## Evidence for glacial lakes at Banchor and lower in the Findhorn Catchment

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The existence and location of former glacial lakes within the catchment of the River Findhorn has been the subject of debate for more than a century, with early researchers such as Lauder (1830), Bain (1911), Hinxman and Anderson (1915) and Charlesworth (1956) proposing the presence of lakes, but disagreeing about their locations and extent. For example, many of these workers, as well as MacDonald and Fraser (1881), Wallace (1898) and Horne (1923), suggested that a glacial lake occupied the valley of the River Findhorn at Polochaig [NH 8286 3495] (the name, not now shown on Ordnance Survey maps, is of a ruined farm on the eastern bank of the river, opposite Shenachie) (**Daless Viewpoint**, Fig. 107). A second (possibly contiguous) lake that occupied Strathdearn, around Loch Moy [NH 775 345] (Fig. 12), was postulated by MacDonald and Fraser (1881) to have been dammed at the 'Pass of Polochaig' (at the head of the Streens Gorge) 'by ice and gravel at the latest stage of the latest glaciers of the Findhorn valley'. Horne (1923) stated that Glacial Lake Moy was impounded by 'fluvioglacial deposits laid down against an isolated mass of ice during the retreat of the Findhorn glacier'. Bremner (1939) argued strongly against the former presence of lakes at both localities, but he postulated that an ice-dam formed by the 'Moray Firth Ice-lobe' was responsible for blocking drainage much lower in the Findhorn Valley, between Dulsie Bridge [NH 932 417] and Dounduff [NH 993 494] (Fig. 12), leading to the ponding of the 'Findhorn Glacial Lake'. Charlesworth (1956) proposed a more extensive 'Lake Findhorn,' which also occupied the Findhorn Valley 'upstream of Lethan Bar' [NH 956 494]. Young (1980), however, found no evidence for ponding in the Middle Findhorn Valley during deglaciation. These differing arguments were discussed in more detail by Auton (1990), who argued that temporary ponding of the Middle Findhorn occurred upstream of Daless, with drainage impeded by an isolated, decaying ice mass in the bottom of the valley (see **Daless Viewpoint**).

