Site 13 Windy Hills

Quarries in the Windy Hills area (Map 5) provide outstanding exposures of deeply weathered pre-Quaternary gravels that give a unique insight to the geological and geomorphological evolution of Buchan during the Tertiary. Primary sedimentary structures within the gravels indicate their deposition by a river that flowed north-eastwards across an exposed Neogene land surface (Chapters 3 and 4). Quaternary modification of the deposits has been generally limited to minor glacial erosion, local deposition of a thin overlying till and to subsequent periglacial churning (Cryoturbation).

The white quartz and quartzite gravels that crop out in the vicinity of Windy Hills (Figure A1.17), about 12 km south-east of Turriff, are thought to be of early Pleistocene or Neogene age (Plate 4a). They have been assigned to the Windy Hills Gravel Member of the Buchan Gravels Formation (Chapter 4). Similar deposits occur at Dalgatty (Hospital) Wood [NJ 735 460] and Delgaty [NJ 744 508]. Type sections of the Windy Hills Gravel Member occur in a sand and gravel pit ((Figure A1.17)a, Pit 1) [NJ 800 400] (Clapperton, 1977; McMillan and Merritt, 1980, Auton, 2000) and in BGS Borehole NJ73NE/2 (Merritt, 1981), sited adjacent to the pit. The borehole proved 11.3 m of predominantly quartzite gravel, interbedded with pale yellow, clayey pebbly sand, overlying deeply weathered and kaolinized Dalradian schistose pelite. Reference sections have been recorded in a small gravel pit (Pit 2) [NJ 802 401] (Koppi and Fitzpatrick, 1980); at Pit 3 [NJ 793 393] (Kesel and Gemmell, 1981; Gemmell and Auton, 2000) and in BGS Borehole NJ73NE/1, about 400 m north-north-west of Mosslip (Merritt, 1981).

Spreads of quartzite and vein-quartz pebbles around Windy Hills had led previous workers to conclude that the gravel deposit caps a low, north-east-orientated ridge (about 2 km in length) overlooking the River Ythan. Recent trial pits and Ground Probing Radar (GPR) traverses in the area (Clapperton and Gemmell, 1998; Greenwood et al., 1995; Gemmell and Stove, 1999) indicate that in situ gravel is present only beneath the high ground at the south-western and north-eastern ends of the ridge. The quartzite and quartz pebbles on the lower ground constitute a veneer of soliflucted material (head) capping till (Figure A1.17). In particular, GPR traverse 1 (Greenwood and Raines, 1994; Greenwood et al., 1995), aligned across the axis of the ridge in the shallow col, between the two main gravel outcrops, showed no signatures characteristic of the Windy Hills Gravel Member throughout its 756 m length. The reflectors were generally more characteristic of till deposits containing scattered large boulders. Similar responses were evident at the southern end of traverse 5, but channelled gravels were imaged at the northern end of the traverse and in adjacent traverse 3.

Both the in situ and soliflucted spreads of the Windy Hills Gravel Member contain quartzite clasts that are generally comparatively fresh and bear 'chatter' or percussion marks. In contrast, scattered cobbles of granite and schistose metamorphic rocks within the gravel are normally decomposed to kaolinitic sand. Logs of BGS boreholes NJ73NE/1 and NJ73NE/2 indicate that decomposed fragments of underlying schistose strata are commonly incorporated into the basal parts of the unit, suggesting that most of the weathering of both the in situ gravel and underlying strata has occurred since the gravel was deposited. Flint clasts are also present in the deposit, although they generally comprise less than 1 per cent of the gravel fraction; some are weathered with a thick, dull grey or white patina, which is common in flints from the Chalk. Rare clasts of Lower Cretaceous chert have also been recorded (Flett and Read, 1921) and Jamieson (1865) reported the presence of 'chalk-fossils' within some of the flints; unfortunately he gave no specific identifications and his observations have not been confirmed by subsequent investigations.

