Sandford Bay - locality, Cainozoic of north-east Scotland

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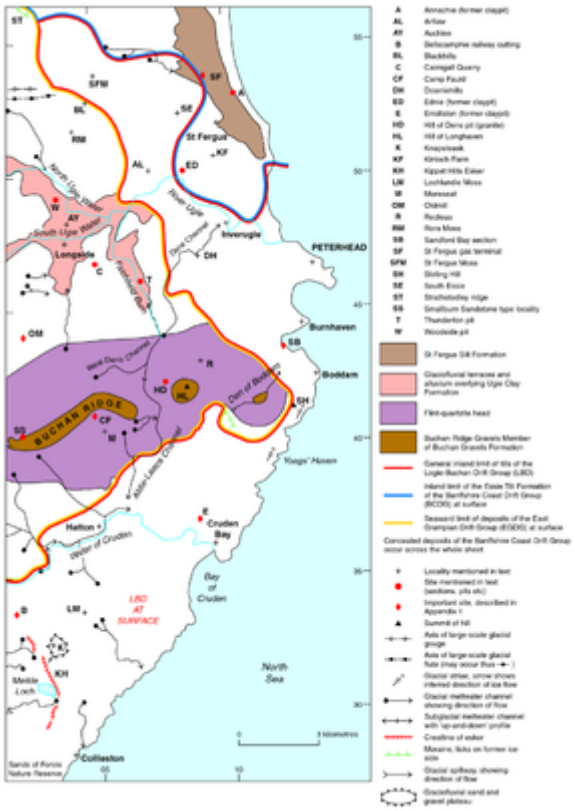

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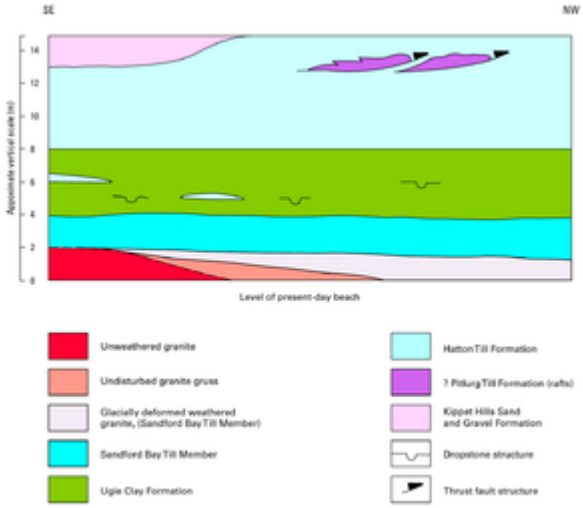


Schematic stratigraphical relationships in the Sandford Bay area. P915315.

In a series of papers Thomas Jamieson described important coastal cliff sections together with exposures in clay pits in the area immediately south of Peterhead (Jamieson, 1858, 1860a, 1865, 1882b, 1906). The thick succession of Pleistocene glacial sediments he recorded proved seminal to his subsequent reconstruction of the relative timing and pattern of glaciation in eastern Buchan (P915283). Since Jamieson's early work the majority of the sections have now become obscured and the clay pits are long disused. At present, the only exposures available for study are those cliff sections in Sandford Bay, close to Sandford Lodge (NK 125 434) and Burnhaven (NK 124 440) (P915377). These sections have been described briefly by Connell and Hall (1984c) and Hall and Connell (1991). Generally exposure inland from the coast is very poor, but a number of recent road improvement schemes and borehole surveys have added important information on the lithology,

sedimentology, thickness and distribution of the glacial deposits (P915315). The Sandford Bay sections are some of the few sites in Buchan where tills of the Hatton Till Formation of the Logie-Buchan Drift Group are accessible, together with older glacial deposits.

Glacial stratigraphy described by Jamieson

Immediately to the south of Peterhead, in Peterhead Bay, Jamieson (1882b, 1906) recorded drift deposits overlying outcrops of 'somewhat soft and disintegrated' red (Peterhead) granite. Overlying the bedrock was 3.05 to 3.66 m of hard 'grey boulder clay full of granite and gneiss debris'. In places he described the grey boulder clay as thinning into a 'mass of coarse granite rubble'. Above the grey boulder clay he described up to 3.05 m of 'hard and firm' unstratified red clay from which he reported clasts from Old Red Sandstone conglomerate.