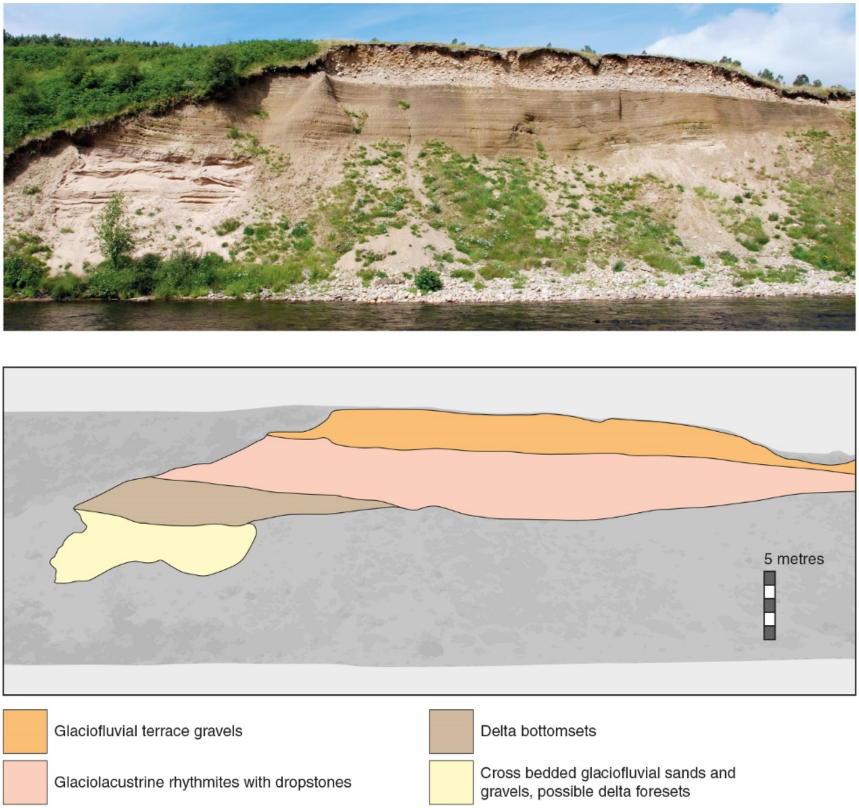


**Figure 114.** Glaciofluvial terrace gravel overlying sand-silt-clay rhythmites and cross-bedded sand and gravel exposed in the main river cliff section at Banchor in 2010.

## The glaciofluvial and lacustrine sequence southwest of Banchor [NH 905 401]

The succession exposed in a river cliff on the northern side of the River Findhorn near Banchor, 4.5 km downstream of the Daless Viewpoint, shows compelling evidence of ponding within that stretch the valley during deglaciation (Fig. 114). When the locality was first visited, in July 2010, it was evident that the thickest sequence occurred at the upstream end of the main section. A generally fining-upward succession of gravels, sands and silts was exposed, truncated by a flat-lying spread of cobble and boulder gravel up to 3 m in thickness (Fig. 114). The latter underlies a terrace that stands some 15 m above river level. The lower units comprised flat-lying, thinly interbedded sands and silty sands that passed upwards into gently dipping sands with ripple-drift cross lamination (Fig. 115 D). These were overlain by planar and trough cross-bedded sands (Fig. 115 B, C). Flat-lying, imbricated, gravel (Fig. 115 B) was seen to rest with an erosional contact on the cross-stratified sands.


**Figure 115.** Sedimentary structures within the glaciofluvial sands and gravels underlying delta bottom-sets in 2010. (A) rhythmites in upstream end of the main cliff section, (B) lens of imbricated gravel, (C) trough cross-bedded sand, (D) sand with ripple drift lamination.

Interbedded sands and silty sands (Fig. 115 A), dipping 10-15° eastwards, were seen to overlie the gravel and pass laterally into sand-silt rhythmites. The rhythmite sequence exceeded 5 m in thickness (Fig. 116), cropping out across about 60 m in the main section. Individual fining-upward units generally range in thickness from 3-5 cm, with many of the sandier beds exhibiting climbing ripple lamination and mud-drapes (Fig. 117). Isolated dropstone pebbles are common, notably in the middle of the unit.

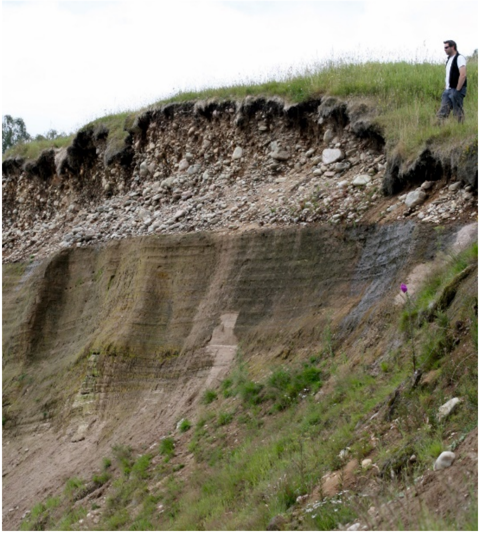

**Figure 116.** Poorly sorted cobble gravel terrace deposit resting on rhythmically bedded sands and silts at the eastern end of main section in 2010.


**Figure 117.** Fining-upward silt –clay rhythmites with dropstone pebbles and interbeds of fine-grained sand with ripple drift lamination exposed in the main section in 2010.