The matrix of the gravel contains two types of quartz sand grains (Hall, 1983). Predominant are angular grains that show abundant evidence of breakage and conchoidal fracture and only limited edge rounding. Kesel and Gemmell (1981) suggested that these features were indicative of glacial transport. Less abundant are rounded grains with surface textures indicative of environments of high silica mobility, with deep etch pits and smooth precipitation surfaces. These latter surfaces are indented by crescentic chocks and coalescing impact pits, which Hall (1982) attributed to a later phase of highenergy subaqueous transport. A few of the rounded grains have been broken subsequently. The dominant heavy mineral in the sands is ilmenite, with subsidiary staurolite, andalusite, zircon and garnet (Hall, 1983). The gravel and sand is bound in places with white silt and clay, comprising mainly b-axis disordered kaolinite with minor illite. Discrete beds of silty sand also occur.

North-east outcrop

Primary sedimentary structures are variably developed in the in situ gravel in the Windy Hills type area. Horizontally interbedded gravels and sands are illustrated by Kesel and Gemmell (1981, fig.3 F and G) and Clapperton (1977, fig.15). Cross-bedding, dipping at about 20° towards the north-east was recorded by McMillan and Merritt (1980) from a gravel pit [NJ 800 400]. Imbrication of gravel clasts within the cross-sets was seen to dip at about 40° towards the south-west and cross-bedding dipping at about 20° towards the north-west was recorded in a small gravel working [NJ 8035 4015]. Interstratification of horizontal and cross-bedded units is clearly displayed in the GPR traverse 4 (Figure A1.17)c, aligned west to east and adjacent to the type section north-north-east of Windyhills. The radar penetrated the gravel to a depth of about 14 m.

Clast imbrication recorded by Clapperton (1977) was taken to indicate that the gravels were laid down by water that flowed east-north-eastward (roughly parallel to the present line of the ridge), a view supported by McMillan and Merritt (1980).

South-west outcrop

A series of benches is developed towards the south-western end of the body of Windy Hills Gravel Formation that crops out north of Mosslip. The surfaces of the benches, which slope gently south-eastwards are dissected by a series of narrow glacial drainage channels, apparently up to about 5 m deep, that trend north-westwards. A trial pit ((Figure A1.17)a, Trial Pit C) on the floor of one of the channels showed a stratified sequence of disturbed quartz and quartzite gravel beneath thin peaty soil. The stratification within the disturbed gravel dipped at shallow angles towards the channel axis, indicating that the gravel in the floor of the channel probably accumulated by mass movement (slippage and solifluction) from the channel sides. It also suggests that each channel may be considerably deeper (more than 5 m) than its present subdued surface expression implies.

Large angular clasts of relatively fresh metamorphic rocks have been recovered from beneath kaolinised quartz and quartzite gravel exposed in trial pit A near to the western edge of the south-western outcrop of the Windy Hills Gravel Member (Figure A1.17)a. The pit, which was sited on the lowest bench, penetrated apparently in situ gravel to a depth of more than 2 m, overlying reddened diamictic gravel. The gravel contained fresh, angular metamorphic clasts, some of which appeared to be striated. This suggests that the gravel at the western end of the outcrop may include some glacially reworked material.

Sunnybrae outcrop

A small outcrop of quartz–quartzite gravel has been mapped adjacent to the Sunnybrae Centre at the western end of the Windy Hills area. Whether this deposit is essentially in situ or soliflucted is unclear on present evidence, but it is of sufficient thickness to have been formerly worked in a small gravel pit.

Interpretation

The gravel exposed in a working at [NJ 793 393] appears to be in situ. Kesel and Gemmell (1981) interpreted 'planar foreset' bedding and imbrication from the gravel pit as indicating transport from the west. However, GPR traverse 2 (Figure A1.17)b aligned north-westwards and adjacent to the pit, which penetrated the gravel to a depth of about 10 m, shows the true nature of the cross-bedding at the site. The GPR profile indicates the presence of large-scale, shallow (more than 10 m wide and up to 2 m deep), trough cross-stratified units with the axes of the troughs apparently aligned south-west to north-east.

