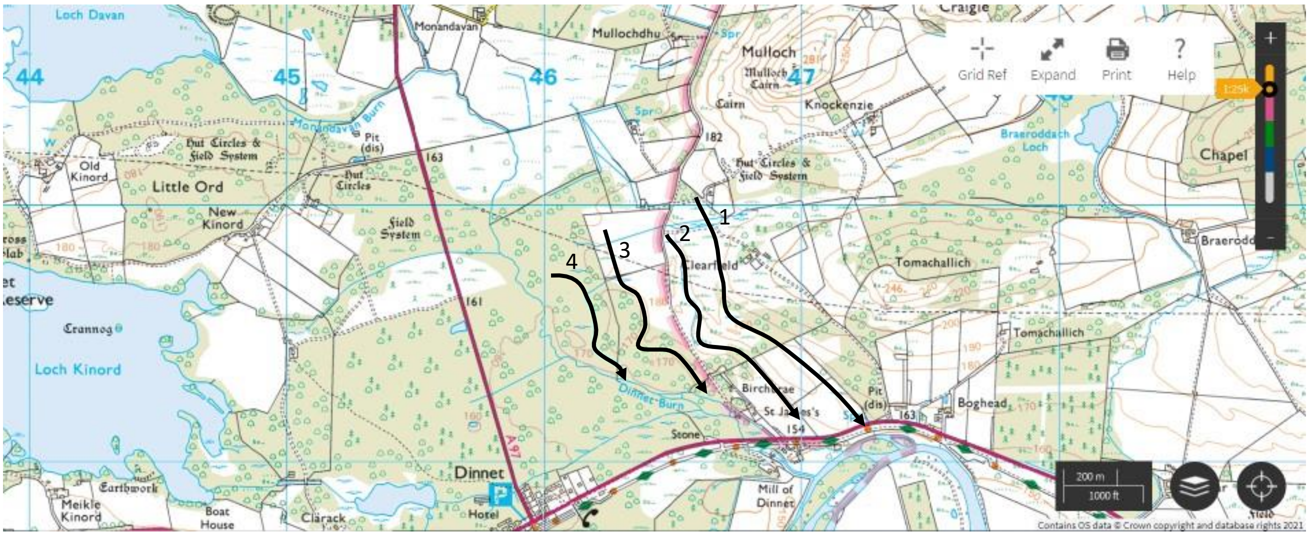
Channel 4

- Looking NNW up channel from near the channel end point

Interpretation

These palaeo-channels are likely to be outflow channels from a lake because there is no sufficiently-large catchment or headwater area to offer a solely fluvial explanation for the origin of the channels. The systematic reduction in height and scale of the channels from east to west (channel 1 to 4) is indicative of both the lowering and shrinking of lake levels and a reduction in outflow discharge as the lake margin in this area retreated from east to west.

Channels 1, 2, 3 and 4
in the context of the current lochs and outflows

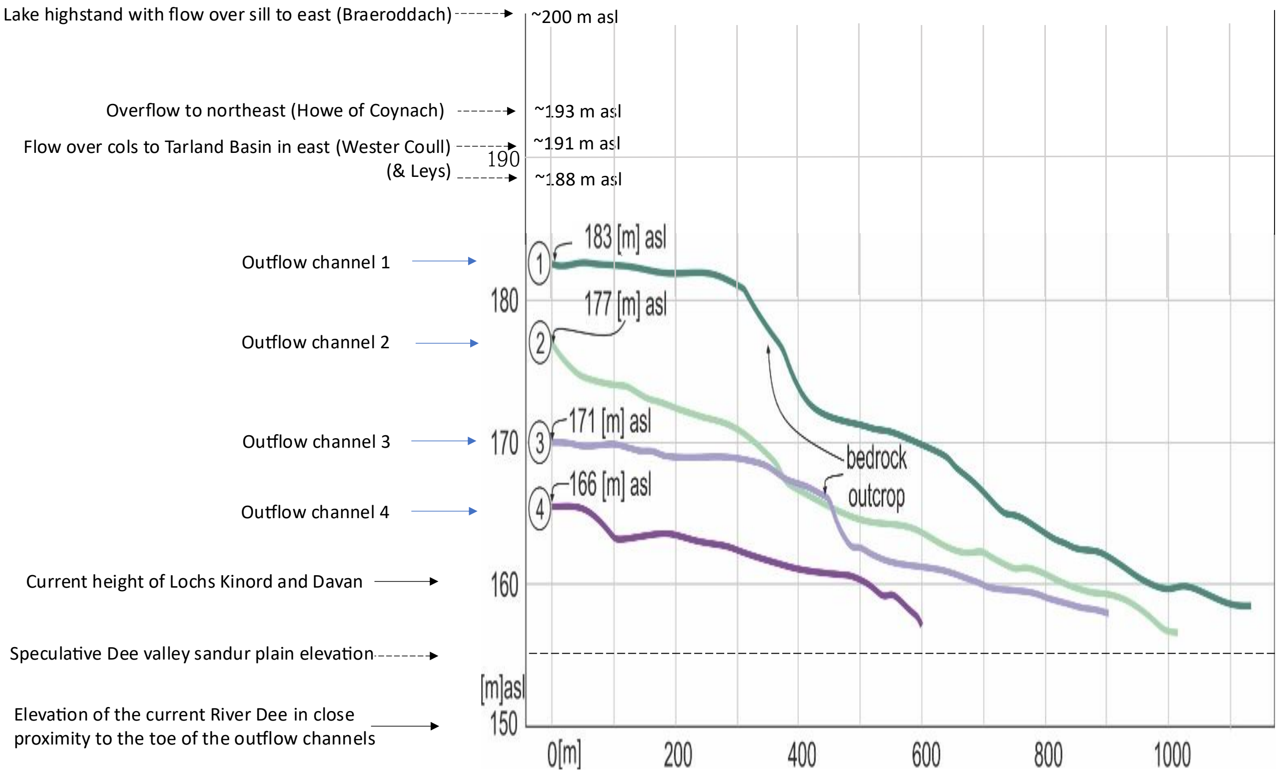


The generally smooth shape of the channels suggests that they are cut into relatively soft glacial fore-field material (diamicton) rather than bedrock. Such material lends itself well to the rapid formation of natural trapezoidal channels, given high enough discharge rates. There are a number of large bullet-shaped, striated clasts, which sit in the bases of the channels and which are unlikely to have been moved as bedload in the outflow channels but are more likely to have been winnowed out of the local till during the erosion of the outflow channels. The till would have been subject to peri-glacial processes and may have provided a relatively impermeable and indurated substrate upon which to sculpt these hydraulic forms.

