Site 24 Balnakettle

An unusual succession of Quaternary sediments occurs in a section at Balnakettle (Plate 26), on Sheet 66E, and in a nearby small gravel pit at Winney Hillocks (Map 10). It provides a unique insight into the sequence of events that took place during the glaciation and deglaciation of the upland flanking the western side of Strathmore. The stratigraphical and structural relationships between deformed and undeformed glacigenic sediments indicate that a late, local advance of East Grampian ice occurred after retreat of the Strathmore ice stream. The latter deposited till and outwash on the flanks of the upland.

Stratigraphy and structure

A complex, deformed sequence of glacigenic deposits of the Mearns Drift Group is exposed in the back scar of a landslip [NO 618 757] on the southern side of a western headwater tributary of the Burn of Caldcotts (the Burn of Balnakettle), north-east of Fettercairn on Sheet 66E Banchory. The deformed glacial sediments are moderate brown to red-brown in colour. They are interstratified with clast-supported gravel, composed predominantly of angular clasts of dark grey phyllite and greenish grey psammite, derived from underlying Dalradian bedrock. The interstratified sequence is overlain by a thin, undeformed, moderate to dark yellowish brown sandy till, containing a preponderance of Dalradian schistose psammite and semi-pelite clasts.

The sequence at Balnakettle ((Figure A1.29)a) is exposed to a depth of about 8 m, over a distance of about 28 m, in a valleyside cliff at about 225 m above OD. The section, which is aligned east-north-east, forms part of the undisturbed back scar of a landslip in which material has slipped northwards towards the valley floor. The lower part of the succession consists of a tectonised sequence of tills, silts, clays, sands and gravels, in which bedding has been reorientated by folding and shearing so that many originally flat-lying contacts are now steeply dipping (some are almost vertical and a few are slightly overturned) ((Figure A1.29)b). The upper part consists of an undeformed, till unit that truncates the tectonised sediments.

Although original stratigraphical relationships between the units in the lower sequence are highly deformed, it is apparent that the grey, matrix-rich, phyllite-psammite gravel is the oldest deposit exposed in the section. The gravel is extremely angular and ranges in grain-size from boulder to pebble. The clasts exhibit a strongly developed, tightly clustered bedding-parallel fabric, which has an upright orientation in the lowest part of the sequence ((Figure A1.29)a, 6–10 m along the section). Fining-upward units that occur within the gravel higher in the section, indicate younging towards the west-south-west and small irregular lenses of the gravel are incorporated within a raft of red-brown till caught up in the overlying brown sandy till.

The till within the tectonised sequence is of two types. The predominant sediment is a moderate brown, stiff, silty and clayey matrix-supported diamicton. It contains subangular pebbles and cobbles of Dalradian metamorphic rocks (principally psammite, semipelite, and phyllite) granitic rocks and some Old Red Sandstone clasts (mainly quartzite and sandstone). The clasts display a tightly clustered fabric, and stoss and lee pebbles (compare with Benn and Evans, 1998) are present, some of which bear striations; all of these attributes suggest subglacial deposition.

The clast fabric and composition of the till at the east-north-eastern end of the section would appear to suggest deposition from ice moving north-eastwards (from Strathmore), but nearer to the middle of the section, where bedding has clearly been rotated into an upright position, the fabric is less tightly clustered. It has a south-directed vector mean, similar to that from the matrix-rich gravel, described above.

Reddish brown sandy silty diamicton, containing small pebbles of Dalradian and Old Red Sandstone rock types forms the second type of till in the tectonised sequence. It occurs as deformed lenses, caught up along upright shear planes bounding the displaced beds of silty angular gravel. It also forms a raft, containing lenses of angular phyllite/psammite gravel, within the upper yellowish brown till and pods of diamicton within the red-brown sand and gravel towards the west-south-western end of the section ((Figure A1.29)a, 20–26 m along the section).

Beds and lenses of red-brown laminated silt and clay occur within the tectonised unit of moderate brown till and an overlying unit of red-brown glaciofluvial sand and gravel. At the base of the sequence, and towards the west-south-western end of the section, the glaciofluvial sand and gravel fines upwards, from a gravel lag (containing angular to rounded boulders up to 0.5 m in diameter), into clast-supported coarse sandy gravel and finally into pebbly sand. The pebbly sands and gravels all contain a high proportion of Old Red Sandstone clasts (including purple and maroon sandstone and andesite) many of which are highly decomposed. In the middle of the section ((Figure A1.29)a, 14–22 m), the upward-fining gravel unit has been reorientated into an upright position, by folding and movement along steeply inclined curved shear planes, which are lined by red-brown silt and silty clay. The shear planes are inclined towards the north-west and east and total displacements, possibly of several metres, must have taken place along them during deformation.

