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Report on Commissioned Research project 2K06E007

Geology & Landscape (North) Programme
Internal Report IR/07/058

BRITISH GEOLOGICAL SURVEY

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Foreword

This report is the published product of a one year collaborative study by the British Geological Survey (BGS) and the University of St. Andrews focussed on dating glacial deposits in part of the western Scottish Highlands through the application of optically stimulated luminescence (OSL) techniques. The work was funded by the University Collaboration Advisory Committee (UCAC), and was supported by the Grampian Highlands project of the Geology and Landscape (North) Programme.

Acknowledgements

We are particularly grateful to the University Collaboration Advisory Committee for funding this research, and to the Grampian Highlands project for supporting it. Thanks are also due to Auch Estate and to Cononish Farm for allowing access to the sample sites. Donald Herd is gratefully acknowledged for providing technical assistance during the OSL analysis of the sediments at the University of St Andrews Luminescence Dating Laboratory.

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Summary

BGS resurvey of Sheet 46W (Crianlarich) over the period 2003-2006 identified a number of exposures of glacial deposits that were deemed suitable for dating by optically stimulated luminescence. A c. 30 m high section in Coire Chailein preserves a long sequence of diamicton, gravel and sand units that appear to indicate at least three separate glacial events. A 1-2 m thick bedded sand unit within this section was interpreted as subaerial outwash deposited close to an ice margin during a early phase of at least partial deglaciation. Having already established a local stratigraphy, we aimed to date the sand unit in order to constrain the age of the sediments above and below. Our second sample site was at Dalrigh, where ‘hummocky moraine’ are widespread and are thought to relate to the retreat of a glacier lobe embayed in the eastern end of Cononish glen. We sampled sand and silt from one of these moraines in an attempt to obtain a date for deglaciation of this area.

1 Introduction

Oxygen isotope data obtained from Greenland ice cores show that the climate of the northern hemisphere oscillated between cold and warm phases throughout the late Pleistocene, giving rise to particularly long-lasting cold periods from c. 70–57 ka BP (Oxygen Isotope Stage 4) and from c. 25–15 ka BP (Oxygen Isotope Stage 2) (Dansgaard et al., 1993). Interstadials punctuated these colder spells, most notably prior to c. 90 ka BP and from c. 35–28 ka BP, during which temperatures ameliorated slightly, but were still sufficiently low that glaciers would have survived in the Scottish Highlands (Clapperton, 1997). Palaeoclimatic data based on coleopteran and chironomid data from four sites in Britain indicate that even during the Windermere Interstadial, (c. 15–13 ka BP), the climate affecting Scotland was warm for only a short time before renewed cooling and instability led to the onset of the Younger Dryas stadial (Mayle et al., 1999), the last glacial episode to have affected Britain.

The onset of this transition into a cooler climate in the Northern Hemisphere is inferred from the oxygen isotopes records from the Greenland ice cores (mainly GRIP and GISP2), and is thought to have occurred around 12.7 ka BP (Alley, 2000). Mean annual temperature in Scotland at this time dropped by c. 8–10°C (Clapperton, 1997; Hubbard, 1999; Isarin & Renssen, 1999). A decline in precipitation due to sea ice formation during the Stadial was then followed by rapid warming that terminated the glacial readvance (Benn et al., 1992). The timing of re-establishment of a temperate climate marking the beginning of the Holocene is also inferred from oxygen isotope records, and is placed at around 11.3 ka BP (Alley 2000).

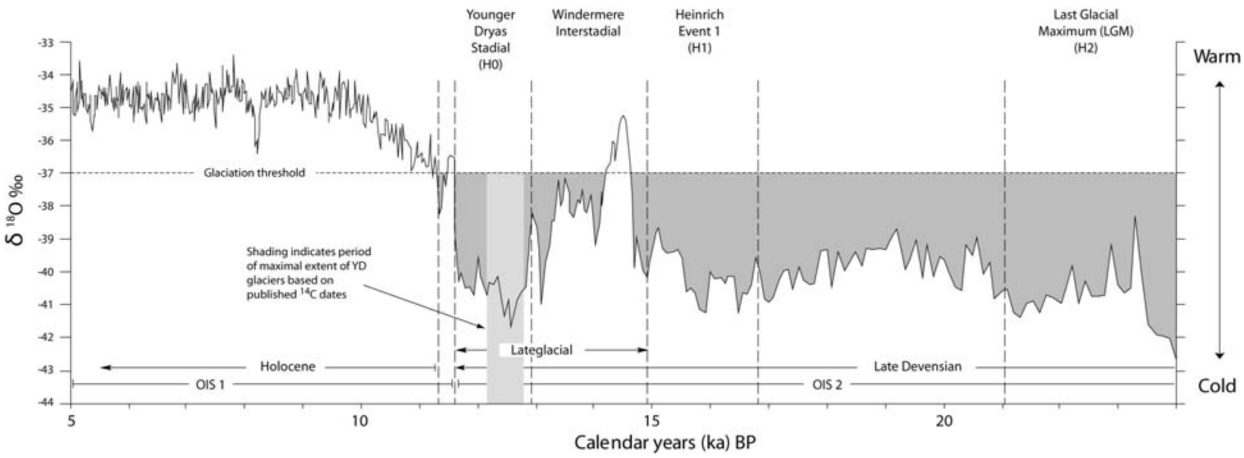

Figure. 1: The GISP2 ice-core record showing principal episodes of the Late Pleistocene and early Holocene. Shaded area denotes periods when glaciers could have formed in Scotland.