The Monandavan Burn is a miss-fit stream in quite a wide palaeo-valley and that leads to the possibility that there were five ancient outflow channels – the fifth one still occupied by the current outflow from Loch Davan.

There are a couple of areas where modern drainage has altered the post-glacial geomorphology and which, causes complexity. This is particularly true of channels 3 and 4, where more recent alteration and modification, need to be considered in the interpretation of former lake heights.

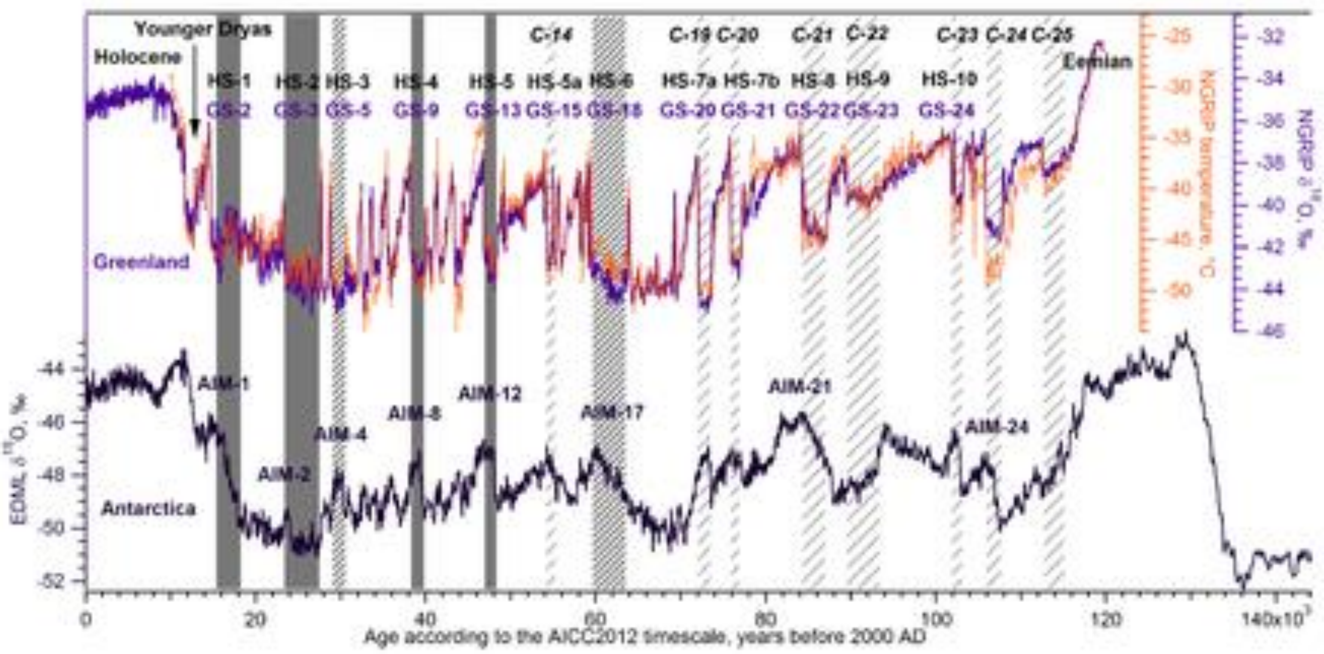
Fig 6



Lake heights (interpreted from the height of the proximal side of the outflows) and long profiles of the four channels. Profiles contructed by Bartek Kurjanski of UoA.

Geochronology

Uncertainty exists as to the exact timing of events. However, from the excellent preservation of the channels and the requirement of the ice dam to hem-in the lake on its southern margin, we suggest the end of the most recent major glacial period (Devensian ice age spanned 115,000 – 12,000 years BP).



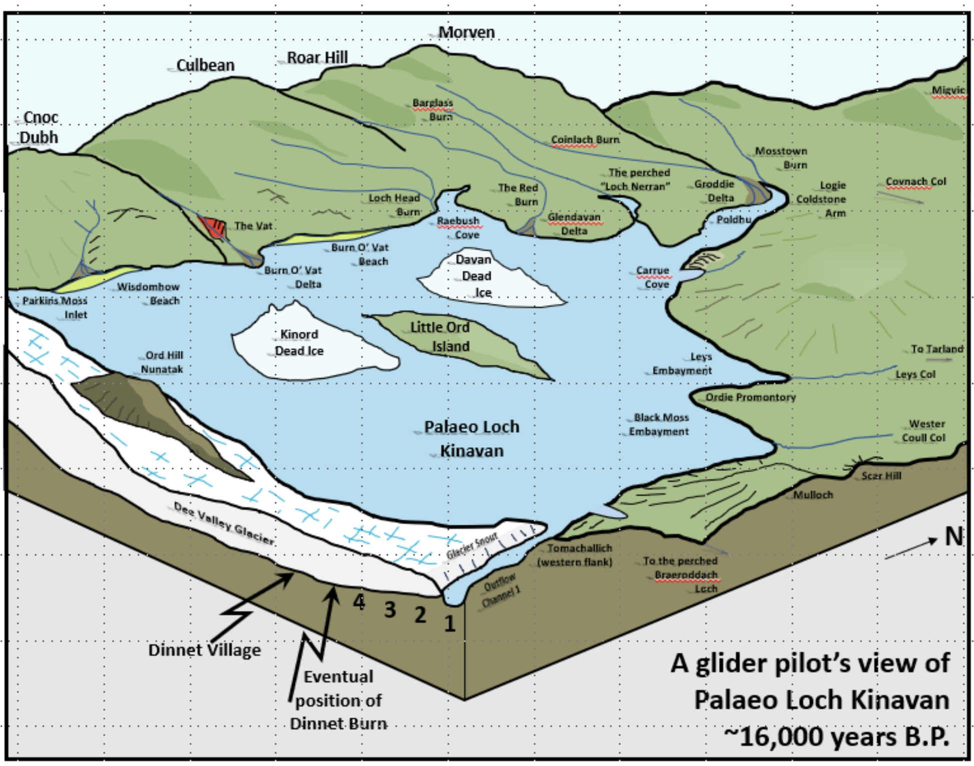
The Last Glacial Maximum Period (Dimlington Stadial) lasted from circa 27,000 to 20,000 years BP (with a maximum ice extent at around 24,000 years BP) and all of the channels and deposits seen on this trip presumably post date this maximum as glacial retreated from the North Sea was required.

