Excursion 33 Quaternary

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Introduction

Until comparatively recently, the Quaternary 'Ice Age' was frequently regarded as a time of continuous glaciation of the British Isles. Research over the last 25–30 years has shown such a concept to be incorrect. To date, at least six major cold intervals, alternating with major temperate intervals, have been distinguished in the British Quaternary stratigraphical record. The last three major cold intervals are represented by glacial deposits in parts of Britain north of the Bristol Channel–Thames Estuary isthmus, so that demonstrably the Quaternary Period (Sub-era of some authorities) included at least three 'ice ages'. Also, in keeping with terrestrial evidence of multiple-rather than mono-glaciation, cores of Quaternary sediments from the Atlantic and Pacific Oceans have revealed a series of more than twenty alternating cold and temperate Isotopic Stages (some of these being major climatic intervals, and some minor). In the Glasgow district, the visible effects of glaciation–both erosive and depositional–are believed to be due to ice masses that originated in the SW Highlands (and perhaps to a lesser extent in the Renfrewshire uplands) and had their greatest effect during the last major cold interval. This interval is thought to have commenced approximately either 125 or 70 thousand years ago (depending on the authority quoted and the evidence that is accepted) and to have lasted until about ten thousand years ago (Price 1983; Sutherland 1984; Jardine 1986).

Important effects of the alternation of major cold and temperate climatic phases were world-wide changes in sea level and regional changes in land level. These changes accompanied, and were due to, the growth and decay of enormous ice sheets approximately contemporaneously in North America, Fennoscandia and northern Britain: global sea level was at least 100 m lower than its present level during intervals of glaciation, and approximated to its present level during interglacial intervals; in a severely-glaciated area the landmass was depressed appreciably during glaciations by the weight of superincumbent ice, whence rebound of the landmass occurred in the intervening interglacial intervals. The combined effects of global changes of sea level and regional changes of land level produced in the Glasgow area, in the course of the last thirteen thousand years or so, a series of tilted marine shorelines: these now stand at various heights above present sea level due to differential land uplift having continued after sea level had approximately attained equilibrium.

A number of secondary recessions and advances of ice fronts, corresponding respectively with milder and more severe climatic intervals within the last major glaciation, occurred in western central Scotland. During the milder climatic phases (known as 'interstadials') sub-arctic type vegetation and animals occupied parts of the region outside the static or receding ice fronts. When conditions again became more severe and the ice readvanced (during a 'stadial'), remnants of flora and fauna were occasionally buried by the advancing ice and its deposits. A few of the interstadial deposits have been fortuitously preserved in the Glasgow area, and have been temporarily exposed in excavations during the last 150 years or so.

A summary of the sequence of events in the Glasgow district during the Quaternary Period is given in (Table 33.1).

a. Erosive effects of glaciation

In the Glasgow district, as in other parts of western Scotland, the relative importance of erosion by ice in the course of the Quaternary period and denudation by river action during the immediately preceding Tertiary time interval in determining the configuration of the present land surface is still an unsolved problem (cf. Jardine 1986, pp. 28–30). Many geomorphologists would agree with George (1955, p. 302) that 'The local effects of glaciation in the modification of landscape ... are no more than the final touches given to the pre-Glacial landforms by ice; and ... compared with the radical transformations that took place during the 50 or 60 million years of Tertiary times, the changes in surface grain arising through the coming and going of glaciers and ice-sheets during the past half-million years or so are more spectacular than fundamental'. Despite this claim, since Linton (1951) suggested that many major valleys were produced

by 'diffluent' Quaternary ice that caused watershed breaching, there has been a nagging doubt concerning the relative erosive efficacy of river action and ice action.