Preservation of well-developed stratification and imbrication, as well as large-scale cross-bedding seen on many of the GPR profiles, from both outcrops of the Windy Hills Gravel Member implies little disturbance of the bulk of the deposit since its deposition. Nevertheless, the soliflucted gravel infilling glacial drainage channels and the presence of striated clasts indicate possible glacial and glaciofluvial reworking of parts of at least the western end of the south-west outcrop.

Reworking of the upper parts of the in situ sequence by periglacial activity is also widespread in both outcrop areas. This is indicated by a well-defined layer of cryoturbated material, typically between 0.6 and 1.0 m thick, that caps many of the exposures. This layer is best developed where the gravel crops out at the surface and has been described by FitzPatrick (1975b, c), Gemmell and Kesel (1979) and McMillan and Merritt (1980). Cryoturbation features include the widespread and pervasive development of an erect clast fabric within the top of the gravel. This fabric was seen to truncate an ice-wedge cast which extended for 1 m into the underlying gravel at the type section in the gravel pit [NJ 800 400] (McMillan and Merritt, 1980). Clasts commonly fine upwards within the cryoturbated layer of gravel and become more numerous towards the top of the unit (Fitzpatrick, 1975b, c). Many of the cobbles have a thin layer of silt capping their upper surface. These silt cappings have been interpreted as the infilled remnants of voids, left following melting of sheaths of ice that formed when the sediments were affected by permafrost activity (Fitzpatrick, 1987). At Woodhead [NJ 788 384], a peat bed lying beneath 1.5 m of soliflucted till has yielded a radiocarbon date of 10 780 ± 50 BP (SRR–1723) (Table 8), implying that significant periglacial activity took place in this area during the Loch Lomond Stadial (Connell and Hall, 1987).

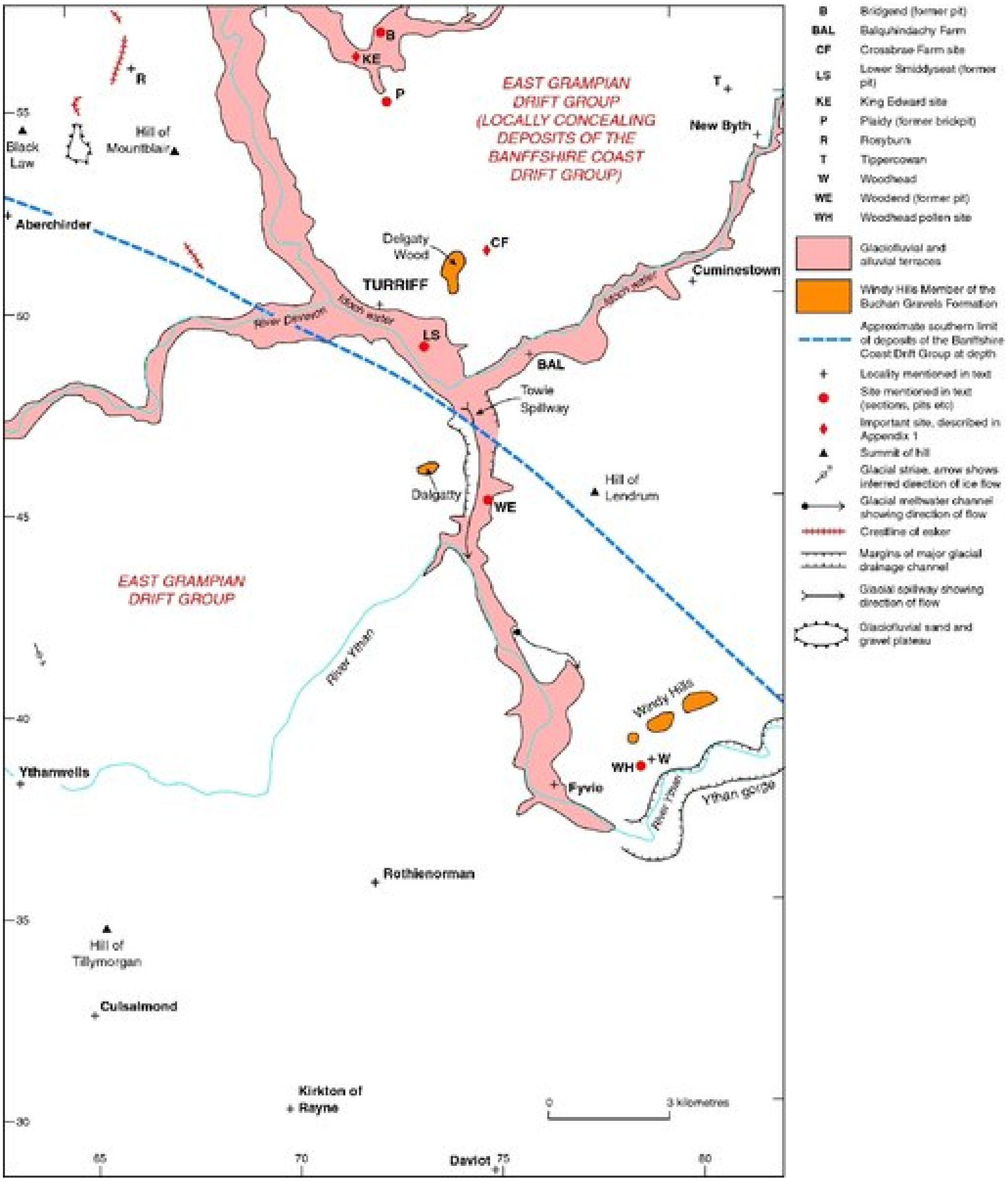
Where the Windy Hills Gravel Member is overlain by thin spreads of 'moderate brown' till, as in the gravel pit type section (Bremner, 1916; Kesel and Gemmell, 1981; Clapperton and Gemmell, 1998) unweathered erratics have been incorporated locally into the upper parts of the gravel, probably by frost churning (Clapperton, 1977). The clasts within the till also display a pronounced erect fabric indicating that much periglacial activity postdates the last glacial event preserved at the site. The till includes sparse unweathered striated pebbles of metamorphic and igneous rocks, but most of the clasts are of quartz and quartzite derived from the underlying gravel. The presence of the till close to the highest point of the north-western outcrop of gravel indicates that ice probably overrode the whole of the outcrop of the Windy Hills Gravel Formation at least once during the Quaternary. The precise age of this glaciation is not known.