Several readvances of Scottish-centred ice have been proposed based upon extensive and substantial moraine systems. Linear accumulations of glacifluvial deposits were mapped in the Aberdeen area by Synge (1963) and associated with glacier margins. The Aberdeen / Lammermuir Readvance (Synge, 1956; Sissons, 1967, 1981) was proposed to account for almost continuous assemblages of glacifluvial sands and gravels. In the Aberdeen area this is typified by a 3 km wide belt of ice-marginal deposits stretching across the lower Dee valley (Brown, 1993).

In Deeside, such features were previously assigned to a Dinnet Readvance by Bremner (1931) and Synge (1956). The Dinnet Readvance was correlated previously to a Perth Readvance but this link appears to have been discredited and in Dinnet, the deposits have been reinterpreted as stagnation deposits by Clapperton and Sugden (1972, 1977), Sugden and Clapperton (1975) and Murdoch (1975).

The most recent assessment of the ice-marginal deposits in the Dee Valley by Brown (1993) proposes a marginal supraglacial origin similar to the evolution of moraines on sub-polar glaciers. This explains their linearity and diverse sedimentology and indicates a series of glacier recessional stages. Additionally, the meltwater channels of the area are subdivided by Brown into discordant (subglacial) and concordant (ice-marginal) types.

The Dinnet readvance was previously thought to be related to the Loch Lomond Stadial (Synge, 1956) but following new work, the Dinnet area appears to be too far to the east of the Cairngorm massif for this event to be related in anyway to the Loch Lomond Stadial. This short duration cool pulse and readvance (Everest and Kublik, 2006) is dated as 12,900-11,700 yrs BP and also known as the Younger Dryas event. Please note the 2000 yrs older difference between BP and BCE dates.



A glider pilot's view of Palaeo Loch Kinavan ~16,000 years B.P.

In summary, it is believed that due to the pristine preservation of the outflow channels, the existence of the palaeo-lake is related to the steady ice retreat over the last phase of glaciation (Dimlington Stadial) and was never again advanced over. It seems clear that we still require an ice dam to remain present in the landscape but more work is required to work out what lake threshold could be retained in the area without an ice dam.

Dates of c. 16,000 – 15,000 years BP provide an approximate age for the channels and deposits seen on this trip. More work (new, modern dating techniques) or more reading of the current literature will be required to refine this.

Analogues

The form of these palaeo outflow channels near Dinnet closely resemble those seen in other parts of the world where glaciation is active or far more recent. For example, abandoned outflow channels from the pro-glacial lake that exists in the foreland of Heinabergsjokull, SE Iceland (Evans et al. 1999) provide excellent analogues for the Dinnet / Clearfield channels.

In the forefield of Heinabergsjokull there are examples of both simple hydraulic forms that drained a proglacial lake (see above) and also more unconfined glacial outwash, providing a vast range of fluivioglacial forms. An understanding of the full spectrum of process-form analogues is critical to the interpretation of the fluvioglacial geomorphology in the Dee Valley.

The parallel roads of Glen Roy in Lochaber…

An analogue or non-alogue for palaeo Loch Kinavan?

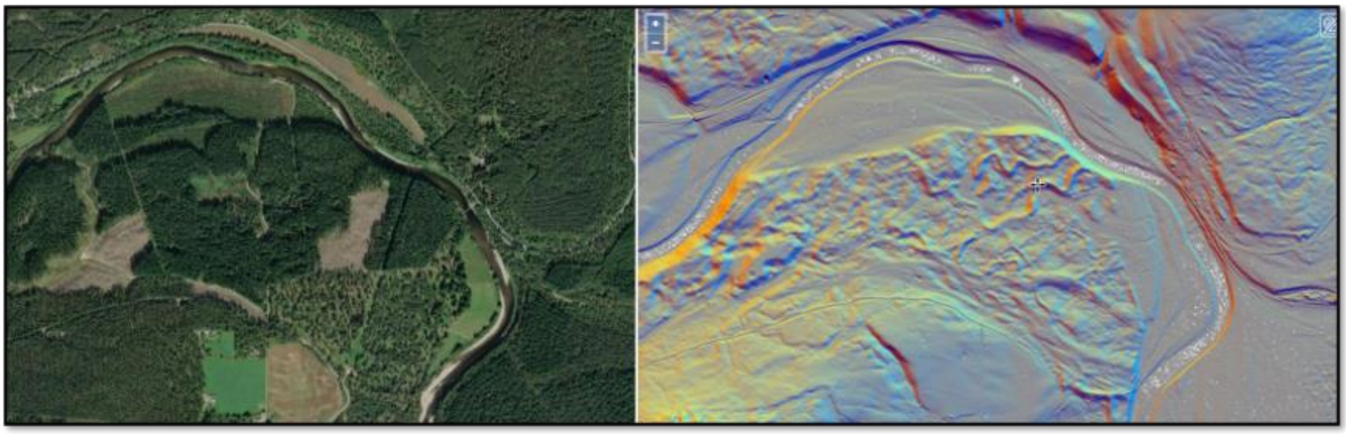
An obvious question that leads on from the interpretation of a palaeolake in the Cromar bowl is why we don't see more obvious shoreline benches / strand lines? Although in broad terms the analogue of the palaeo Loch Roy and palaeo Loch Kinavan is enticing there are major differences:

- Steepness of the Glen Roy glacial valley means that the "bathtub rings" are more easily etched than on the rolling hills of the Cromar.
- Land use has been very different with no farming on this steep ground but most of the Cromar has been farmed for thousands of years. Many tracks, then eventually roads, in this part of the Cromar have been built on the former lake benches – obscuring the geomorphic forms.
- The length of time that the lochs were stabilsed and at still-stand as well as the available fetch and wave action upon the paleo-shore may both have been very different. These aspects require more detailed work.