Allowing for this doubt, and accepting that the configuration of the landscape of the Glasgow district as the product of glacier erosion is the cumulative result of multiple- rather than mono-glaciation, several good examples of both large-scale and small-scale glacial erosion may be recognised. The most impressive examples of the former are the overdeepened basin of the Firth of Clyde between the islands of Arran and Bute (rockhead at –320 m O.D.) and the depths of the basins of the northern part of Loch Lomond (to c. –170 m O.D.) compared with the depth of the southern part of the loch (to c. –10 m O.D.). Further examples of large-scale erosion are the so-called 'buried channels' that are cut in solid rock to depths as low as –75 m O.D below the Rivers Clyde, Kelvin and Leven (and to a lesser extent the River Cart). The origin of these channels is controversial, but excavation by subglacial meltwater streams under hydrostatic pressure, rather thanby glacier ice, probably was an important process involved in their formation (Jardine 1986, pp. 31–32). Another frequently cited example of marked glacial erosion is the deepening of the WNW–ESE oriented valley between Strathblane and Lennoxtown; especially when the Campsie Fells are covered with a thin sprinkling of snow, the tributary valley of Fin Glen is seen to 'hang' above the main valley. To the south of Strathblane, much smaller ice-scooped hollows, including that now occupied by Loch Ardinning (Locality 1, [NS 564 780], (Figure 33.1)), also testify to the erosive action of the Quaternary ice, and suggest its WNW–ESE passage over the area. Corries on the northern face of the Campsie Fells, especially the impressive Corrie of Balglass (Locality A, [NS 589 850]), provide evidence of cirque erosion.

Small-scale effects of glacial erosion are more difficult to find, mainly since much of the solid rock is covered by at least a thin veneer of Quaternary deposits (see below). Near the NW end of Loch Ardinning, however, striations are developed, even if only poorly, on the upper surface of the quartz conglomerate that is exposed in the nearby quarry. In contrast, 40 km to the north of Glasgow, on the eastern shore of Loch Lomond 50 m to the east of Rowardennan pier (Locality B, [NS 358 986]), excellent examples of glacial striae are to be seen on an ice-smoothed roche moutonnee of quartz mica schist. The striations are oriented N–S, at right angles to the foliation of the schist. The small hill named Dunglass (Locality 2, NS [575 789], located on the floor of the valley between Strathblane and Lennoxtown, combines the effects of ice erosion and deposition, its western end being (mainly) the crag, and its eastern end the corresponding tail, of a crag-and-tail ice-moulded landform.

b. Quaternary deposits

The Quatemary deposits of the Glasgow district comprise sediments laid down by ice and its meltwaters in the course of glaciation and deglaciation, together with sediments deposited by marine waters, by the River Clyde and its tributaries and by other terrestrial agents during interstadial intervals and after the ice had finally melted. Broadly, the Quaternary sedimentary succession is that shown in the right-hand column of (Table 33.1).

(i) The types and sequences of deposits filling the buried channels that underlie the Rivers Clyde and Kelvin are uncertain, being known mainly from occasional temporary exposures of the uppermost sediments and from borehole data recorded by drillers rather than geologists (Clough et al. 1925; Menzies 1981; Browne and McMillan 1985). The buried channels appear to contain beds of mainly water-laid (? glaciofluvial) sands and gravels, together with occasional layers or lenses of till. The uppermost sand and gravel deposits are almost certainly Devensian in age, since fossils of this age have been found in them (see next paragraph). Many of the other deposits, both tills and water-laid sediments, may also date from the Devensian glacial age. In the 1960s and 1970s, deposits in the vicinity of the buried channel that underlies the River Kelvin were exposed extensively in commercial sand and gravel pits within the burgh of Bishopbriggs. Sections on the site of the former Cawdor golf course (Locality C, [NS 610 721]) and in the Wilderness pit (Locality D, [NS 600 722]), together with borehole records (Browne and McMillan 1985, fig. 11), indicated that 3–7 m of red till rest on a thick sequence of gravel and sand layers. The gravels comprise pebbles mainly of quartzite, vein quartz, schistose grit and basalt–all durable, but non-local, rock or mineral clasts–with occasional locally-derived white/yellow sandstone. The sands are mainly of quartz grains with sporadic concentrations of small coal fragments. Stratification in both the gravels and sands is horizontal for the most part, but occasional cross-stratification and cut-and-fill structures do occur. From time to time fossil ice wedges and involutions were exposed in the working faces in the gravels, indicating periglacial frost action after deposition of the gravels but before deposition of the overlying cover of red till (Galloway 1961).