Although recent interpretations are agreed that the Windy Hills Gravel Member is primarily of fluvial origin, Jamieson (1858, 1865) originally suggested that the deposit was locally derived and of preglacial marine origin. However, he later proposed a glacial derivation from the floor of the Moray Firth (Jamieson, 1906). Wilson (1886) concluded that the gravel was a residual deposit from a denuded Chalk cover and that it had been glacially reworked. Flett and Read (1921) suggested that the gravel outcrops were remnants of formerly more extensive marine deposits resting on an ancient land surface. The more recent evidence, cited above, clearly suggests that most of the in situ Windy Hills Gravel Member was laid down by a pre-Quaternary river and that subsequent erosion has lowered the adjacent landscape, preserving the deposits in their present hill-top locations (Figure 20). The nature of the cross-stratification evident in the GPR profiles supports the interpretation that the bulk of the Windy Hills Gravel Member in its type area is a fluvial deposit. It was probably laid down by waters that flowed north-eastwards across an exposed Neogene land surface.

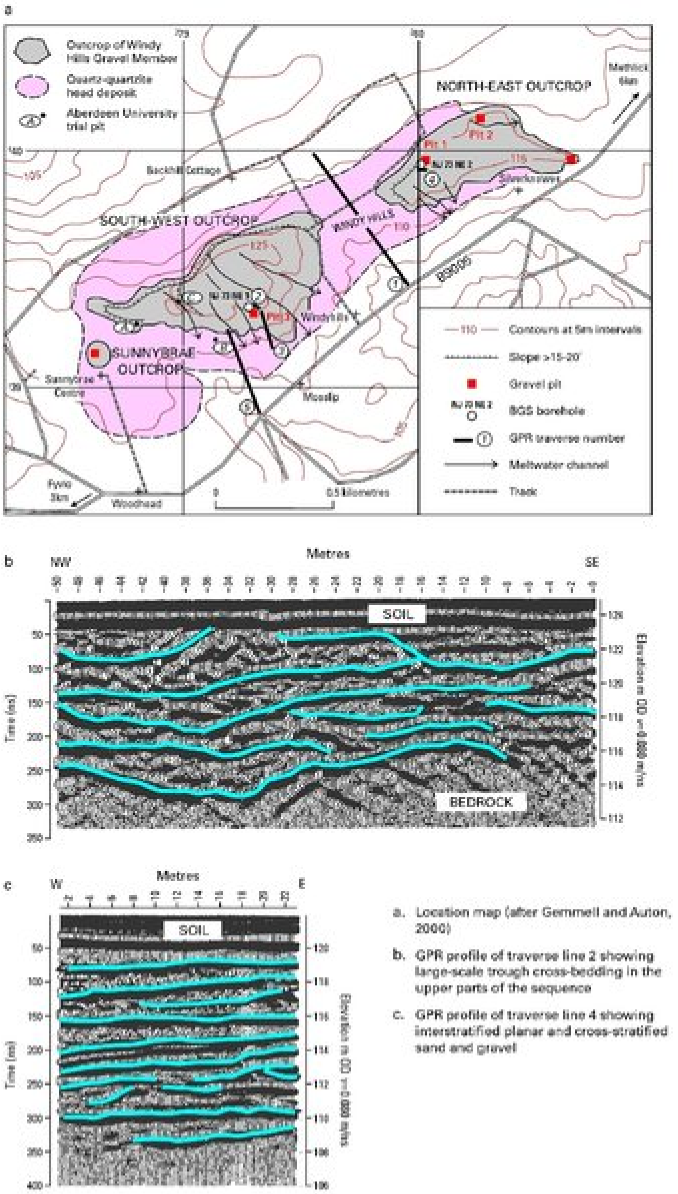
If the evidence of breakage of grains cited above is accepted as implying glaciofluvial transport, the degree of alteration is demonstrably less than seen in the Denend Gravel Formation at Leys Quarry (see Site 7 Kirkhill and Leys quarries). The deposition would have had to have occurred in the early Pleistocene, perhaps the Baventian (Table 1), in order to have allowed sufficient time (over half a million years) to weather the gravels under temperate conditions.

The character and depth of the weathering that affects the deposit also indicates that during the Quaternary, modification of the bulk of the sequence has been limited to glacial erosion, deposition of overlying till and subsequent periglacial churning. Consequently the deeply weathered gravel at Windy Hills preserves unique evidence concerning the long-term evolution of the landscape in north-east Scotland, both before, during and after the Quaternary ice ages.

References



(Map 5) Glacial and glaciofluvial features and the distribution of glacigenic deposits on Sheet 86E Turriff.



a. Location map (after Gemmell and Auton, 2000)

b. GPR profile of traverse line 2 showing large-scale trough cross-bedding in the upper parts of the sequence