Locality 2

The Torphantrick Esker Complex, Cambus o' May

In Torphantrick Wood, west of the Cambus o' May suspension bridge, a fantastic mosaic of esker forms may be observed. Cambus o' May lies to the east of Ballater, Aberdeenshire and is located on a large bend of the River Dee. Its name derives from the Gaelic place name Cama a' Mhaigh ("bend of the plain").

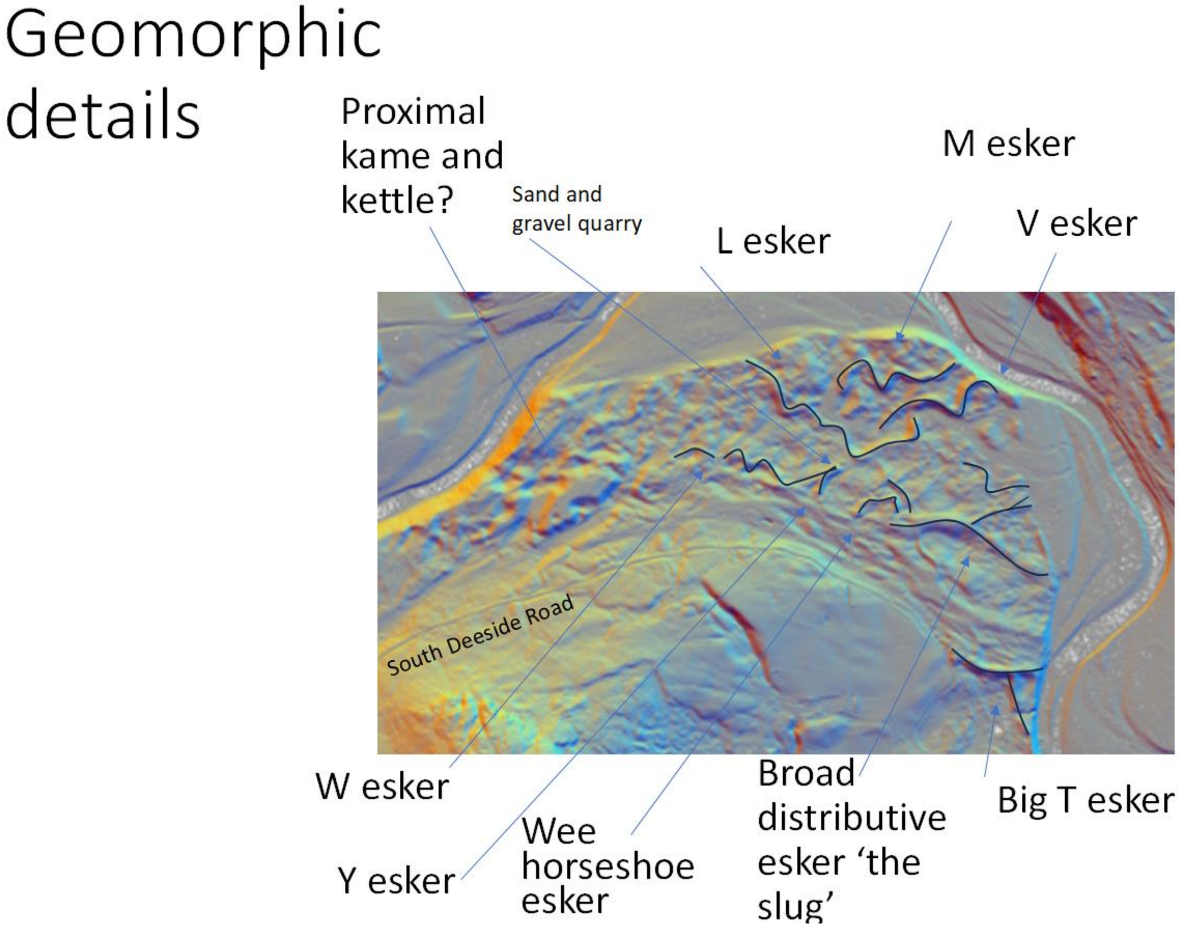


The Cambus o' May river bend and preserved eskers in a high terrace on the inside of the bend. Utilising the 2012 LiDAR Digital terrain model 1m - Scotland, Ph 1 – Acquired for flood risk management.

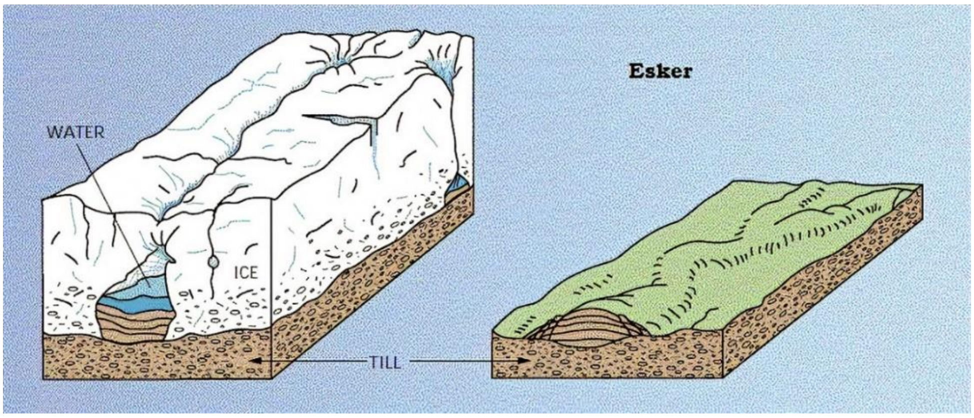
The esker orientations have no similarity to the present course of the River Dee, which is more incised and the esker field has been truncated by the Dee (particularly well observed on the east side). This truncation and the height of the terrace that the esker field sits on suggests that these forms are much older. The eskers are depositional ridges up to ~8 m high – and although altered by immediately post glacial drainage (in a relatively minor way) are thought to be well preserved examples of sinuous eskers.