Whilst the data from Greenland is often used as a proxy for all amphi-North Atlantic climate change, few direct dates exist to confirm that the climate in Britain behaved synchronously. Until recently, the best constraint on the Younger Dryas in Scotland was a ^{14}C date from Rannoch Moor, which suggested that deglaciation was complete by 12.8 – 12.2 ka (Lowe & Walker, 1976, calibrated using CALIB v5.0.2), but this age was quickly recognised as being too old as a result of mineral carbon error associated with the groundwater (Sissons 1979; Lowe & Walker 1980; Sutherland 1980). New cosmogenic expsoure ages for glacial erratics and abraded bedrock at a site 20 km from Rannoch Moor suggest in fact that deglaciation occurred some time after 11.6 ± 1.0 ka BP (Golledge et al., 2007). The research presented here aimed to improve this chronology through the use of optically-stimulated luminescence (OSL) techniques to derive age estimates from:

1) a rare buried sand layer that separates subglacial till units in Coire Chailein (Fig. 2)

2) a sand layer within a recessional moraine at Dalrigh (Fig. 2), thought to have been deposited in an ice-marginal pond

The intention was to bracket the onset and demise of Younger Dryas-age glaciers in this area, and thereby gain some insight into the degree of synchroneity between hemispheric cooling as shown in the ice-core records, and the response of glaciers in the Scottish Highlands.

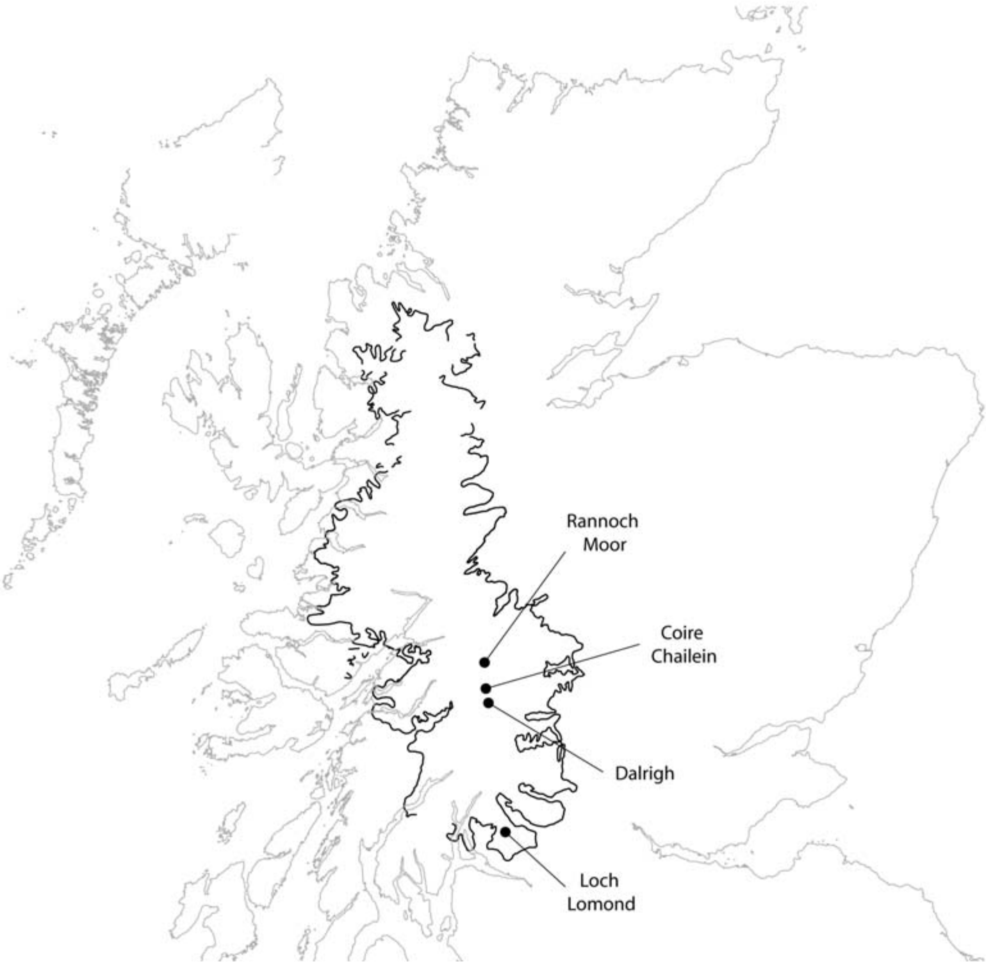

Figure 2. Sample sites in relation to presumed maximal limits of Younger Dryas ice cap in western Scotland (dark line) (after Ballantyne 1997).

2 Study area & previous work

The study area lies to the south of Rannoch Moor (Fig. 2), the main dispersal centre of the ice cap that overwhelmed the western Scottish Highlands during the Younger Dryas, or Loch Lomond Stadial (Golledge & Hubbard 2005).

The field area has many steep-sided mountains and intervening ‘U’-shaped valleys, and many of the mountain tops are covered in regolith derived from the metasedimentary bedrock. Solifluction terracettes occur in some areas, as a result of frost-heave, saturation of the regolith by rainfall, and gravity. Exposed bedrock is widespread, and talus aprons or cones have developed below many of the crags. Till is present in many of the valleys, and although its thickness ranges from 1-30 m, the thicker instances are very localised and more typical valley floor cover is less than 2 m. Often the till is superimposed with morainic deposits of poorly-sorted sand, gravel and diamicton, forming elongate boulder-strewn ridges. Few glaciofluvial deposits occur in this area, and are mainly present as large fans and sparse ice-contact features. Most valley floors exhibit rock-cut channels, thin bouldery alluvium, or large and extensive terraces of sand and gravel that reflect fluvial activity since deglaciation. Peat up to 3 m thick (but often less) overlies much of the ground at both high and low levels.