In 1963, there was found in the sands directly below the uppermost gravels of the former Wilderness pit (Locality D, [NS 600 722]), a bone of the woolly rhinoceros, *Coelodonta antiquitatis* (Blumenbach), dated 27, 550 +1370/−680 years B.P. (before present) by radiocarbon assay (Rolfe 1966). Until recently, it was considered possible that the age of the bone is greater than the age of the gravels in which it was contained. The discovery in 1986, however, of a well-authenticated interstadial site at Sourlie [NS 336 414], near Irvine, Cunninghame District; with a possible time range of c. 33, 500–29, 000 years B.P. established by radiocarbon dating of plant debris, a reindeer antler and carbonaceous silt/clay underlain and overlain by thick till deposits, suggests that the Wilderness bone and gravels are contemporaneous. More significantly, the combined evidence from Souffle and Wilderness is strongly indicative of interstadial conditions in at least low-lying parts of Scotland during the period c. 33, 500–26, 000 years B.P. (Jardine et al. 1988).

Two other examples of interstadial fossiliferous deposits are known from the Glasgow district. In 1937 the remains of bones of the reindeer, *Rangifer tarandus* Linne, were found in SE Glasgow near Queen's Park (Locality E, at approximately [NS 588 618]) in water-laid sands and gravels that were overlain by up to 20 m of till forming a drumlin (Macgregor & Ritchie 1940). The age of the reindeer bones is unknown, but the overlying till almost certainly dates from the (Late Devensian) main phase of the last major cold interval in Britain (Dimlington Stadial, (Table 33.1)), a phase that is thought to have had its glacial climax in northern Britain around 20, 000–18, 000 years B.P. and perhaps lasted from c. 25, 000–14, 000 years B.P. It is possible, but by no means certain, that the interstadial deposits at Queen's Park and those in which the dated bone was found at the Wilderness pit, Bishopbriggs, are of approximately the same age and that they represent the same interstadial interlude within the last major cold interval. The Queen's Park section is no longer exposed, but the reindeer remains from it are preserved in the Glasgow Art Gallery and Museum at Kelvingrove.

In the 1850s, part of the beam of a reindeer antler was found in a thin succession of stratified deposits near Croftamie, Dunbartonshire, in the (former) railway cutting (Locality 3, [NS 473 860]) a few metres north-east of the point where the minor road between Croftamie and Kilmaronock Church intersects the cutting (Jack 1877). The stratified deposits were overlain by shelly till of the Loch Lomond Stadial (see below). More recently, felted organic detritus obtained from approximately the same horizon as the reindeer antler was dated 10, 560 ± 160 years B.P. (Rose 1981; Rose et al. 1988). The recent records also show that the stratified deposits are underlain by up to 1.5 m of till that is attributed to deposition during the Dimlington Stadial. The deposits containing the reindeer antler and dated organic detritus at Croftamie, therefore, represent a later interstadial (Windermere Interstadial, (Table 33.1)) than the interstadial or interstadials represented by the ossiferous deposits at Wilderness and Queen's Park. The antler from Croftamie is now in the Royal Museum of Scotland, Edinburgh.

(ii) Most of the low hills on which central and western Glasgow is built are glacial drumlins consisting of grey till (boulder clay) with a mainly silty mud and sandy silt matrix, derived largely from local Carboniferous shales and sandstones (Abd-alla 1988, p.77 and p.263). Embedded in the matrix are stones of variable size up to boulders about one metre in diameter. The stones, which frequently bear striations, are dominantly of the same local rocks as the matrix, but occasional erratic quartz schists and schistose grits (from NW of the Highland Boundary Fault), Carboniferous basalts (? from the Kilpa trick Hills) and Devonian (ORS) sandstones (? from the vicinity of Dumbarton) occur. Opportunity to examine the nature and characteristics of the till is provided occasionally in temporary excavations within the city. The drumlins, of which Garnethill (Locality F, [NS 582 661]) and the large hill within Bellahouston Park (Locality G, [NS 549 638]) are good morphological examples, are streamlined ground morainic forms, and the grey till is a lodgement till of the last major ice sheet that moved over the Glasgow area (in a WNW–ESE direction during the Dimlington Stadial). In central Glasgow (e.g. within the precincts of the University of Strathclyde) the uppermost two or three metres of the grey till are strongly weathered to a rusty brown colour.