An esker with around 5 m of topographic height

Close up DEM (Digital Elevation Model) of the Torphantrick Esker Complex near Cambus o' May



Eskers are topographically high ridges, usually composed of gravel, pebbles and cobbles that were deposited at the base of a glaciers in a tunnel that partially filled with sediment and partially with water. The supra-glacial ponded water may enter the ice mass via moulins and the crevasse and bergschrund network.



Due to the confinement offered by the ice during deposition, eskers often collapse at their margins and show evidence of deformation once the ice melts back.

Eskers may be many km's long, may bifurcate and even anastomose – they are testament to the complex hydrological system that form in a sub-glacial position once a glacier begins to melt and water is in abundance.

This example is from Ontario, Canada

The best examples in Scotland are the Carstairs esker (which has been mined for sand and gravel for many years now) and the Flemington Esker Complex near Nairn.

Locality 3

Burn o' Vat

To the west of Loch Kinord lies 'The Vat' which is a site of great geomorphological interest in Aberdeenshire. The Vat is a mega-pothole carved into pink granitic bedrock with approximate dimensions of 20 m width, 30 m length and possibly up to 40 m from top to bottom (although it is partially filled with sand and gravel – with an approximate thickness of 5-6 m). The exact origin of The Vat remains enigmatic with theories encompassing both a sub-glacial and pro-glacial meltwater scoured pothole.

One aspect that is clear in the Vat is that vertical fractures in the granite have played a role in developing weaknesses and heterogeneities in the otherwise homogenous lithology. These are oriented roughly W-E. The other aspect that is easy to see in the Vat is the sub-horizontal jointing that is present – and appears to dip gently to the east. The jointing could be the product of the cooling of the pluton at depth in the crust or could be a response to glacio-isostatic rebound and uplift.

Looking west up towards the waterfall. Donnie for scale.

Due to the topographic height of the Vat pothole being 200 m, and therefore higher than the highest recognised lake level (c. 183 m) we suggest that there is no genetic relationship between the Vat and palaeo-lake Kinavan – except that it would have been one of the main freshwater input points to the palaeo-lake.

Looking east towards the where the burn exits past the fallen blocks. From here the interior egg formation can be observed at the base of the vertical walls. This is likely to be a mega-scour hollow and will project down to depths of 4-5m.

The exact timings of ‘The Vat’ relative to the formation of the lake remain unresolved. However, the formation of the Vat would have required high volumes of glacial meltwater, suggesting that the ice front was most likely to be still in the catchment area. In which case, it is likely that the Vat was created at the same time that the palaeo-lake existed and when the Loch Kinord ice-berg was present.

It is also possible that the Vat owes its existence to a much older glaciation event, in which case the scour into the bedrock simply continued to exist below Dimlington age ice and was re-used as a meltwater channel.

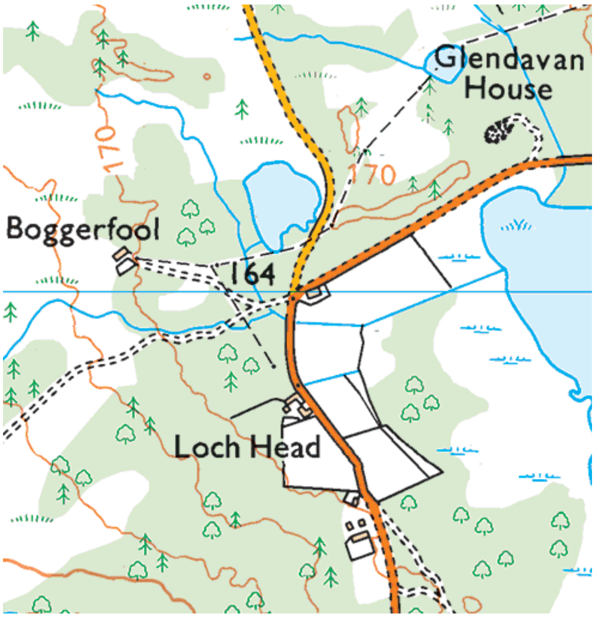
Locality 4

Loch Kinord Overlook

Loch Kinord – looking Northeast. Castle Island and the Crannog Island are obvious on the north side of the lake. Mulloch and Tomachallich are seen in the middle distance and the Queens View in the far distance.

Locality 5

Glen Davan Esker



This esker is picked out nicely on OS maps by the 170 m contour, just to the NW of Loch Davan, and due east of the Boggerfool kettle-hole.

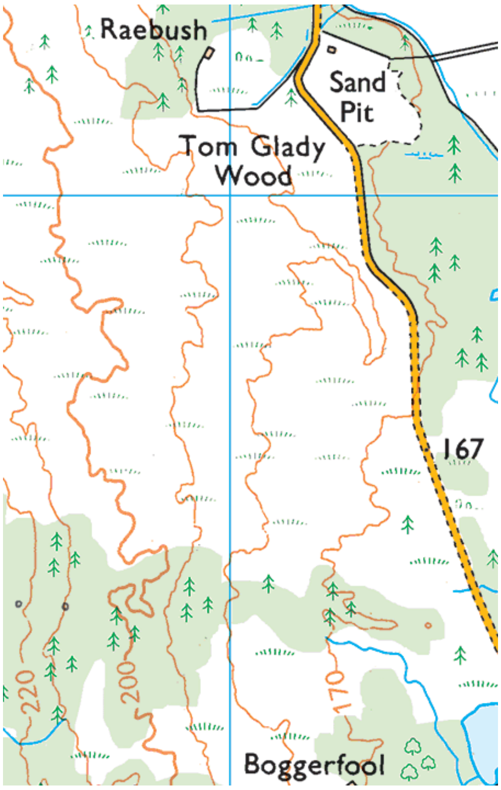
Excellent sedimentary structures can be observed in the open face. Photo looks NE.