Beds of red-brown silty sand are interstratified with gravel and pebbly sand higher in the glaciofluvial sequence. Towards the top of the section, the bedding is contorted into small-scale, tight flat-lying folds and is also displaced along low-angle thrust planes. The thrusts dip between 27° and 30° towards the south-east and north-west; the maximum measured displacement was about 0.3 m.

The upper till, with its slope-parallel base, cuts across and incorporates rafts of the underlying sediments (including pods of the underlying red-brown gravel). It has a sandy matrix and is moderate to dark yellowish brown in colour. The matrix exhibits pronounced subhorizontal fissile layering, suggesting deposition beneath the sole of a glacier (Benn and Evans, 1998). The clast fabric of the unit is weakly clustered compared with that of the underlying moderate brown till. The clasts within the sandy till are predominantly of Dalradian metamorphic and Caledonian igneous rocks, though a few rounded quartzite pebbles (probably initially derived from Old Red Sandstone conglomerate) are also present. The composition of the till, its clast fabric, and the included rafts of red-brown gravel all indicate deposition by East Grampian ice.

Moderate brown interbedded sands, silts and clays, similar to those at the west-south-western end of the main Balnakettle section, rest with a sharp, undulating contact on gravel, composed mainly of angular clasts of grey phyllite and psammite, in exposures to the north-east at [NO 619 758]. This gravel resembles the grey matrix-rich gravel at the base of the tectonised sequence. The exposures occur at about 200 m above OD, towards the base of large slipped blocks at the toe of the landslip. The exact relationship of the interbedded deposits and the underlying gravel, with the sequence exposed in the landslip scar some 25 m above is unclear.

Interpretation

The sorting, grain size and angularity of the grey, matrix-rich, gravel and its restricted composition (which clearly reflects the Dalradian bedrock that crops out in the flanks of the Burn of Balnakettle adjacent to the section), all suggest accumulation as a 'head' deposit formed by frost shattering and mass movement of debris in periglacial conditions. The fact that the gravel occurs both as discrete beds at the base of the tectonised sequence, and within rafts in the upper till (rather than being incorporated and homogenised), indicate that it probably accumulated prior to the deposition of all of the glacigenic sediments. Hence, it is the oldest deposit exposed in the landslip scar section and is probably of pre-Late Devensian age.

The oldest glacigenic sediments are the moderate-brown and red-brown diamictons that contain significant numbers of clasts derived from the Old Red Sandstone bedrock of Strathmore. The colour of most of the diamictons is not typical of tills of the Mearns Drift Group (reddish brown), but their compostion indicates derivation from Strathmore ice that had passed over the Dalradian outcrop; their tightly clustered clast fabrics are typical of subglacially deposited tills. The glacitectonic disturbance of the sequence, however, precludes precise interpretation of the direction of former flow of the Strathmore ice from the orientation of the till fabrics alone.