The 1890's mapping by officers of the Geological Survey concentrated for the most part on the bedrock geology, and relatively little description was made of the abundant glacial deposits. Hinxman et al., (1923), recognised that most of the area had been glaciated by ice from Rannoch Moor during the Last Glacial Maximum (LGM), and subsequently Charlesworth (1955) and Sissons (1965) described the moraines and ice-marginal features of the area. Recent studies that cover separate parts of the area have done much to further our knowledge of local glacial history (Thompson 1972; Horsfield 1983; Thorp 1984, 1986, 1987, 1991), but these have focussed on geomorphology in preference to sedimentology or stratigraphy. Ongoing resurvey of the area by the BGS (2003-) found evidence indicating a thicker ice cap than the one proposed by Thorp, suggesting a very different climate (Fig. 3) (Golledge & Hubbard, 2005). The change in climate at the end of the Younger Dryas was very rapid and of high magnitude, perhaps amounting to 7°C warming in only a few decades, or even a few years (Alley 2000) and may have produced glacier responses perhaps comparable to the recent acceleration of contemporary glaciers in Greenland.

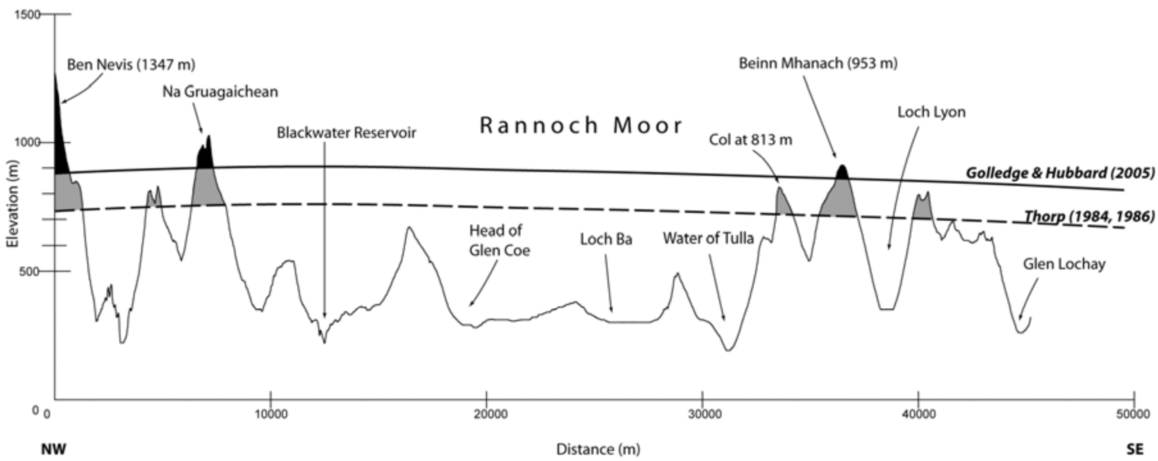

Figure 3. Cross-section through the main dispersal area of the Younger Dryas ice cap, showing contrasting interpretations of ice thickness. Thicker ice implies either a wetter or colder climate.

3 Local stratigraphy

Table 1 shows the facies types that are present in the field area, together with details of their occurrence and genetic interpretation. Colour, texture, composition and internal structure are used to differentiate the facies, which are coded A–H. Facies A, B, C, and D are all diamictons, of which Facies A, B and D are locally weakly stratified and relatively sandy, and Facies C is massive and has a finer-grained matrix. The diamictons are all well-consolidated but differ from one another in colour. Facies A and B are reddish-brown and yellow-brown respectively, whereas Facies C is blue- grey or greenish-grey, Facies D is light olive-brown and Facies E and F are similarly-colored to Facies D but are considerably less consolidated. Facies E and F are often stratified, with sand beds up to 1 m thick in Facies E and thinner lenses and beds in Facies F. In both diamictons well-rounded to very angular clasts are dominant, ranging in size from gravel to boulders. Facies G encompasses a range of grain-sizes but is characterized by a high degree of size sorting not seen in the other units. Some Facies G units are massive, whereas others show planar bedding, trough cross-bedding or lamination. Facies H units are composed of boulders, and lack any sedimentary structures. Deposits of this facies are restricted to very local occurences.