Wilson (1886) also recorded sections in Peterhead Bay, together with others farther south in 'Brickworks Bay' (probably at about NK 123 451). He noted m of 'red stony boulder clay with blocks of Old Red Sandstone' resting on 'bands of yellow silt and sand'. He did not record any of Jamieson's lower boulder clay. To the south of Brickworks Bay, Jamieson recorded outcrops of red clay (at about NK 126 447), near Peterhead Prison. Here he noted (1906) 'an irregular, undulating band of blue clay', a bed of gravel containing a 'few broken shells', many blocks of red sandstone, and 'a bit of hard Chalk with a possible Belemnite fragment attached'. Amongst the shell fragments in the gravel he observed (nomenclature not revised) *Cyprina islandica*, *Pecten islandicus, Astarte arctica, Panopoea, Mytilus, Cardium, Fusus*, and *Balanus*.

Some of the most important sections recorded by Jamieson were those in the long-established Invernettie brick and tile works pit on the north side of Sandford Bay (probably close to NK 126 441). In 1858, he published the following section (bottom up) from the pit.

		Thickness m
5	Blackish loamy earth	0.3
4	Reddish brown clay, apparently devoid of structure or lamination, and containing stones of various kinds, and of all sizes up to 1.4 m in diameter, often striated and grooved on the surface	9.14–12.19
3	Clay of a brick-red colour and finer nature, and apparently free from boulders	0.30–0.61
2	Very finely laminated, dark brown stone-free clay	0.61–1.22
1	Fine sand, brownish grey	>6.10

Clasts of red and grey granite, schist, 'greenstone and trap', greyish sandstone and flint were noted in unit 4, together with broken shells in a coarse reddish sand. Later (1865) he recalled finding *Astarte borealis*, *Cyprina islandica* and *Littorina squalida* (nomenclature not revised). Jamieson also recorded (1858, 1882b) that an almost complete skeleton of a large bird had been found in the clay pit at a depth of either 7.6 m (1858) or 9.1 m (1882). If correct, it would place the find either within the base of unit 4 or close to the boundary between units 4 and 3. He also noted that a large vertebra (possibly fish) had been found earlier at a depth of 11.6 m, probably from unit 1. Seal bones have also been reported from Invernettie (D Page *in* Turner, 1870), but the horizon is uncertain.

In his 1906 paper, Jamieson noted that the upper reddish brown clays at Invernettie were somewhat different to the usually vivid red clays of his Red Series deposits. The upper 6 m or more were composed of 'darkish mottled brown clay, varying much in colour, as if red and blue had been jumbled together'. Furthermore, in places, the 'Red Clay' was 'curiously streaked with clay of a dark bluish colour, derived apparently from a different source'.

Jamieson recognised the following sequence of events.

1. Ice advance from the west to beyond the present coastline, depositing the lower grey boulder clay, with clasts predominantly of granite and metamorphic rocks derived from the underlying bedrock and outcrops, farther west.
2. Deposition of glaciolacustrine (or possibly glaciomarine) laminated silts, sands and clays of brick red, dark brown, yellow and brownish grey colour. Deposition occurred following retreat of the earlier ice mass and in front of ice advancing from the south-south-east. The varying colour of the deposits suggested that the sediment was derived from both ice masses (see Site 10 Ugie Valley).
3. Ice advance from the south or south-east deposited a thick sequence of the red and reddish brown shelly diamictons and clays with local 'streaks of dark bluish clay'. The presence of conspicuous clasts of Old Red Sandstone rocks suggest derivation from offshore and from the south.

From his observations and his wide knowledge of the drift deposits in the region, Jamieson (1906) concluded that the 'Red Clay' was deposited 'close upon the retreat of the ice which lodged the grey Boulder-Clay'. It is likely that the inclusions of dark bluish clay within the red deposits were either derived from his older 'Indigo boulder clay', known from the Ellon and Slains area to the south (see Site 15 Ellon), or from the interaction of ice from the Moray Firth and Strathmore in the Peterhead area. The significance of the bird, seal and fish bones at Invernettie is uncertain. It is possible that the vertebrae noted by Jamieson and the seal bones reported by Page (*in* Turner, 1870) are one and the same.