Dropstone cobbles are also present in silty sandy interbeds developed locally within the imbricated gravels that cap the sequence immediately downstream of the main section (Fig. 118). Their presence suggests that periodic episodes of quiescent deposition from floating ice occurred, which contrasts markedly with the high-energy water flow indicated by the cobble and boulder grade clasts that comprise most of this topmost unit. The cobble and boulder gravels underlie a lower terrace that is cut into the main section sequence.

**Figure 118.** Silty sand with large dropstone cobbles, interbedded within glaciofluvial terrace gravel, downstream of the main section in 2010.

The locality was visited again in April 2017 when parts of the cliff section had receded some 5 m from their positions in July 2010 following a flood event. Consequently, parts of the sequence that were concealed beneath slipped debris in 2010 are now exposed, and some elements of the sequence that were present at the western end of the main section have now been lost. In particular, the upward transition from flat-lying, thinly interbedded sands and silty sands into sands with ripple-drift cross lamination (Fig. 119), at the base of the section, is now largely concealed by debris. The planar and trough cross-bedded sand sequence and the overlying unit of flat-lying, imbricated gravel, are now largely absent from the exposure. Instead, there appears to be a largely conformable upward transition, from sands with 'in-phase' and climbing ripple lamination into the overlying interbedded silty sands.

**Figure 119.** Sands with 'in-phase' and climbing ripple lamination exposed at the western end of main section in 2017.

Gravel is now only present as irregular, discontinuous, cross-cutting lenses, commonly composed of poorly sorted, angular pebbles and cobbles (Fig. 120). These lenses occur close to the level of the imbricated, pebble gravel observed in 2010. They are associated with brecciation and soft sediment deformation of the overlying sands and silty sands. The eastern end of the main section has also changed considerably since 2010, notably with new exposures where the lower terrace cuts into sequence underlying the upper terrace. Here the rhythmites abut a large mass of boulder gravel, with a highly irregular, often complexly faulted, contact (Fig. 121). The gravel incorporates large detached blocks of interbedded sand and silty sand containing evidence of microfaulting and soft sediment deformation (Fig. 122).

**Figure 120.** Lens of poorly sorted, angular gravel beneath sandy rhythmites exposed in 2017.

**Figure 121.** Complexly faulted contact between boulder gravel and sandy rhythmites exposed in the eastern end of main section in 2017.