Facies	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Sediment type	Diamicton	Diamicton	Diamicton	Diamicton	Diamicton	Diamicton	Sorted sediments	Boulders
Structure	Massive to weakly-stratified, some centimeter to decimeter-scale pods, lenses and beds of silt and sand.	Massive to weakly-stratified, some laterally-persistant partings of silt and fine sand.	Massive, never stratified. Matrix has conchoidal cleavage, no apparent fissility	Massive to weakly-stratified	Stratified, containing sand lenses and beds up to 1m thick. These range from planar bedded to highly folded	Stratified, often clast-rich, containing folded and / or faulted sand lenses and beds	Bedded and / or laminated	Clast-supported beds
Facies code (after Eyles & Miall 1984)	Dmm	Dmm	Dmm	Dmm	Dms	Dms	Gfo, Gm, St, Sfo, Sm, Fl	Bcm
Matrix material	Sand	Silt and sand	Silt and clay	Silt and sand	Coarse sand and fine gravel	Coarse sand and fine gravel	Gravel, sand, silt, clay	Sand, gravel
Matrix Particle Size Distribution	Trimodal, main peak in fine sand, secondary peak in fine silt, tertiary peak in clay	Trimodal, main peak in fine sand, secondary peak in fine silt, tertiary peak in clay	Bimodal, main peak in fine-med silt, secondary peak in med sand	Unimodal to bimodal, peak in med-coarse silt, weak secondary peak in med sand	N/A	N/A	N/A	N/A
Consolidation	Firm but friable	Very firm	Firm to very firm	Firm	Often friable but highly variable	Often friable but highly variable	Compact to firm	N/A
Upper contact	Sharp, conformable, planar, marked by SA boulders > 1m diameter	Conformable	Conformable, sharp, planar	Conformable, in places undulose or gradational	Undulose, sometimes erosional	Undulose	Often erosional	Undulose
Lower contact	Not seen	Not seen	Conformable, sharp, planar	Conformable, sharp, planar	Conformable, in places undulose or gradational	Conformable / undulose, sometimes erosional	Conformable and planar, or erosional	Undulose
Colour	Reddish to yellow-brown	Yellowish-brown (2.5Y 6/3)	Blue-grey or greenish-grey (5GY 5/1)	Light olive brown (2.5Y 5/4 -- 5/6)	Olive-brown or light olive brown (2.5Y 4/4 -- 5/6)	Olive-brown or light olive brown (2.5Y 4/4 -- 5/6)	Variably grey, brown or yellow	N/A
Matrix mineralogy (XRD)	Contains kaolinite	Possible kaolinite	Contains calcite	Neither kaolinite or calcite present	N/A	N/A	N/A	N/A
Clast lithologies	Metasedimentary rock	Psammite, semi-pelite, rare white granodiorite	Metasedimentary rock and rare granite	Metasedimentary rock, quartzite, rare pegmatite	Metasedimentary rock	Metasedimentary rock	N/A	Psammite, semi-pelite, rare granite
Clast grade	Cobbles & gravel	Cobbles & gravel	Cobbles	Cobbles & gravel	Cobbles, gravel, boulders	Cobbles, gravel, boulders	N/A	Boulders, some cobbles
Clast rounding	SA / SR	SR / SA	R / SR / SA	R / SR / SA	WR -- VA	WR -- VA	N/A	A / SA
Occurrence	Coire Thoin only	Coire Chailein only	Well-distributed but limited	Ubiquitous	Widespread but patchy	Widespread but patchy	Glens Orchy & Cononish, Strathfillan, Coire Earb	Coire Chailein and Glen Orchy only
Maximum thickness	c. 25m	c. 13 m	c. 5 m	< 5 m	c. 5 m	> 5 m	< 5 m	< 2 m
Depositional environment	Subglacial	Subglacial	Subglacial	Subglacial	Submarginal	Ice-marginal, sub-aerial	Sub-aerial, proglacial and ice-marginal	Ice-marginal, sub-aerial
Genetic interpretation	Basal substrate ('till')	Basal substrate ('till')	Basal substrate ('till')	Basal substrate ('till')	Melt-out from basal ice	Debris flows and basal melt-out	Glaciofluvial outwash	Debris avalanche
Landform association	None	None	Flat spreads and streamlined mounds	Flat spreads and streamlined mounds	Hummocky spreads	Moraine ridges and mounds	Fans, deltas and terraces	None
Comments	Some pervasively weathered pelite clasts present	Poorly-exposed due to slippage from above	Evidence of hydrofracturing in Coire Chailein	Often the only facies seen exposed	Transitional between Facies D & F	Highly variable composition	Wide range of grading, sorting and structure	May reflect very local source
Interpreted age	Pre-Main Late Devensian	Pre-Main Late Devensian	Main Late Devensian	Main Late Devensian	Younger Dryas	Pre-MLD to YD	Pre-MLD to YD	Pre-MLD to YD

Table 1: Facies types in the study area. From Golledge (2007).