Glacial stratigraphy in recent exposures at Sandford Bay

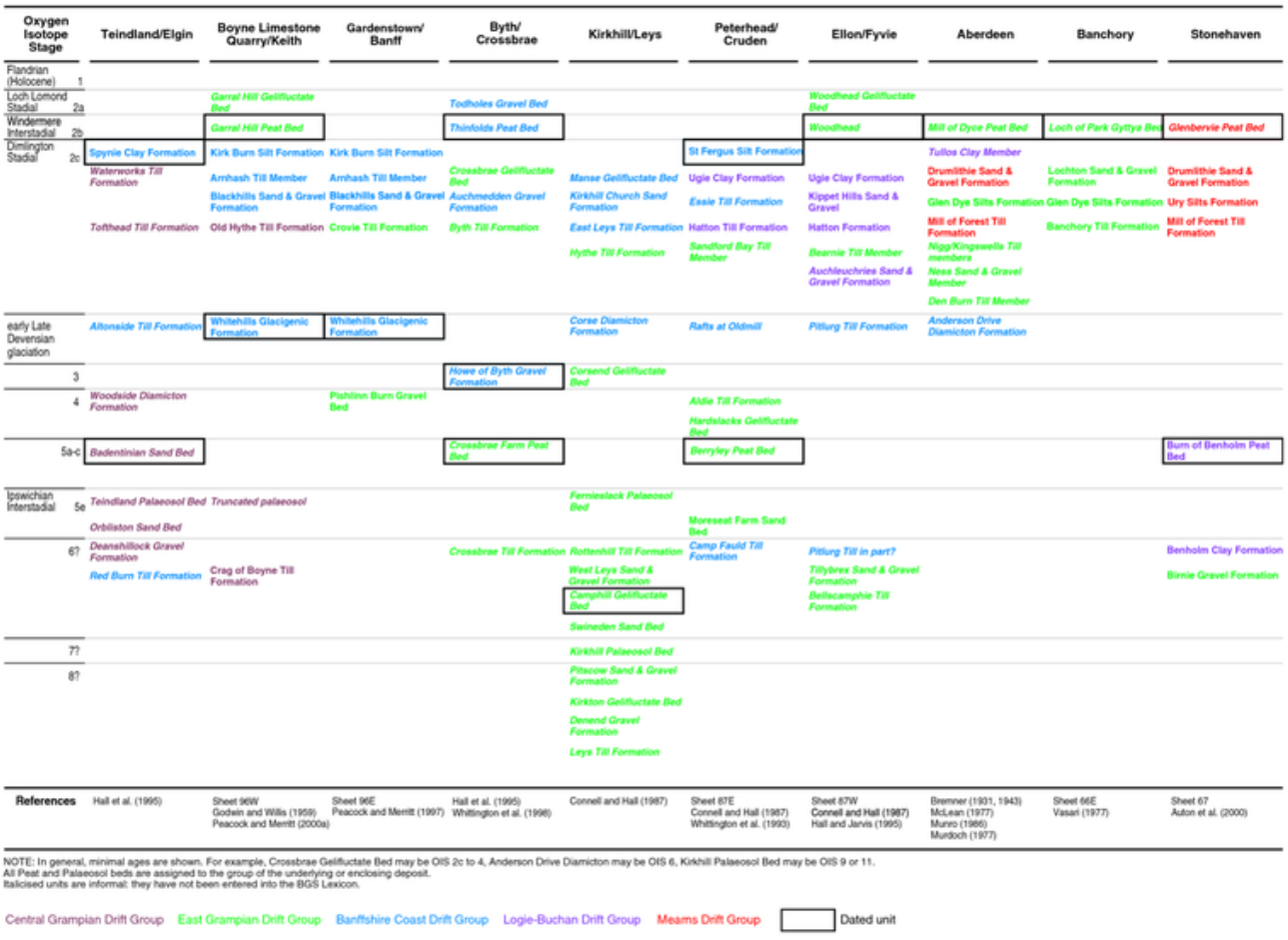
Sections described at Sandford Bay over the last 23 years have confirmed much of Jamieson's earlier interpretation. Additional information on the provenance and sedimentology of the deposits has, however, allowed amplification of many of his conclusions.

The stratigraphy described below is a composite of cliff exposures near Sandford Lodge (NK 125 434) and Burnhaven (NK 124 440) close to the site of the old Invernettie brick pit.