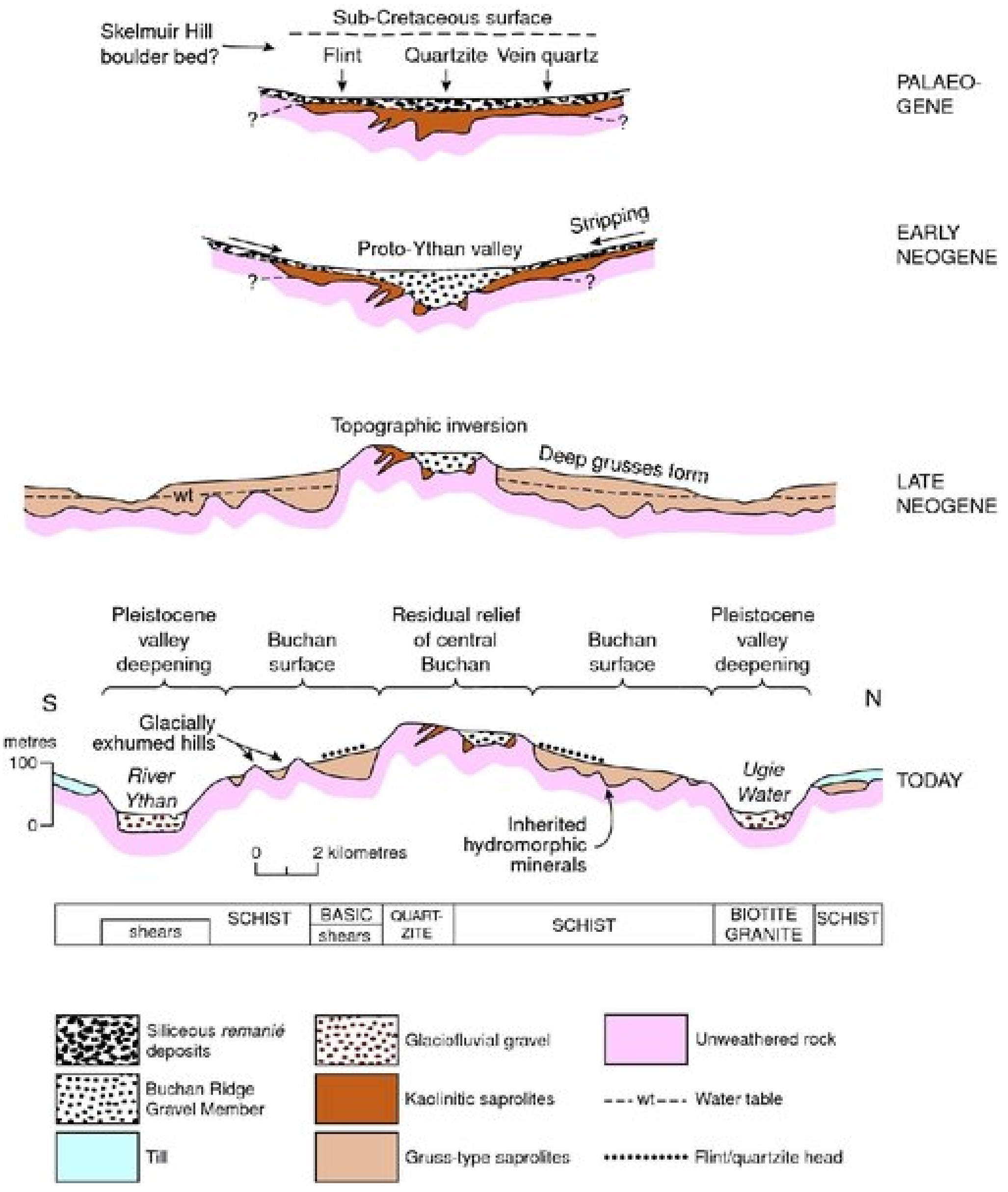
c. GPR profile of traverse line 4 showing interstratified planar and cross-stratified sand and gravel

(Figure A1.17) The principle outcrops of the Windy Hills Gravel Member of the