From the morphology of the feature alone, it could be a moraine or an esker. However, there is evidence here for unidirectional flow (planar cross bedding). This feature is more likely to be an esker. The eastern end could be eroded and reworked by a delta or young fluvial system?

Was the esker transgressed by the large palaeo-lake? What evidence would we be looking for to demonstrate this?

Locality 6

Raebush terminal moraine or esker?



On days out with the family, this became known as the Witches nose feature due to its arcuate platform nicely picked out by the 180 m contour.

Some asymmetric slopes at the margins of this feature give the impression that the glacier may have bulldozed from right to left (W-E). View looking south-east.

Locality 7

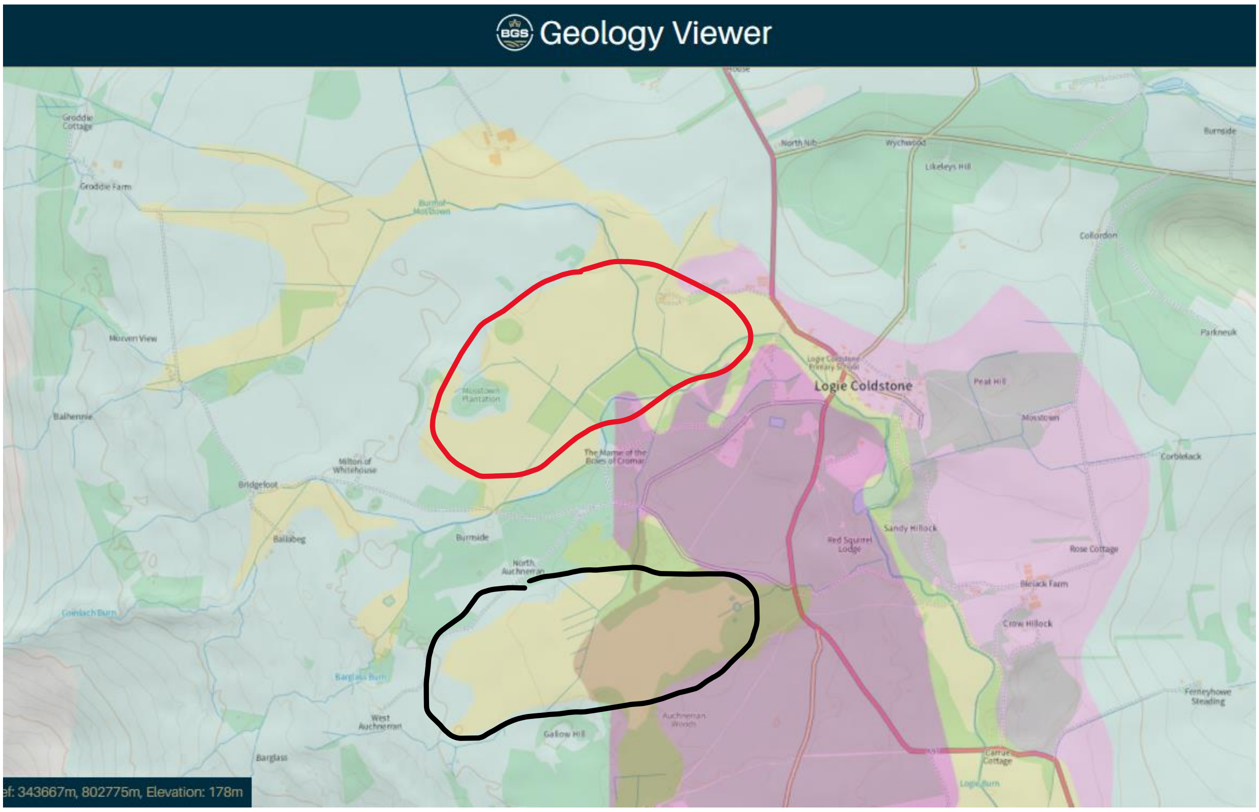
Groddie - bifurcating esker?

The Groddie esker near Bridgefoot (looking north). This esker has an arc like sinuosity to it and bifurcates at its northern end. In places the esker appears subdued topographically and is eroded or aggraded over - suggesting some later fluvial / alluvial activity - possibly delta fan progradation as the lake regressed?

Looking south from Groddie at the bifurcations in the distal portion of the esker. Note that the very crest of Culblean has no hummocks, suggesting that it may have remained a nunatak during the readvance, which deposited hummocky moraine or the drumlins on the north and east flanks of Culblean. The landforms are slightly asymmetric with the right sides appearing smoother than west (drumlinoid?).

Locality 8

Auchnerran palaeo-lake (Loch Nerran?)



Geological map from the BGS showing Quaternary deposits in yellow – these could be palaeo-deltas, palaeo-lake floors just silted up by modern fluvial sediments.

They areas are large and give an idea of just how much of this basin floor has been filled in and covered up in the recent geological past. The crude outline of the Auchnerran palaeo-lake is in (now silted up) in black and Mosstown (or Newton) palaeo-lake in red (now just boggy ground). These lakes may have been linked arms of a single water body at the maximum lacustrine highstand. The long, linear alluvial floor to the ground SE of Logie Coldstone is likely to represent a narrow arm of palaeo Loch Kinavan. Alternatively, the sediments in yellow could be delta deposits that prograded down this narrow belt as the lake regressed.

Locality 9

Kieselghur

An aspect of economic geology interest is that palaeo Loch Kinavan hosted freshwater lacustrine diatoms. The Dinnet diatomite was first discovered by Rev. George Davidson in 1876 who was accomplished in microscopy and palaeontology. He was able to analyse the 'white moss' and his identification of over 200 types of diatoms was a remarkable feat for the time. The deposits of diatomaceous earth were mined extensively in the late 1800's and early 1900's.