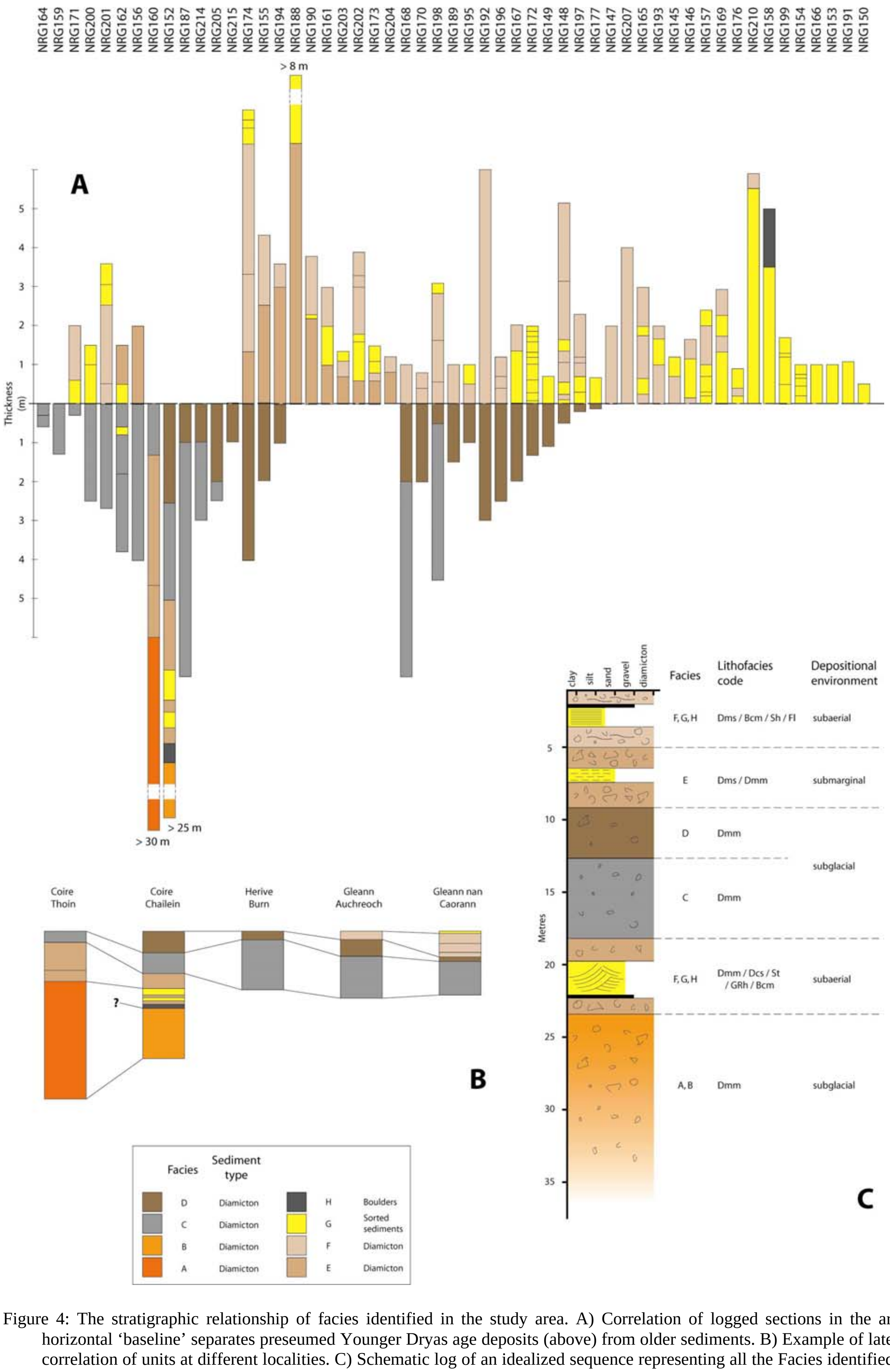

Figure 4: The stratigraphic relationship of facies identified in the study area. A) Correlation of logged sections in the area, horizontal 'baseline' separates preseumed Younger Dryas age deposits (above) from older sediments. B) Example of lateral correlation of units at different localities. C) Schematic log of an idealized sequence representing all the Facies identified in the area. Figure taken from Golledge (2007).

4 Sample localities

4.1 COIRE CHAILEIN

The section exposed in Coire Chailein is shown below (Fig. 5). Despite some lateral variation, the general sequence can be summarised as follows. Facies B forms the lowest, 12–13m thick, unit. It is a very firm, yellow-brown, sandy diamicton containing subangular and subrounded metasedimentary clasts. Overlying this is an interbedded sequence of sand, gravel and diamicton units. The thicknesses of these units are laterally variable but include an approximately 1 m thick clast-supported predominantly sub-angular psammite boulder bed, (Facies H), beds of weakly stratified sandy and gravelly diamicton up to 1 m thick (Facies F), and an overlying unit of laminated clay, silt and trough-cross-bedded sand 1–2 m thick (Facies G). The bedded sand exhibits centimetre-scale faults and folds in some areas, but is undisturbed in others. The sand is overlain by weakly stratified gravel that grades upward into a gravelly diamicton (Facies F), which is then capped by 8 m of grey, clayey diamicton (Facies C), and firm, brown, diamicton (Facies D).

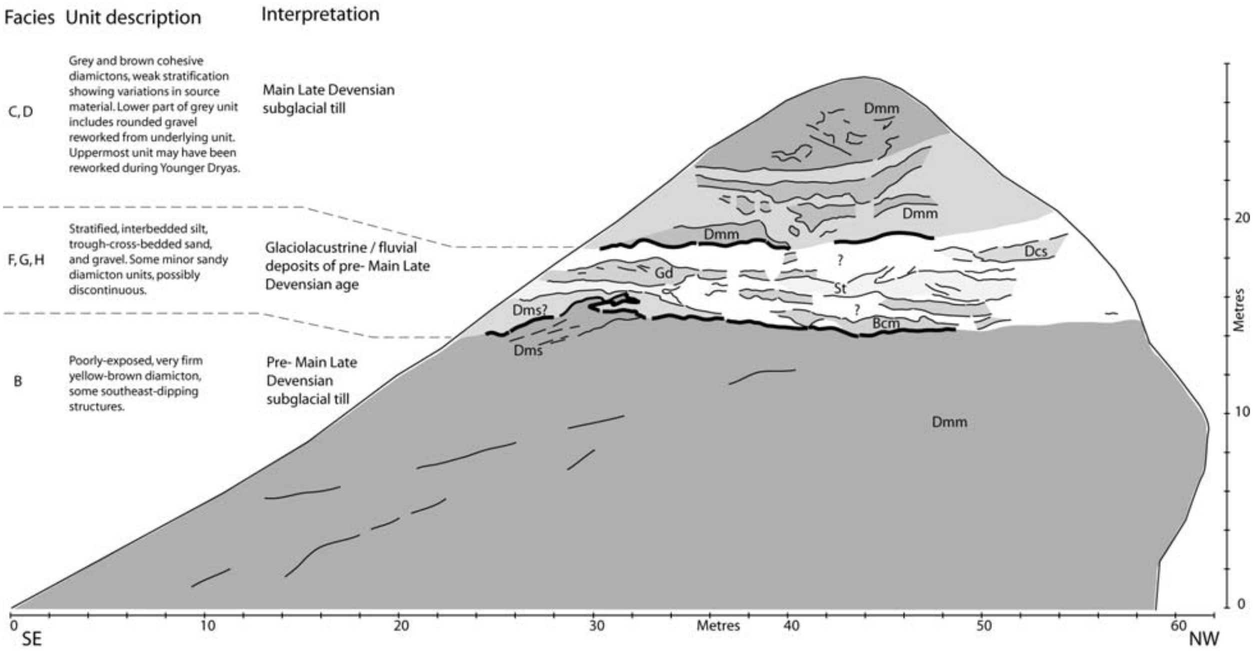

Figure 5: The section exposed in Coire Chailein. The middle (white) Facies G units were targeted for luminescence sampling.

4.2 GLEN CONONISH

The target site in Glen Cononish was a moraine mound of presumed Younger Dryas age composed almost entirely of bedded sand and silt (Facies G). The mound is approximately 6 m high and the exposed face approximately 15 m wide (Fig. 6). The sand that makes up the majority of the mound is largely undisturbed, and is only moderately compacted. Units within the sand showed normally graded couplets up to 30 mm thick, which locally exhibited shallow scours. Unit boundaries appear to dip out of the face, at approximately 10°, to the north. The sandy, poorly consolidated diamicton (Facies F) that caps the sequence contains sub-angular (SA) predominantly meta-sedimentary rocks, but no clasts of garnet-mica-schist (which outcrops at the head of Glen Cononish) were seen.