Buchan Gravels Formation near Fyvie.

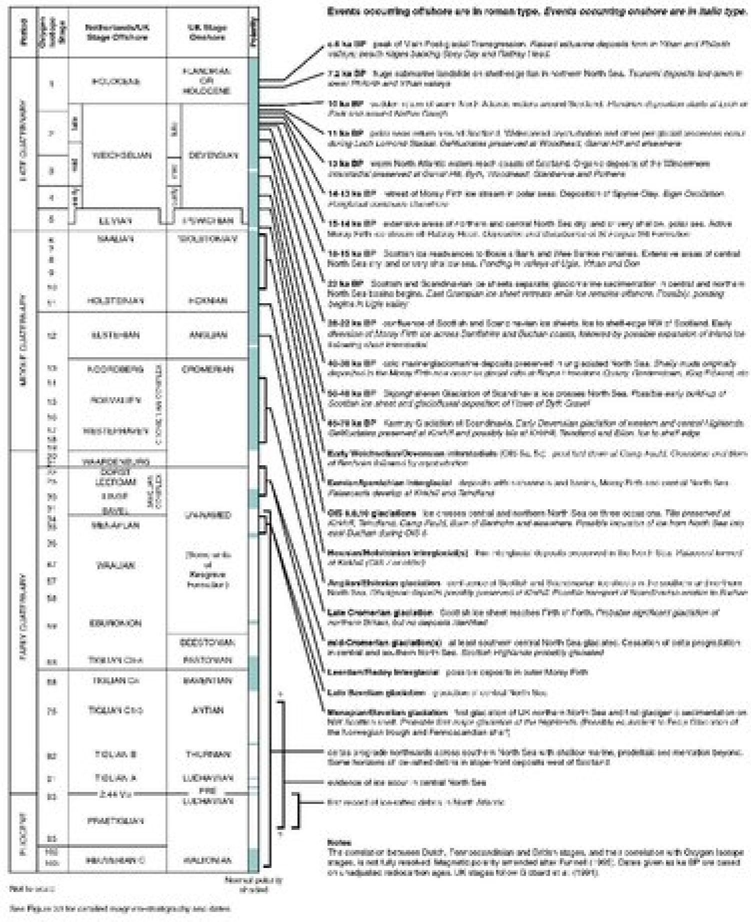
(Plate 4a) Buchan Gravels Formation at Windyhills. a Quartz-quartzite gravel of the Windy Hills Gravel Member at its type locality (P104101)