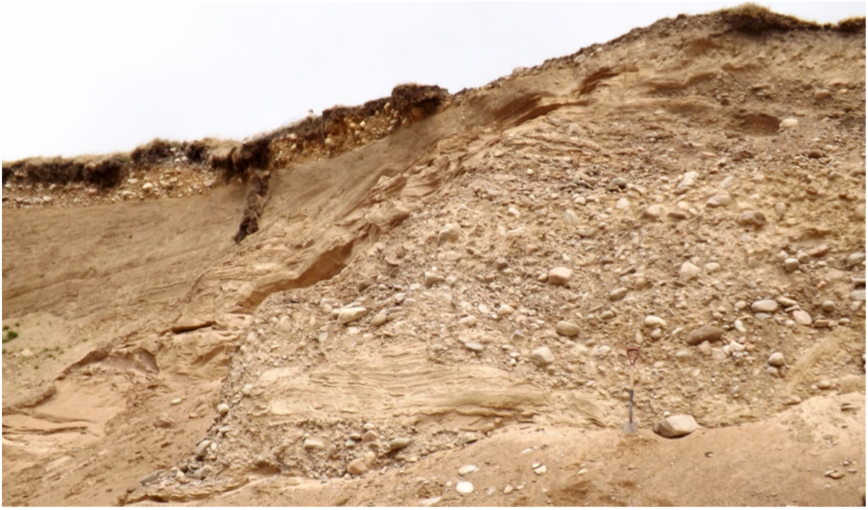

**Figure 122.** Detached block of interbedded sand and silty sand within boulder gravel exposed in 2017.

## Interpretation

**Exposures in 2010:** The sediments formerly exposed in the river cliff section provide clear evidence of changes in both local base level and depositional environment as the deglaciation of the Findhorn valley took place. At the western end of the main section, the sediments in lower parts of succession revealed a generally coarsening upward sequence, from generally flat-lying planar bedded sands and silty sands, passing upwards into cross-bedded sands that were capped by a bed of imbricated gravel. The base of the gravel showed a gently sloping erosional contact on the underlying sands. This part of the sequence, as a whole, showed many of the sedimentary characteristics typical of glaciolacustrine delta and subaqueous fan sequences found elsewhere in the area. Most of these deltas and fans, however, occur at the top of the glacial sequence and generally display characteristic landforms, including gently sloping planar upper surfaces that are evident in the landscape upstream of the **Daless Viewpoint**. Nevertheless, the bottom part of the succession seen here suggests that glacial meltwaters, draining from an ice-front to the west of site, laid down a small delta or fan that prograded down-valley (i.e. eastwards or north-eastwards). These deposits were graded to a base level perhaps 10 m above the present river level, at c. 200 m OD.

The deltaic/fan deposits in the lower (western) part of the succession were conformably overlain by gently dipping interbedded sands and silty sands, which pass laterally eastwards into the lower parts of the rhythmites containing dropstones. The sand/silty sand units were interpreted as bottom set beds of a delta that prograded down-valley. The delta developed in a lake, which was probably impounded by a readvance of Moray Firth ice into the lower reaches of the Findhorn catchment (see **Highland Boath**). The top of the rhythmite sequence lies at c. 210 m OD. This is the minimum level of the former lake surface, but it was probably higher, as the upper surface of the lake sediments is truncated by the erosive base of the overlying imbricated cobble/boulder gravel. This cobbly unit forms one of the lowest of the glaciofluvial terraces that are widely developed within the lower reaches of the catchment. Most of these terraces represent remnants of former outwash plains that formed at successively lower elevations as the ice gradually retreated.

**Exposures in 2017:** The recent visit provided new data that impacts on some of the interpretation given above. In particular, the absence of the coarsening-upwards sequence from flat-lying planar bedded sands and silty sands, into sands with ripple cross lamination, which were in turn overlain by cross-bedded sands, capped by imbricated gravel, is no longer apparent. This sequence was taken to suggest that the lower part of the succession represented part of a small glaciolacustrine delta or subaqueous fan that was buried beneath glaciolacustrine rhythmites as local base level rose. The apparently more conformable contact now evident between the sands with ripple-drift lamination and the overlying interbedded sands and silty sands and the silty rhythmites with dropstones, shows that a clear upward transition from deltaic, or fan deposition, is no longer seen. However, the succession beneath the uppermost terrace gravel, still fines upwards and shows evidence of waning flow. Both indicate a rising base level. This suggests that exposures of the deltaic/fan sequence in 2010 probably represented the 'feather edge' of these deposits that has been removed by subsequent erosion of the cliff.

Discontinuous cross-cutting lenses of poorly sorted angular gravel are now present between the ripple cross-laminated sands and the interbedded sand-silty sand sequence. The angularity of the gravel suggests deposition from subaqueous debris flows into the lake, either from the valley side or from a nearby delta front. However, the origin of the large chaotic mass of poorly sorted cobble gravel now exposed at the eastern end of the main section is difficult to explain. The position of this gravel body, at the base of the bluff of the upper terrace, is perhaps important to understanding how it may have formed. It could be the result of slumping and collapse of the sediment pile during erosion that preceded the aggradation of the lower terrace. However, in most other localities where younger terraces cut into older glaciofluvial/deltaic sequences, the erosive contact is much clearer and deposition of remobilized material does not extend beneath the level of the base of the lower terrace. The contorted and chaotic nature of gravel, splaying faults and the presence of detached angular blocks of sand within the unit may also suggest the former presence of ice within the sediment, which melted out after the gravel was deposited, perhaps while the lower terrace was forming.