		Thickness m
Unit 5	Pebble and cobble gravel showing crude up to 2.00 bedding with interbedded medium to coarse sand.In the Burnhaven exposure, the gravel appears to fill a shallow channel cut into unit 4 diamicton and has a clast composition similar to it, though with fewer nondurable clast types. The gravel sequence at the top of the Sandford Lodge exposure has a very high concentration of Peterhead granite clasts presumably derived from the high ground to the south-west.	up to 2.00
Unit 4	Silty clay diamicton, massive, locally up to 7.0 sheared, hard, calcareous. Typically dark reddish brown (5YR 3/3), but also dark brown (7.5YR 4/4 or 10YR 3/3) in the northern exposures. Lenses and attenuated laminae (up to 3 cm-thick) of grey and black clays (10YR 2/1, 5YR 2.5/1, 5Y 5/2) have been noted in the Burnhaven section. Clast assemblages contain red stained Old Red Sandstone conglomerate cobbles, red and green sandstones, striated *Arctica islandica* hinge fragments plus other comminuted shell debris, flint and dolomite. Weakly clustered north–south and north-north-west–south-south-east clast fabrics.	up to 7.0

Unit 3	Clay, silt, fine sand and thin diamicton, up to 4.0 horizontally laminated and bedded. Both the laminated deposits (with sparse dropstones) and thin diamictons are brown or dark brown in colour (10YR 4/3–3/3), but the colour changes upwards into reddish brown (5YR 4/3–4/4).	up to 4.0
Unit 2	Sandy clayey diamicton, massive, with a up to 3.5 strongly clustered west–east clast fabric, brown/dark brown to dark yellowish brown (10YR 4/3–3/3 to 10YR 4/4–4/4). Clasts predominantly of 'Peterhead' granite and metamorphic rocks with some well-rounded pebbles and cobbles of metaquartzite and chatter-marked flint (reworked from the Buchan Gravels Formation). Two well-rounded pebbles of 'Norwegian rhomb porphyry' have been identified. The diamicton merges downwards into glacially disturbed grussified Peterhead granite over 0.3 m.	up to 3.5
Unit 1	Grussified and unweathered Peterhead granite bedrock.	

Interpretation of the sedimentology and stratigraphy at Sandford Bay



Correlation of lithostratigraphical units in north-east Scotland. P915347.

Unit 2 - This diamicton is the oldest unit in the local succession. It is named here as the **Sandford Bay Till Member** of the Hythie Till Formation (East Grampian Drift Group) (P915347) Locally, it includes a lower sub-unit interpreted as a deformation till derived from the immediately underlying grussified granite. The main unit contains more far-travelled westerly derived material, has a strong west–east clast fabric and is interpreted to be a lodgement till laid down by East Grampian ice as it advanced to a position beyond the present coastline. The west–east or west-south-west orientated

striae recorded by Jamieson (1882b) on nearby Stirling Hill were probably formed during this advance. It is noteworthy that two well-rounded erratics of Norwegian rhomb porphyry (information from J A Dons, Mineralogisk-Geologisk Museum, Sars' Gate, N-Oslo, Norway, 1979) have been found in this unit, similar to those found in the Hythie Till Formation at Kirkhill; they probably all have been derived from older deposits.

Unit 3 - The colours of these deposits, which are assigned here to the **Ugie Clay Formation** of the Logie-Buchan Drift Group, suggest that sediment was supplied both from the retreating East Grampian ice sheet and from 'Logie-Buchan' ice advancing from the south. The deposits contain dropstones and thin beds of diamicton (debris flows) and are interpreted as glaciolacustrine. Peacock (1975) has also reported red 'flow till' units associated with red- coloured silts and clays in the area at Boddam.

Only a single unit of dominantly red-brown laminated sediment has been recorded in the cliff exposures. However, in the 28 boreholes drilled at the nearby Peterhead Power Station site (average drift thickness 13.7 m; only a few hundred metres to the south-west and centred on NK 125 433) multiple laminated units, up to 2.0 m in thickness, have been recorded interbedded with red-coloured diamictons. As no exposures are available to check the sedimentology or structural characteristics of these deposits it is unclear if these multiple units reflect a number of discrete ponding events followed by readvances, or a stack of glacitectonic thrust slices emplaced by a single readvance of 'Logie-Buchan' ice.

Unit 4 - This thick unit of massive to locally sheared diamicton was emplaced by the north or north-westwardly advancing Logie-Buchan ice. It is assigned here to the **Hatton Till Formation** of the Logie-Buchan Drift Group. Both the matrix, and elements of the clast assemblage, are derived mainly from deposits that crop out on the sea bed to the east and south of Buchan. The distinctive reddish brown, calcareous matrix of the diamictons contains rich palynomorph assemblages (information from R Harland, BGS, 1980). These contain Permo–Triassic miospore species, Jurassic to Early Cretaceous dinoflagellate cysts, together with sparse Early Pleistocene cysts of *Operculdinium israelianum* and *Tectatodinium pellitum*. Additionally, striated hinge fragments of the bivalve *Arctica islandica* from the diamicton have yielded the following Total D/L amino-acid ratios (information from D Q Bowen, University of Wales, Cardiff, 1988):