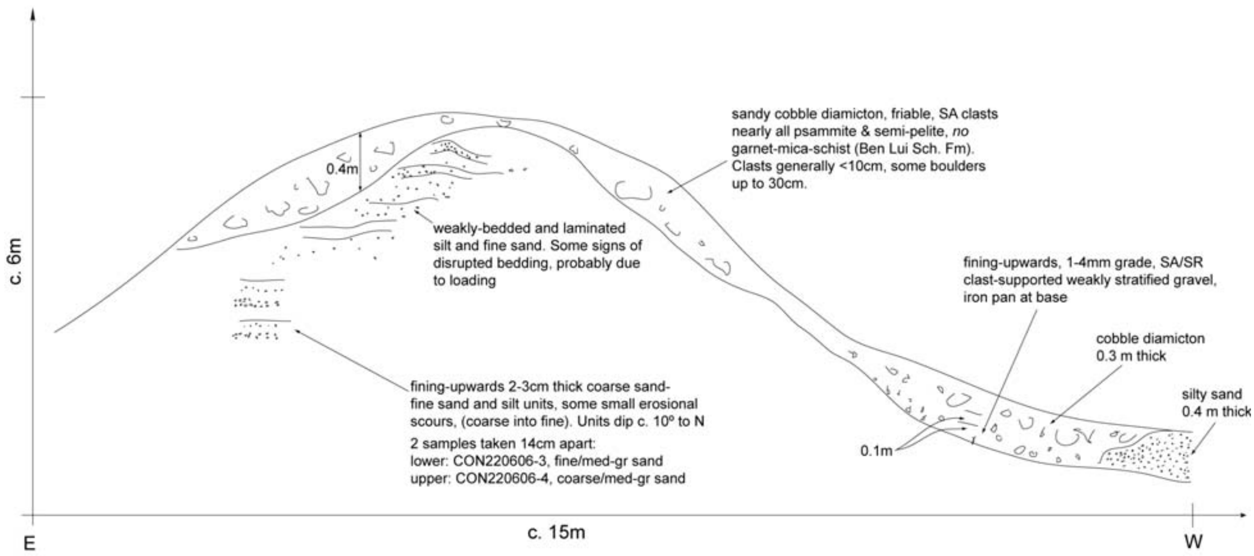

Figure 6: The section of bedded sand and silt forming a moraine, exposed at NRG 210, Glen Cononish

5 Methodology

A field visit was made during June 2006 to the study area. Six samples of bedded sand and silt were collected in black plastic tubing from the two exposures described above. Only facies considered suitable in terms of grain size and likely depositional environment were sampled. Logs of the sections were made, and all sample localities were photographed.

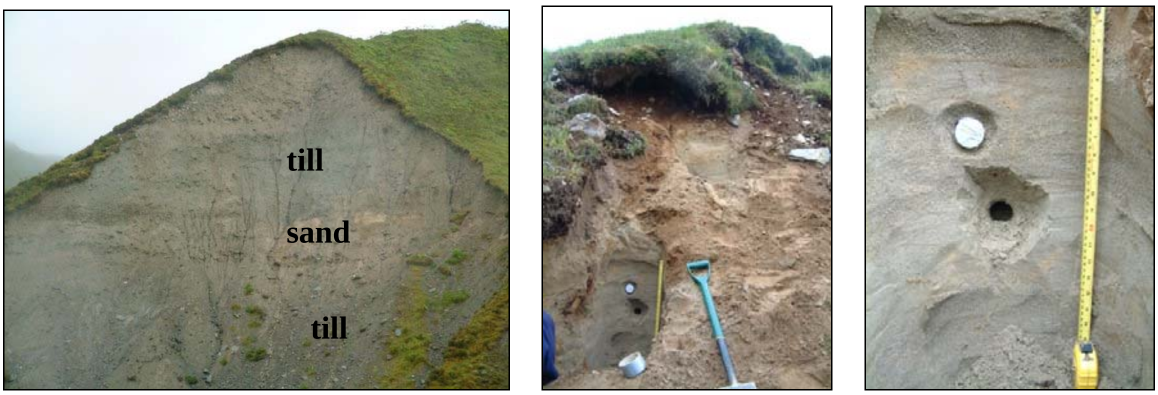

Figure 7: A: The Coire Chailein section, sand unit forms light band in centre; B: The Dalrigh moraine section, composed primarily of bedded sand; C: Close-up of the sand being sampled at Dalrigh

Preparation procedures of the six samples were carried out under safelight conditions to prevent bleaching the luminescence signals. The first 2-3 cm of sediment, which may have been inadvertently exposed to daylight while sampling, was removed from the tube samples. The remaining sediment was removed and the as-received moisture content measured by comparing wet mass with dry mass after weight stabilisation in a 50°C oven. Coarse-grained quartz with size fractions ranging from 180-500 µm was extracted from each sediment sample. This procedure involved dry sieving and extracting the 180-212µm fraction, removal of carbonates with HCl, removal of organic material with H_2O_2, removal of heavy minerals by density separation techniques using a heavy liquid solution of 2.70 g.cm-3 and removal of feldspars and etching of the surface of the quartz grains with 40% HF for 80 minutes. The quartz grains were etched and mounted onto stainless steel discs coated with a layer of silicone grease.

OSL measurements were carried out using two Risø TL/OSL-DA-15 automated systems. Luminescence from the quartz grains was stimulated using blue LEDs (420-550 nm) with detection in the ultraviolet defined by a Hoya U340 filter and a 9635Q photomultiplier tube. A single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000, 2003) was used to measure the stored or equivalent dose (D_e) of environmental radiation on each disc measured. In a single-aliquot approach, repeated cycles of laboratory irradiation, preheating and luminescence measurement are made on a single disc (aliquot) of quartz grains to estimate the D_e. Measurements on several (>24) such aliquots enable assessment of the distribution in D_e, and hence distribution in age, of the deposit.