**Discussion**

Regional mapping of the lower Findhorn catchment on BGS 1:50k sheets 84Wand 84E, since 2000, has identified glaciolacustrine rhythmite sequences at 8 localities and glacial deltaic/subaqueous fan sequences at 34 localities downstream of Ballachrochin (Fig. 123). These principally occur in two areas on the south-eastern side of the course of the present river, south-west of Dulsie Bridge and around the Dorback Burn (Fig. B10), a tributary of the Findhorn. Several characteristics are apparent about the sequences in both areas; all of the deltas and fans are either located within the valley of the Findhorn or those of its present tributaries. All prograde down valley or in a northward or north-eastward direction; broadly towards the present coastline. Also, apart from isolated examples such as the sequence exposed at Banchor, the fans and deltas comprise coarsening upward sequences that form the youngest glacigenic features in the landscape and commonly overlie either till or bedrock.

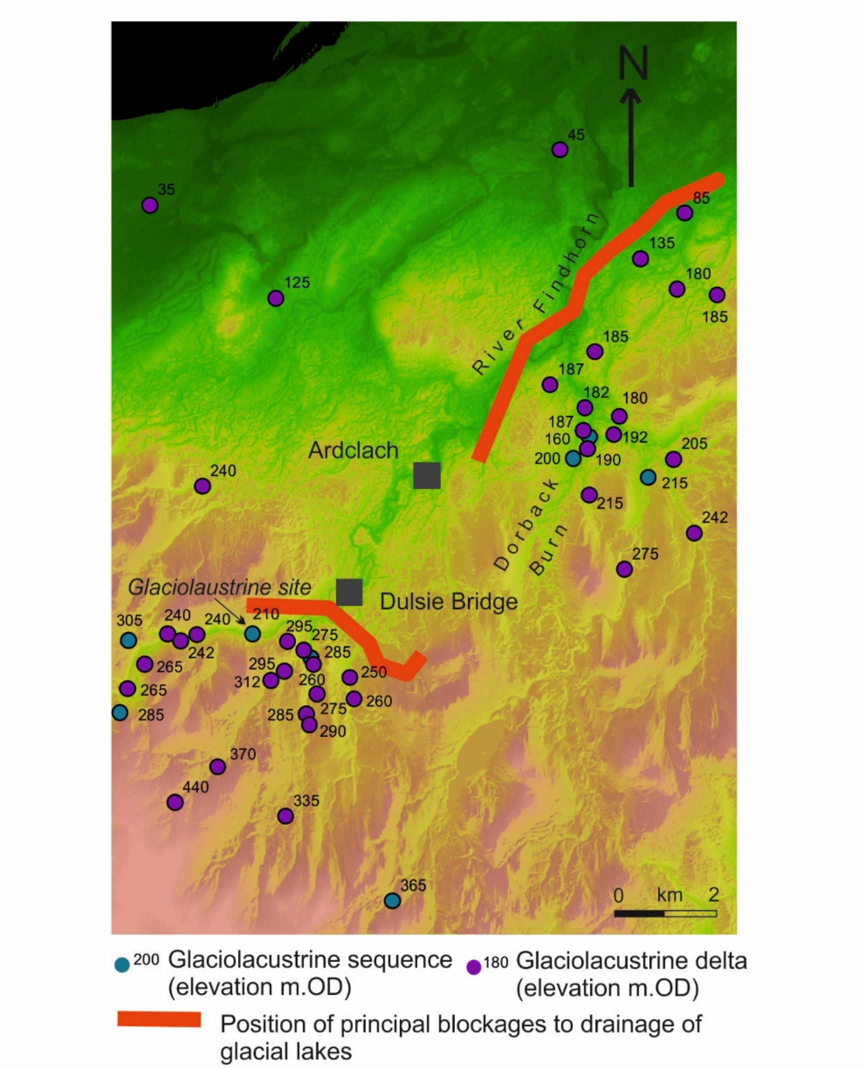


**Figure 123.** Distribution of glaciolacustrine and deltaic sequences in the middle to lower Findhorn Catchment, downstream of Ballachrochin.