W.I. Macadam was the first to estimate the size of the reserve in the 1880's at 800,000 cubic yards. Diatomite was an important component in dynamite and the deposits were taken via train to the Nobel works in Ardeer, Ayrshire. Swedish chemist, Alfred Nobel had discovering that nitroglycerin could be stabilised if it was first absorbed in diatomaceous sand, known as kieselguhr, to produce a pliable dough-like material, which he called dynamite.

Dynamite, became very successful and made Nobel a very wealthy man indeed. It is no over-exaggeration to say that without the Dinnet Diatomite, the Nobel Prizes may never have been created!

Nobel also made several important contributions to science, holding 355 patents in his lifetime. The fortune that he made from its sale and the sale of other explosive products is the basis of the modern Nobel Prizes. By 1907, Nobel's dynamite factory at Ardeer was reputed to be the largest explosives factory in the world; it closed only relatively recently. Today, much of the nitroglycerin in explosives has been replaced with ammonium nitrate.

The location of the richest area that was mined is north of Dinnet at a location called the Black Moss; interestingly the location of the ruins of the mine workings is named Keiselguhr on OS maps (GR 462 010), which we believe is a miss-spelling. Kieselghur is the german word for diatomite (Kies = sand, gravel or pebbles / Ghur = earthy, treacley).

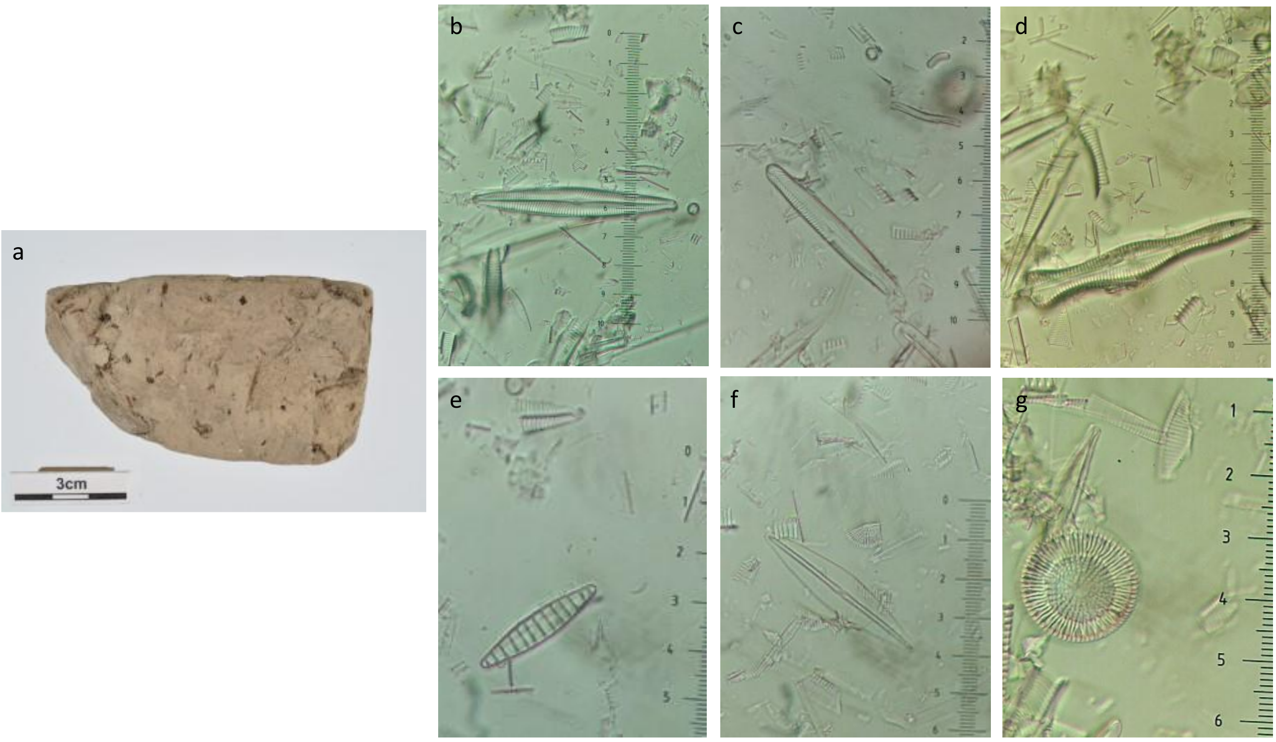
These locations, at which the diatomaceous earth was strip mined, are never higher than 166 m, which suggests that the lake, in which the diatomite was deposited, was most likely at 171 m or even higher. The diatomite formed in the Late Glacial interstadial, was replaced by a clay in the Loch Lomond Stadial and then deposited again in the Holocene.

A narrow gauge railway was used at the mine workings at Kieselghur then transported via horse and cart to the main line (Ballater-Aberdeen, Deeside Line) at Dinnet. All mining stopped in 1918 at the end of WWI. Sale of the already mined material continued until 1921 or 1922.

Another Scottish diatomite deposit with a history of extraction, exists on the Isle of Skye on the Trotternish peninsula at Loch Cuithir near Lealt. These deposits were also taken to Ardeer in Ayrshire. Diatomite is also mined from Northern Ireland, but the largest known deposit globally, is at Lompoc, California.

Diatom basics

Diatoms are single-celled, photosynthetic algae with a skeleton (frustule) made of silica. They can be found in almost any aquatic environment - fresh, brackish and salt water, and even in soils. They are typically 20-200 microns in length or diameter though occassionaly, as large as 2 mm; are either solitary or form chains.



The Dinnet Diatomite in hand specimen and in photomicrograph. Picture taken by Walter Ritchie (Dept of Geology, UoA) and biostratigraphy undertaken by Emma Sheldon (GEUS in Denmark)

To build their cell wall, diatoms extract dissolved silicic acid from water as they grow and return it to the water when they die. Silicon in water comes from aeolian dust, weathering, via rivers, from hydrothermal activity and by seafloor sediment recycling. The growth of diatoms can be limited by nutrients such as nitrates, phosphates and iron. Extant diatoms produce between 20 and 50% of the oxygen produced on Earth each year.