These techniques offer the best potential for dating non-organic sediments on the age-range of 10’s – 10000’s years. Known issues were addressed in order to minimise errors and ensure greatest accuracy, for example, preheating steps were incorporated to thermally remove unstable luminescence, and each natural or laboratory regenerated OSL signal in the SAR method was corrected for possible changes in sensitivity using the luminescence response to a subsequent constant test dose. Standard tests of luminescence behaviour (recycling, thermal transfer and known-dose recovery) were conducted on each sample before being used for dating. Statistical analysis of each D_e distribution involved Finite Mixture modeling (Galbraith & Green, 1990; Galbraith & Laslett., 1993). Final modeled D_e values were divided by the total dose rate derived from the *in situ* dosimetry in order to calculate the sample ages.

6 Results

The luminescence behaviour of the samples is characterised by ultra-fast, fast and medium components (Bulur, 1996). The ultra-fast components (in this case, the first second of the luminescence decay curves) are thermally unstable and are not included in the calculation of the equivalent dose (D_e) and all D_e values are based on the integral of the luminescence intensity over ~1 to ~2.5 seconds.

Field sample ID	*U conc (ppm)*	*Error (ppm)*	*Th conc (ppm)*	*Error (ppm)*	*K conc (%)*	*Total quartz Gy/ka*	*Error Gy/ka*	***FAM D_e Gy***	*Error Gy*	***Age ka***	*Error ka*	***N***	*Mean D_e Gy*	*Median D_e Gy*	*Stand. Error Gy*
CHA-210606-1	1.06	0.106	3.86	0.2	1.237	1.7329	0.09	**264.7**	85.7	**153**	50.1	**78**	460.3	430.1	23.9
CHA-210606-2	1.36	0.136	5.1	0.3	1.54	2.1655	0.11	**484**	63.9	**224**	31.8	**65**	556.3	510.4	23.6
CON-220606-3	1.04	0.104	5.04	0.3	1.346	2.08	0.1	**90**	7.3	**43.3**	4.1	**40**	276.3	221.5	24.5
CON-220606-4	1.1	0.11	5.56	0.3	1.26	2.0481	0.1	**199**	12.7	**97.2**	6.2	**42**	240.9	217.4	17.3
CHA-220606-5	1.32	0.132	5.45	0.3	1.692	2.3211	0.12	**310.8**	45.2	**134**	19.2	**63**	498.7	478	24.6
CHA-220606-6	1.1	0.11	5.56	0.3	1.26	1.8762	0.1	**445.7**	305.4	**238**	163	**42**	591.3	543.4	31.3

Table 2. OSL elemental concentrations for *in situ* environmental dose rate calculations and laboratory measured equivalent doses (D_e)

The distributions for all six samples show a spread of values and therefore are likely to contain multiple populations of D_e (heterogeneous bleaching or dose). The distributions have been modelled using the Finite Mixture Model of Galbraith & Green (1990) which allows the discrimination of separate sub-populations. The number of possible components is based on achieving the best maximum likehood criterion and avoiding over-fitting that data.

The data are presented in radial plots which show the D_e in Gy for each data point, as well as the relative error and precision on the x-axis and how the data fall within two standardised estimates of the mean on the y-axis (Fig. 8). Lines are drawn that represent the mean of each modelled component and each distribution is best modelled as containing either 2 or 3 components. For each of the six samples, the modelled age is based on the lowest modelled D_e value (Table 2) with a standard error based on the data falling within that component, but the mean and median D_e are also presented for comparison. In all the samples, the median D_e is less than the mean D_e and therefore all the distributions are positively skewed. In contrast, very well bleached grains, such as aeolian sand, should give a D_e distribution that follows a normal distribution. The Finite Mixture Model minimum ages for the Coire Chailein samples are 224 ± 32 ka (lower glaciolacustine deposit), 238 ± 163 ka, 153 ± 50 ka, and 134 ± 19.2 ka (the overlying glaciofluvial sand horizons), and 43.3 ± 4.1 ka and 98 ± 6 ka for the two samples extracted from the sand-silt deposits of a hummocky moraine in Glen Cononish.