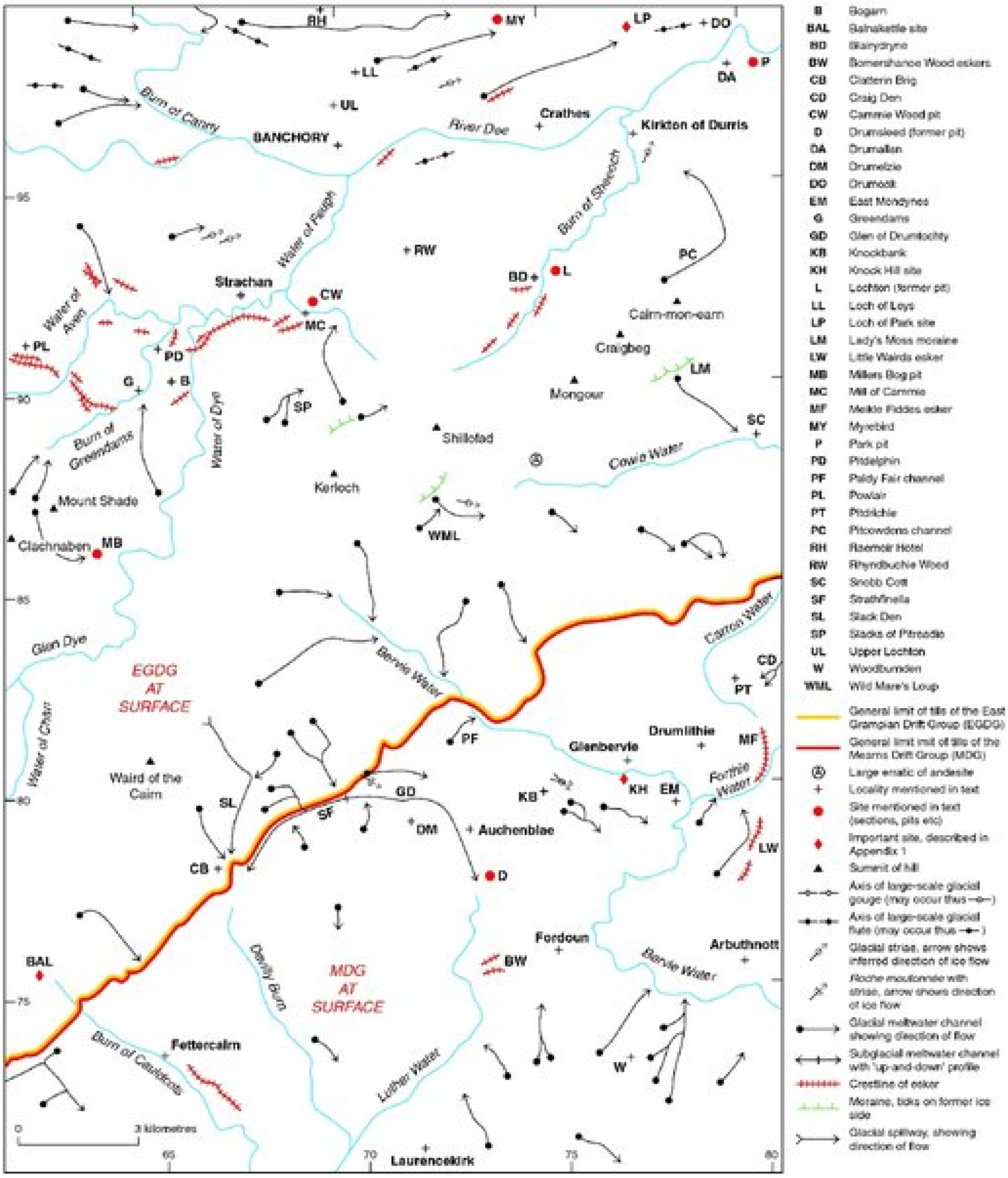
The preservation of head deposits within the moderate brown till suggest that little mixing of pre-existing sediments occurred during the deposition of the Mearns Drift tills. The head gravel was probably frozen onto the base of the Strathmore ice, close to the front of the ice as it impinged onto the upland. The absence of any fragments of an early till of clear East Grampian provenance within the Mearns Drift deposits (while the masses of head gravel are preserved), suggests that it was not present at the site prior to the advance of Strathmore ice.

The north-eastward movement of Strathmore ice across the Balnakettle site initially resulted in stacking of slices of the moderate brown till and head gravel by thrusting. This was followed by the deposition of the overlying glaciofluvial sand and gravel exposed at the west-south-western end of the section. The colour and composition of the sand and gravel are typical of outwash associated with the Strathmore ice. These glaciofluvial deposits were probably laid down as an ice-marginal fan or fan-delta directly on the moderate-brown and red-brown tills, and the intercalated head deposits, before East Grampian ice reached the site. Continued north-eastward movement of the Strathmore ice caused initial shearing within the sand and gravel, followed by tilting and localised folding of both the sand and gravel and the earlier developed thrust stack. This rotated both sequences into their upright positions, and was followed by the development of the small-scale thrusts and flat-lying folds towards the top of the sand and gravel unit.