In NW Glasgow and adjacent parts of Dunbartonshire there occurs a red till that is distinctly different in appearance and nature from the grey till of central Glasgow. The red till has a dominantly silty sand matrix, derived mainly from Devonian (ORS) sandstone fragments (Abd-alla 1988, p.77 and p.263). The stone content is dominantly of Highland quartzite and schistose grit, ORS rock fragments and Carboniferous lavas, but occasional small fragments of local Carboniferous shale and white/yellow sandstone occur (cf. Menzies 1981). The thickness of the till increases in a north-westerly direction, from about 1 m or less near a SW–NE oriented line extending approximately from Partick railway station [NS 556 664] to Possil Loch [NS 585 698], to several metres or tens of metres in Bearsden and Milngavie District. Although only occasional small temporary exposures of the red till are now to be seen, in the 1960s and 1970s extensive exposures at

Cawdor (Locality C, [NS 610 721]) and Wilderness (Locality D, [NS 600 722]) showed that about 3–7 m of red till (rather stonier here than 1 km to the west, where it also is thicker) rest on stratified gravels and sands in the vicinity of the Kelvin buried channel (see above).

The nature and mode of origin of the red till and its relationships with the grey till were subjects of debate in the late 1960s and early 1970s (e.g. Jardine 1968; Sissons 1968). It is now generally agreed that the two tills are lodgement deposits of a single ice advance (during the Dimlington Stadial), differences in the characteristics of the tills, including colour, being due to derivation from different source rocks (see above; Menzies 1981; Browne and McMillan 1985). There still remain, however, a few puzzling aspects of the relationships between the tills. For example, it has long been known that there is a 3–4 km wide zone, immediately to the NW of the 'feather edge' of the red till (see above), within which both the grey and red tills are present and where, in places, the red till rests on grey till. Recently, grain-size, clay mineralogical and geochemical analyses of the matrices of the two tills (Abd-alla 1988, pp. 476–477) confirmed earlier field observations by Jardine (1968) that at a few locations within this zone a thin cover of red till rests on weathered rather than fresh grey till. This poses a problem, since such evidence suggests that at least a short period of exposure of the grey till occurred at these locations before the red till was deposited on the grey till. A possible sequence of events is as follows:

1. The main advance of the Late Devensian ice sheet deposited grey lodgement till in the central Glasgow area, red lodgement till in NW Glasgow and Dunbartonshire and red-on-grey lodgement till in the zone mentioned above.
2. During general recession of the ice front from east to west, there was a short period of stillstand of the front in the vicinity of sites within the zone where red till now rests on weathered grey till. At these sites, grey till was exposed beyond the ice front, or perhaps in hollows in the ice near the front.
3. Following alteration of 'fresh' grey till to weathered grey till at these sites, thin covers of red till were deposited as flow till on top of the weathered grey till.

Such an explanation is in keeping with the thickness of the red till that rests on weathered grey till at these sites being less than two metres.

In addition to the grey and red tills described above, there are other distinctive tills occurring over limited areas within the Glasgow district. They are exposed occasionally, as in the Toryglen area (Locality H, [NS 600 618]), where a bright orange red till, probably derived from soft red sandstones of the (locally) underlying Barren Red Measures, occurred in an excavation in 1965 (see also Clough et al. 1925, pp. 223–227).

(iii) In western and central Glasgow, and also in the neighbourhood of Renfrew and Paisley, marine and brackish-water Late Devensian sediments occupy the low ground (up to 25 m or 41 m above O.D., depending on the author quoted: Rose 1975, p. 20; Sissons 1976, p.128; Browne in Jardine 1980, p.13; Browne et al. 1983) (Figure 33.2). The sediments concerned, deposited during the Windermere Interstadial (Table 1), are part of the well-known Clyde Beds . They are exposed occasionally in artificial excavations; a small natural cliff at Geilston, Cardross (Locality 7, [NS 341 777]), is poorly exposed now compared with its condition when described by Rose (in Jardine 1980, pp. 2527). Broadly, the marine and brackish-water sediments consist of two units (cf. Peacock 1975, p. 46;1981, pp. 225–226), the lower comprising laminated clays, silts and sands, commonly <1 min thickness but 2–3 m in places, the upper comprising fossiliferous clays and silty sands (with locally-abundant remains of large bivalves, e.g. *Arctica islandica*, and with foraminifers and ostracodes), commonly >5 m in thickness.