Site	Grid reference	Laboratory number	Age (years BP)	Dated material and setting	Reference
Rothes cutting	NJ 277 498	Beta-86532	11 110 ± 70	peat under remobilised till	Appendix 1
Garral Hill, Keith	NJ 444 551	Q-104	10 808 ± 230	peat under remobilised till	Godwin and Willis (1959)
Garral Hill, Keith	NJ 444 551	Q-103	11 098 ± 235	peat under remobilised till	Godwin and Willis (1959)
Garral Hill, Keith	NJ 444 551	Q-102	11 308 ± 245	peat under remobilised till	Godwin and Willis (1959)
Garral Hill, Keith	NJ 444 551	Q-101	11 888 ± 225	peat under remobilised till	Godwin and Willis (1959)
Garral Hill, Keith	NJ 444 551	Q-100	11 358 ± 300	peat under remobilised till	Godwin and Willis (1959)
Woodhead, Fyvie	NJ 788 384	SRR-1723	10 780 ± 50	peat under remobilised till	Connell and Hall (1987)
Howe of Byth	NJ 822 571	SRR-4830	11320	peat beneath gravel	Hall et al. (1995)
Moss side, Tarves	NJ 833 318	I 6969	12 200 ± 170	peat under remobilised till	Clapperton and Sugden (1977)
Loch of Park	NO 772 988	HEL-416	10 280 ± 220	kettlehole infill	Vasari and Vasari (1968)
Loch of Park		HEL-417	11 900 ± 260	kettlehole infill	Vasari and Vasari (1968)
Mill of Dyce	NJ 8713 1496	SRR 762	11 550 ± 80	kettlehole infill	Harkness and Wilson (1979)
Mill of Dyce	NJ 8713 1496	SRR-763	11 640 ± 70	kettlehole infill	Harkness and Wilson (1979)
Glenbervie	NO 767 801	CX-14723	12 460 ± 130	peat under remobilised till	Appendix 1
Glenbervie	NO 767 801	SRR-3687a (humic)	12 305 ± 50	peat under remobilised till	Appendix 1
Glenbervie	NO 767 801	SRR-3687b (humin)	12 340 ± 50	peat under remobilised till	Appendix 1
Brinzieshill Farm	NO 7930 7918	SRR-387	12 390 ± 100	peat under remobilised till	Auton et al. (2000)
Rothens	NJ 688 171	SRR-3803	10 680 ± 100	kettlehole infill	Appendix 1
Rothens	NJ 688 171	SRR-3804	11 640 ± 160	kettlehole infill	Appendix 1
Rothens	NJ 688 171	SRR-3805	11 760 ± 140	kettlehole infill	Appendix 1

(Table 8) Radiocarbon dates from Late-glacial sites in the district.



(Figure 20) Summary of Cainozoic relief development in central Buchan (after Hall, 1987).



(Table 1) Summary of events preserved in the marine and onshore records in and around north-east Scotland (after Holmes, 1977).