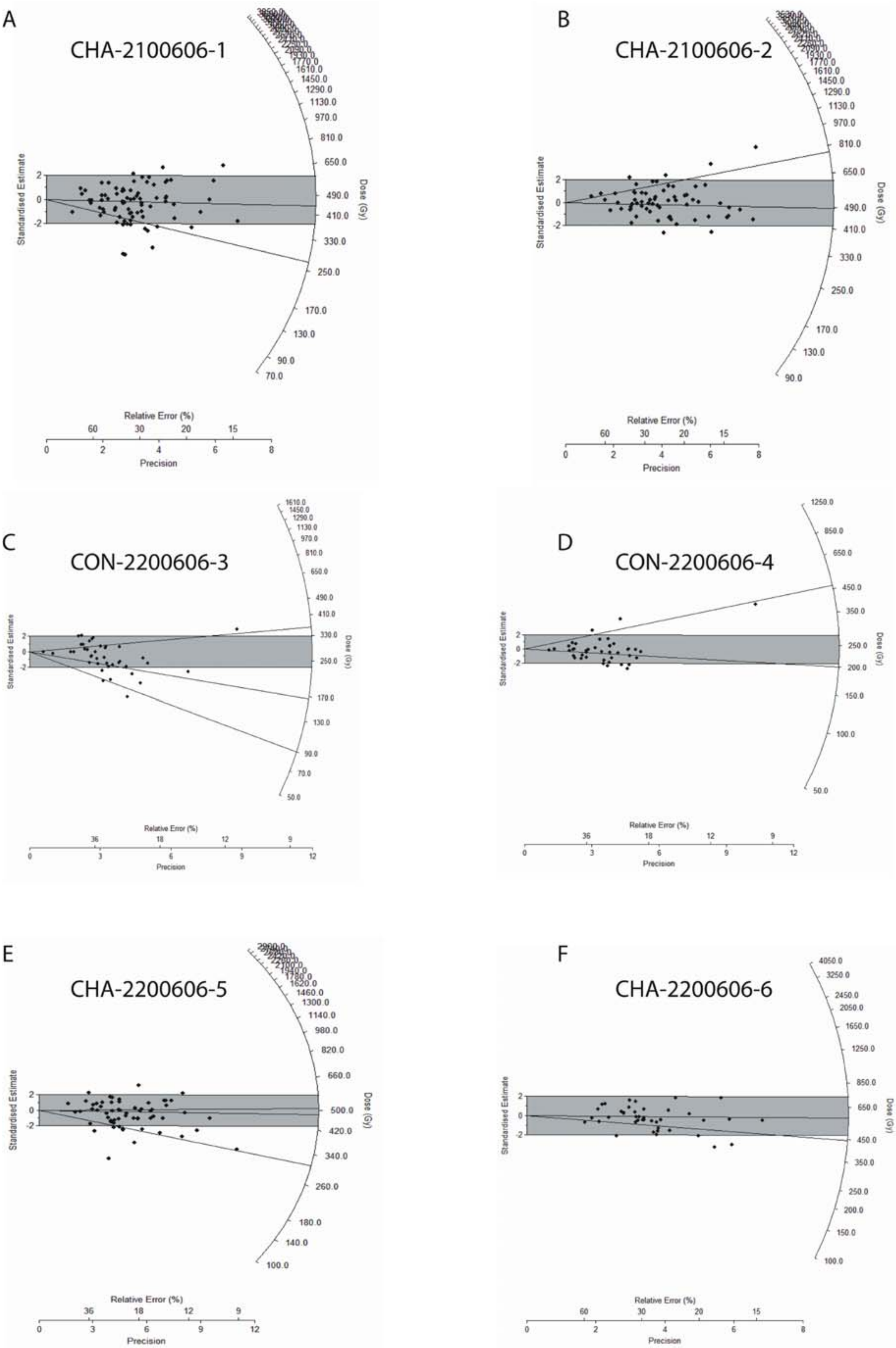

Figure 8. Radial plots of all samples showing De values, relative error and precision of data points. Lines are drawn to delineate the components modelled using the Finite Age Model of Galbraith (2006).

7 Interpretation

All the samples from Coire Chailein come from the same 2 m thick sand unit and were collected no more than 2 metres apart vertically. The sand unit contains a basal glaciolacustrine sand overlain by a trough-cross bedded medium-coarse glaciofluvial sand. The youngest age calculated for Coire Chailein is from sample CHA-220606-5, collected from a medium-grained sand which is part of a dune and contains indicators of high sediment rates (full dune, and ripple, preservation). The age of 134 ± 19.2 ka is pre-Devensian and the other glaciofluvial samples give even older OSL ages (Table 2, Fig. 8) and are from laminated coarse and medium sand layers. The stratigraphically lowest sample is from the glaciolacustrine unit and gives an OSL age of ~224 ka. The youngest OSL age for the Dalrigh site in Glen Cononish is 43 ± 4 ka and the overlying sample gives an OSL age of 98 ± 6 ka, both considerably older than the Younger Dryas age implied by the palaeoglaciological context of the moraine suite.

Whilst all of these age estimates are older than expected for the timing of sediment deposition, they nonetheless provided important constraint on the chronology of glacial events in the area. Lukas et al. (2006) identified two key problems hampering attempts to use OSL techniques to date glacial sediments. These are a) reworking of older sediments, and b) inadequate bleaching prior to redeposition.

a) Correlation of glacigenic units throughout the field area previously enabled Golledge (2007) to present a stratigraphic scheme for the region (Fig. 4). This scheme identified 'old' sediments preserved in Coire Chailein that were interpreted to pre-date the last major glacial episode, the Main Late Devensian. The preservation of older sediments and landforms in the Scottish glacial record has also been demonstrated recently by a number of other authors (e.g. Hodgson 1986; Wilson & Evans 2000), thus the likelihood of 'sediment inheritance' in glaciated areas of Scotland would appear to be relatively high. Significantly, however, the absence of Devensian-age material in the Coire Chailein deposit may suggest that sediments of this period were not available for reworking and redeposition when the sand unit was being laid down, implying that the sand must pre-date the onset of the Devensian (c. 116 ka BP, Merritt et al. 2003). Consequently, the unit could be ascribed to the Ipswichian (Eemian) Interglacial (116-128ka BP), and the underlying till to an even earlier glacial episode – perhaps the Wolstonian (Saalian). Deposits of Wolstonian and Ipswichian age are known to exist elsewhere in Scotland, in particular at Kirkhill and Teindland in NE Scotland (Merritt et al. 2003), in Shetland (Hall et al. 2002).

b) The reasons for poor, to no, bleaching of sediments could be 1) rapid transport times not allowing any exposure of grains to sunlight, 2) transport processes that promote highly turbid water that does not allow light penetration and grain bleaching, and 3) very low UV levels for bleaching. The only method available for exploring their true depositional age would be single grain dating of the samples which can identify small populations of bleached grains within a large population of unbleached grains.

Lukas et al. (2006) also noted that metamorphic bedrock lithologies (such as those forming much of the present study area) yielded quartz grains that were perhaps less suitable for luminescence dating than those derived from sandstones.

8 Conclusions

The application of luminescence dating to quartz grains sampled from glacial deposits in the western Scottish Highlands has produced age determinations ranging from 43.3 ± 4.1 ka BP to 238 ± 163 ka BP. Although these ages are older than expected for the landforms that the sediments compose, they are not inconsistent with the existing regional stratigraphy. They are the first dates assigned to the last Interglacial episode to be published from this part of Scotland, and as such provide essential constraint on the chronology of regional glacial events. Furthermore, the dates lend support to the concept of landscape preservation and sediment inheritance alluded to in other studies, and in doing so advance our understanding of the complexities of glacial processes.

9 References

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