The marine waters perhaps penetrated the Paisley-Glasgow area around 13, 000 years B.P. (Browne et al. 1977; cf. Peacock 1989), initially either by a sinuous channel through the narrow Lochwinnoch Gap (Peacock 1971), or by Greenock along the line of the present estuary of the Clyde (Sissons 1974, p. 330). By c.11, 700 years B.P. the sea had penetrated the Vale of Leven from Dumbarton to Balloch and extended into the Loch Lomond basin (Figure 33.2). Opportunities to examine the Late Devensian marine and associated estuarine deposits are infrequent. Because of this, the sequence shown in an exceptionally fine former section at Junction 27 on the M8 motorway near Paisley (Locality 1, [NS 495 657]) is recorded in (Figure 33.3) (see also Aspen & Jardine 1968). Some compensation for the scarcity of sedimentary exposures is afforded by traces of former shoreline features dating from the same general episode when, in relative terms, sea level stood higher than at present. Some of the best examples occur near Anniesland Cross (Locality

J, (Figure 33.1)) where two abrupt rises along the length of Bearsden Road, at Glencoe Street [NS 546 689] and at Sutcliffe Road [NS 547 690], with intervening terrace, mark former shorelines in this area. Similar terraces and sand- or gravel-covered till slopes, although less well defined, are detectable in the Jordanhill area (Locality K), e.g. in Chamberlain Road (at [NS 541 682]), Jordanhill Drive (at [NS 541 684]) and Seggielea Road (at [NS 539 685]).

(iv) The Dimlington Stadial, in the course of which the main Devensian glaciation of northern Britain took place, was followed by the Windermere Interstadial (Table 33.1). During this fairly short-lived (c. 13, 000–11, 000 years B.P.) temperate interval the ice melted rapidly, and the whole of Britain may have been clear of ice by 12, 500 years B.P. Around 11, 000 years B.P., conditions became colder both on land in NW Britain and in the Atlantic Ocean and neighbouring sea lochs of western Scotland including the Firth and Estuary of the Clyde. In the course of the ensuing Loch Lomond Stadial (broadly from 11, 000–10, 000 years B.P.), glacier ice reappeared in many parts of western Scotland, especially in the Loch Lomond basin (hence the name given to the Stadial) and adjacent valleys. End morainic and associated glaciofluvial deposits dating from this time were formerly well exposed at Rhu Point [NS 265 840], but now are only poorly exposed on rare occasions. A detailed account of their characteristics is given by Rose (in Jardine 1980, pp. 31–37).

Deposits of the Loch Lomond Stadial do not occur within the city of Glasgow itself. Indeed, the nearest these deposits are to be found is 25 km from the city centre in the neighbourhood of the villages of Killearn (Locality L, [NS 523 861]) and Drymen (Locality M, [NS 474 886]). This is because this late phase of glacier advance was not powerful enough to carry ice far beyond the vicinity of the Highland Boundary Fault. In 1970, pipe-line excavations at [NS 430 865] (Locality N), in the vicinity of Gartocharn village, revealed characteristic Loch Lomond Stadial ground-morainic till, with small shell fragments embedded in the till. A typical, though small, end-morainic ridge produced by the same ice advance is to be seen on Highfields Muir (Locality 6, [NS 323 857]) to the north of the B831 road (cf. Rose in Jardine 1980, pp. 37–39). The ridge is readily recognisable since recently a metalled but non-surfaced private road has been constructed along its crest. Meltwater deposits laid down near the ice margin have been extracted extensively from time to time in a sand and gravel pit near Drymen (Drumbeg, Locality 4, [NS 483 880]). The nature and quality of exposure varies as work progresses. The sediments occasionally exhibit structures typical of glacial meltwater deposits: unconformities, top-set and fore-set bedding, cut-and-fill structures, alternation of thick sand beds and thinner gravel layers. In addition, these deposits have yielded shell fragments (of marine molluscs that inhabited the Loch Lomond basin during the immediately preceding Windermere Interstadial, but which were carried out to the Drymen area by ice and meltwaters during the Loch Lomond Stadial) radiocarbon dated at 11, 700 ± 170 years B.P. (Sissons 1967). Between Balloch and Luss on the western side of Loch Lomond, a discontinuous, narrow, sinuous ridge of gravel, occurring a few tens of metres east of Duchlage farm [NS 350 871] and SSW of Muirland School (Locality 5, [NS 348 867]), is an esker formed by the meltwaters of the ice that occupied the Loch Lomond basin.