0.526 ± 0.063 (N=3) (Lond. 402)

0.494 ± 0.004 (N=4) (Lond. 403)

These ratios indicate an Early Pleistocene age for the shells, which are clearly reworked. Like other units of the Logie-Buchan Drift Group (see Site 15 Ellon and Site 16 Kippet Hills) the evidence demonstrates that the matrix of the diamicton is derived mainly from fine-grained, red coloured, Permo–Triassic sedimentary rocks and Early Pleistocene marine beds (possibly the Aberdeen Ground Formation) present to the east and south of Buchan. Jamieson (1906) was the first to note the locally darker brown matrix colour of diamicton in the Invernettie pit, together with inclusions of dark bluish clay. Similar, apparently sheared, laminae of black or dark grey clay a few centimetres thick have been recorded in the Burnhaven exposure. Furthermore, in 1980 extensive road works exposures for the Invernettie Diversion (centred on NK 120 447) revealed large rafts of very dark

grey (5Y 3/1), massive, clayey, shelly, calcareous, clast-poor diamicton in units up to 2.0 m thick and over 50 m in length. These rafts were disrupted by south dipping, low-angle, thrust faults. The margins of the rafts merged over a few centimetres into the enclosing reddish brown diamictons. Darker colours predominated close to the rafts, passing outward into more vivid reddish brown colours suggesting that the rafts were being 'digested' into the diamicton matrix and altering its colour locally. Palynological analysis of the very dark grey diamicton forming the rafts (information from R Harland, BGS, 1980) showed it to be rich in possibly Late Jurassic to Early Cretaceous dinoflagellate cysts. Though being thrust from south to north when deposited, the grey diamicton apparently had an original provenance to the north or north-west of the site.

There are two explanations for the origin of the dark coloured rafts. They could have been reworked from outcrops of the similarly coloured Pitlurg Till Formation in the Slains area to the south (see Site 15 Ellon). Alternatively, they have been derived from a younger dark till deposit. BGS offshore Borehole 72/31 (Owens and Marshall, 1978; Evans et al., 1981), 13 km east off Peterhead, penetrated 23.65 m of grey-black 'boulder clay' beneath a veneer of pebbly, shelly sand. This diamicton sequence yielded Quaternary miospores and microplankton accompanied by a rich assemblage of reworked Late Jurassic and Early Cretaceous palynomorphs indicating a likely north-west provenance for the deposit. While the sequence is not directly dated, it is possible that part of the deposit could be correlated with the late-Late Devensian Essie Till Formation of the Banffshire Coast Drift Group (P915347). This unit crops out north of Peterhead, but it is unclear how far south the ice responsible for its deposition penetrated to the east of Peterhead.

BGS boreholes to the west of Peterhead (McMillan and Aitken, 1981) also locally record thin bands of greenish grey to dark grey laminated silty clay within stiff red brown diamicton (e.g. NK 04 NE 10). This suggests that glacitectonic incorporation of dark coloured clay into Hatton Till Formation diamicton units is quite widespread. This evidence of the incorporated rafts and 'digestion' of dark clays into the otherwise reddish brown matrix of the Hatton Till Formation around Peterhead indicates that it is essentially a thick glacitectonic–deformation till complex (see also Site 10 Ugie Valley and Site 17 Errollston).

Unit 5 - The gravels and sands overlying the Hatton Till Formation are assigned here to the **Kippet Hills Sand and Gravel Formation** of the Logie-Buchan Drift Group although they are not as shelly as equivalent deposits farther south. They represent outwash from Logie-Buchan ice after its withdrawal to the east and south of the area.

Summary

Recent interpretation of the glacial deposits exposed in the Sandford Bay sections broadly follows that of Jamieson in the 19th and early 20th centuries. Early expansion of ice from inland to, and beyond, the present coast line was succeeded by the deposition of a glaciolacustrine (or possibly glaciomarine) sequence that probably received sediment both from the westward retreating East Grampian ice sheet and northward advancing Logie-Buchan ice. Subsequently the Logie-Buchan ice sheet advanced onshore and deposited a thick deformation till complex derived from Permo–Triassic red beds, Early Pleistocene marine sediments and pre-existing dark grey, shelly, clayey diamictons. The ice advanced over 5 km inland into the lower Ugie valley, west of Peterhead, damming meltwater to create an extensive proglacial lake (Lake Ugie). All of the deposits exposed in the Sandford Bay sections are assigned to the Main Late Devensian glaciation (OIS 2).

References

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