In marine environments, diatoms can ‘bloom’ due to upwelling of cold nutrient-rich water. In Germany the diatomite deposits are related to volcanic tuffs but in Scotland they were probably a function of the glacial meltwater.

Fresh water diatom blooms may cause environmental nuisance in cold streams and rivers where they produce mats of a brown jelly-like substance (known as rock snot), which chokes organisms in the water and impacts fish populations.

Diatomite is a highly porous sediment mainly composed of fossilised diatoms and is therefore of biological origin. Practical uses for diatomite include filtration, insulation, pesticides, abrasion (e.g. toothpaste), absorption (e.g. cat litter). A good diatomite will absorb four times its weight in water!

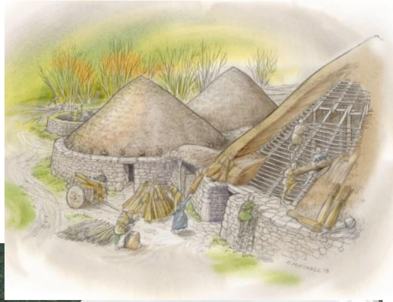
As a function of this high porosity, diatomites can also form hydrocarbon reservoirs; 2 examples include the Miocene Monterey Formation, San Joaquin Basin, California and the Miocene of the Danish and Norwegian North Sea.

Links to archaeological remains?

Numerous hut circles and field systems have been found in this area, showing that the climate / environment was good to live in and that food and water were plentiful. Many of the sites appear to be higher than the current loch heights, possibly suggesting that local people were living close to a palaeo-lake shoreline.

New Kinord hut circles

- Iron Age occupation
- Dating relative to the Crannog Island on Loch Kinord?

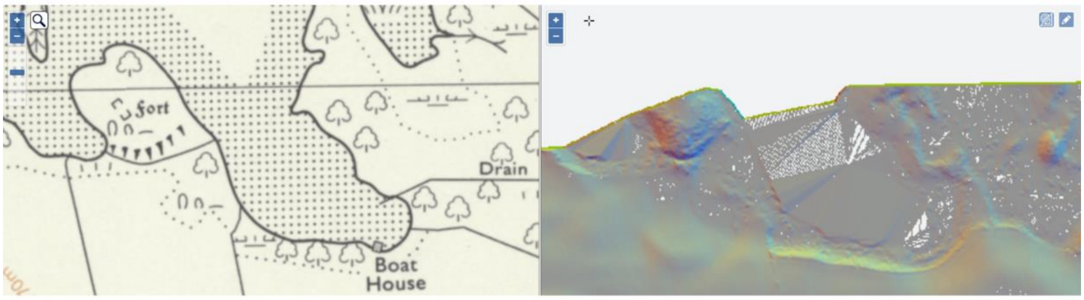


If detailed work in the vein of Edwards (1975) could date the archaeological remains to ancient lake shorelines then the sub-disciplines could be integrated to reconstruct the ancient communities in the context of new palaeogeographies. This type of correlation could well lead to an understanding that ancient peoples were living on island shorelines rather than lake margins? For example, note the New Kinord hut circles at GR 449 002 where a lake at 166 m (Outflow Channel 4) would place these hut circles close to the shoreline of an island.

It is thought that the Pictish town of Devana existed on the edge of palaeo-Loch Davan but was possibly sacked by the Romans under the leadership of Emperor Severus in 208 CE. The unfinished fort to the northeast of Ordie may have been built on higher ground, close to Devana, in response to the Roman threat but apparently was never used.

Earthworks also exist on a promontory on the south eastern shore of Loch Kinord. Part of the outer rim of the Gardybien fort can be proven to have been a moat. A lake level of 1 – 2 m higher would have isolated this fort.

Gardybien – with clear moat



South east side of Loch Kinord

The Crannog on the north of the loch is likely to be from the Iron Age. The Castle on Castle Island is more recent (Malcolm Canmore's hunting lodge) although it could have been built on an older site.

Historical changes to the lochs

A homestead and moat have been recognised as existing 100 – 200 m to the east of Loch Davan (GR 448 008). The level of Loch Davan would need to be only slightly higher for this moat to have been in use. This is likely medieval in age and was a base for an Army general before the battle of Culblean in the 1300's.

As part of a scheme to manage the water resource in this area, a narrow canal was built on the west side between the lochs about 162 m to link the waterbodies in the historical past (GR 438 002). The canal was cut in low ground to the west of Little Ord hill to link the lochs at a height of 1-2 m higher than their current height. Prior to this period of enforced linkage, it is highly likely that the two lochs were of different heights.

The Clarach Loch to the east of Loch Kinord is man-made as it does not appear on maps older than ~1900. After it was created, sluices and dug channels are believed to have been used to create hydro-power - providing electricity to Dinnet House as part of estate improvements in Victorian times. There is another set of sluices on the eastern exit of the Clarach Loch that may have been used to modulate the flow of the Dinnet Burn to Dinnet Mill. Historically, the water from Loch Davan and Loch Kinord was used to power that mill, which was sited just before the Dinnet Burn entered the River Dee.

Conclusions

This excursion has revealed four well preserved outflow channels from palaeo-lake Kinavan – a large glacial lake that was situated in the western part of the Howe of Cromar at the end of the last glacial period.

The lake was hemmed in by high ground on three sides (west, north and east) and presumably required an ice dam on the fourth (southern) side.

Although much more extensive study needs to be undertaken, this reconnaissance work suggests that the palaeolake might have been up to ~30 m higher than the current kettle hole lakes of Loch Davan and Loch Kinord.

Palaeo Loch Kinavan reduced in height and size in phases, the tempo of which was probably controlled by the position and height of the ice dam provided by the snout of a retreating Dee Valley glacier.

This fieldtrip has provided an overview of some spectacular glacial landforms that will hopefully trigger renewed interest in the deglaciation of this part of Deeside.

It is hoped that this cursory, reconnaissance work could catalyse further geomorphological, sedimentological, limnological and palaeo-hydrological analysis to better understand the late-glacial and post-glacial history of NE Scotland. In time, this work on landscape reconstruction could be integrated with archaeological work on the Palaeolithic and Mesolithic of Deeside.

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