The upper surfaces of the glaciolacustrine sequences south-west of Dulsie Bridge range in height from 365 to 210 m OD; the elevation surfaces of the deltas and subaqueous fans are from 440 to 240 m OD.

The height of the glaciolacustrine sequences around the Dorback Burn ranges from 215 to 160 m OD; deltas and fans 275 to 85 m OD. The aerial and altitudinal distribution of these deltaic and lacustrine sequences summarized in Fig. 123 suggest that meltwater ponding was widespread during the deglaciation of the area, occurring not only in the valley of the Findhorn, but also in many tributaries. However, the range in altitude of the sequences (440-210 m OD for those south-west of Dulsie Bridge and 275- 85 m OD east of Ardclach) argues against their deposition in a single 'Findhorn Glacial Lake' as proposed by Bremner (1939), or an even more extensive 'Lake Findhorn' recognised by Charlesworth (1956).

The pattern that has emerged is that meltwater from retreating and thinning Findhorn ice was impounded in a number of valleys by active Moray Firth ice leading to the formation of a number of glacial lakes. This was a diachronous process across the area, with lakes in the highest valleys forming first and then draining away (Fig. 12). As the ice from the Moray Firth gradually retreated northwards and westwards, lakes and deltas formed at successively lower elevations as base level of the drainage fell.

The red line on Fig. 123 equates with the final retreat position of the blocking ice from the Moray Firth. This ice front controlled the lowest base level of glacial lake formation in the catchment and its position agrees, to a considerable degree, with that of the 'Moray Firth Ice-lobe' between Dulsie Bridge and Dounduff [NH 993 494], which Bremner (1939) cited as being responsible for damming drainage in the Lower Findhorn Catchment. It corresponds with arcuate spreads of sands and gravels forming moundy kame and kettle topography. These are indicative of deposition against bodies of dead ice at a decaying ice margin. Although the morphology and distribution of most of the deltas and fans suggest deposition in discrete lakes that formed at successively lower elevations as the Moray Firth ice retreated, the sequence exposed at Banchor shows that there were times when the retreat was punctuated by readvances. These temporarily raised base levels and locally inundated pre-existing deltaic sequences.

In summary, regional investigations have shown widespread deposition of glaciolacustrine rhythmites and deltaic sediments during the deglaciation of the middle to lower Findhorn catchment. Sediments in lakes and deltas were laid down over an altitudinal range in the region of 440-210 m OD (between the heights of the lowest and highest exposures), upstream of Dulsie Bridge. A similar pattern of sedimentation, at generally lower elevations (275-85 m OD) is present east of Ardclach (Fig. 123). In both areas, the distribution of the sediments suggests that deposition took place in small ephemeral lakes that formed in the Findhorn valley and in the valleys of its northerly flowing tributaries, rather than in one large proglacial lake as suggested by Bremner and by Charlesworth. It is noteworthy that no lake shorelines have been recognized associated with any of the lakes. This might be regarded as unusual, if a large, long-lived lake, or even two large lakes, each about 200 m deep, had developed.

The final position of the ice that blocked drainage in the catchment is very similar to that proposed by Bremner nearly a century ago. However, gradual retreat of the ice-front from the uplands, south-east of the Findhorn valley, northwards and eastwards, is indicated by the general decrease in elevation of the deltaic sequences in the tributary valleys towards the main valley. There generally appears to have been an organized pattern of active retreat of the Moray Firth ice, which impeded the meltwater drainage, while ice covering the upland was less active and largely thinned and decayed (Fig. 12). The evidence exposed at Banchor, however, indicates that the retreat of the Moray Firth ice-front was punctuated by a readvance that raised glacial lake levels on at least one occasion.