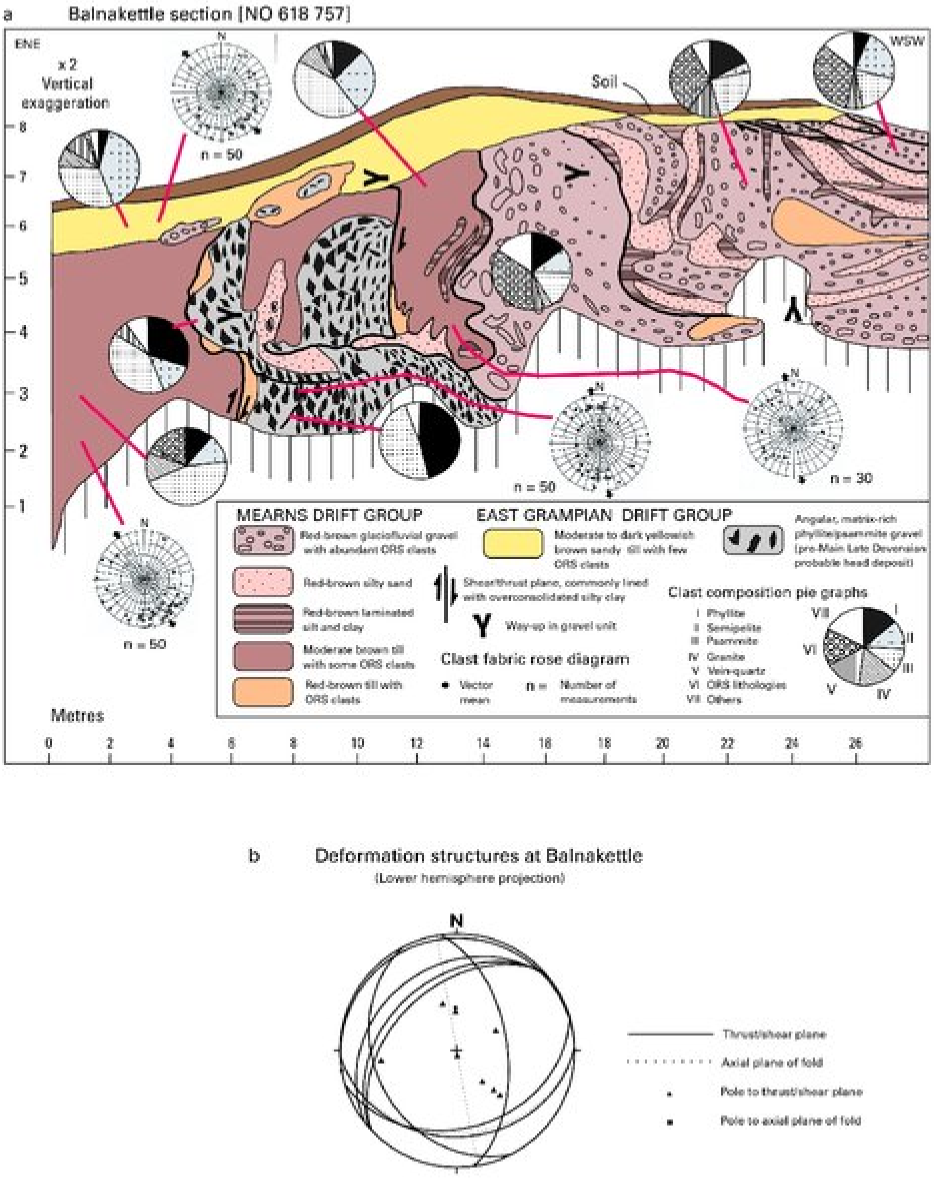
Once the Strathmore ice had retreated on to the lower lying ground to the south, the East Grampian ice advanced into the area from the north-west and overrode the Balnakettle site. It cut across the deformed sequence and laid down the upper yellowish brown sandy till and incorporated the rafts of moderate-brown till and red-brown gravel. Mapping shows that the East Grampian ice advanced south-eastwards for a distance of at least 1.3 km beyond the Balnakettle site. It subsequently retreated north-westwards to a still-stand position about 500 m south-east of the site, where moundy deposits of subangular boulder, cobble and pebble gravel were laid down at the ice margin. These ice-contact gravels are interbedded with thin sandy laminated diamictons, which probably formed as debris flows. The gravels and diamictons contain the wide variety of igneous and metamorphic clasts, typical of deposits of the East Grampian Drift Group. They are well exposed in a small gravel pit at Winney Hillocks [NO 6204 7524]. Ice-wedge casts up to 1.8 m in length, infilled with fine-grained, subangular sandy gravel, are present in the middle part of the gravel sequence exposed in the pit. They occur beneath matrix-rich gravel, up to 2.1 m in thickness. This upper gravel shows evidence of cryoturbation, in the form of involutions and the local development of erect pebble fabrics. These features are attributed to ground ice development within the gravel under periglacial conditions that either occurred towards the end of the Dimlington Stadial, or, less probably, during the Loch Lomond Stadial.

References

(Plate 26) Glacitectonised sequence at Balnakettle, north-east of Fettercairn. Till and gravel of the Mearns Drift Group are tectonically intercalated with older (pre- Late Devensian) head gravel composed of angular clasts derived from local Dalradian pelitic and semipelitic bedrock. The top of the tectonised sequence is truncated by a till of the East Grampians Drift Group, formed during a local re-advance (P100707).



(Map 10) Glacial and glaciofluvial features and the distribution of glacigenic deposits on Sheet 66E Banchory.



(Figure A1.29) Stratigraphy and structure of the Quaternary sediments at Balnakettle.