(v) Flandrian marine and fluviatile deposits occupy the very low ground bordering the River Clyde and its estuary. The sediments vary in nature and composition, in places being silts or fine sands (? fossil tidal-flats) where they occupy wide flat tracts, e.g. between Shieldhall (Locality 0, [NS 532 664]) and Renfrew Cross [NS 507 676], or in places being gravels and sands (fossil beach deposits now forming raised surfaces some 8–10 m above 0.D.), as between Dumbarton and Cardross (Locality 8, [NS 354 767]). In several places the Flandrian raised coastal deposits are backed by low cliffs cut in solid rock or in till. Good examples of cliffs, cut in Old Red Sandstone rocks, occur between Dumbarton and Cardross, at Locality 8.

Itinerary

Themes	A variety of Quaternary landforms and erosive features, and a more limited number of Quaternary deposits, in the area to the NW of Glasgow city centre.

Features	Crag-and-tail, drumlins, dry valley, end-moraine, esker, Flandrian raised beach, beach, former marine embayment, former marine shoreline, former sea cliffs, glacial striations (striae), glacially-deepened valley, 'hanging valley', ice-scooped hollow, position of buried charnel; Clyde Beds deposits; glacial meltwater deposits; shelly till.
Maps	O.S. 1: 50 000 Sheet 56 Inveraray & Loch Lomond Sheet 57 Stirling & The Trossachs Sheet 63 Firth of Clyde Sheet 64 Glasgow B.G.S. 1: 63 360 Sheet 30 Glasgow (Dri ft)
Terrain	Road or easy track, except at Locality 7 (which is optional), where the track is muddy and a stream has to be forded on foot. An easily negotiated fence has to be climbed at Locality 3 (which is also optional).
Distance and Time	Approximately 95 km (60 mls) round trip by car from University of Glasgow. Short walks to exposures. Total time, 6–7 hours.
Short itineraries	Slightly shorter itineraries, each of around 4–5 hours duration, would be to (a) Localities 1, 2, 3 and 4, or (b) Localities 5, 6, 7 and 8.
Access	Many of the stops are made for the purpose of observing landforms from a distance and, therefore, present no access problems. Access at Locality 4, a working pit, is discussed below.

Starting at the University of Glasgow Department of Geology & Applied Geology, which is sited at the SW margin of the Hillhead drumlin, proceed to the northern end of Byres Road. The route from thence, westwards along Great Western Road (and therefore opposite in direction from ice flow during the Dimlington Stadial; Table 33.1), undulates gently over the low till-based ground between the Dowanhill and Kelvindale drumlins as far as Bingham's Pond (beside the Pond Hotel), where it drops for a distance of 200–300 m into what was a marine embayment during the Windermere Interstadial, c.13, 000–11, 000 years B.P. A low till-cored rise is next crossed until, at Anniesland Cross (Locality J), Great Western Road again drops to lower ground underlain, e.g. in the High School playing fields to the SW of the Cross, by marine Clyde Beds deposits.

From Anniesland Cross follow Bearsden Road (A806) through the Temple area, noting in passing that the road rises abruptly at Glencoe Street [NS 546 689] and again at Sutcliffe Road [NS 547 690] as it crosses two former late-Quaternary marine shoreline positions. Having crossed the Forth & Clyde Canal, Bearsden Road rises rapidly to near the southern entrance to the University of Glasgow Garscube Estate, from whence, as far as Canniesburn Toll, it cuts athwart the eastern ends of a series of W–E oriented till-formed hills in what is known as Switchback Road.

At Canniesburn Toll, the A81, Milngavie Road, should be followed, but before this is done it may be worth reflecting that concealed several tens of metres below the ground surface near the Toll is the southern boundary of the buried channel of a former course of the River Kelvin. The northern boundary of the same channel is located about 1.5 km from the Toll. It underlies Milngavie Road 300–400 m north of Hillfoot Station, although no trace of its presence is betrayed by the surface features that occur in this area, mainly the W–E oriented Kilmardinny and Boclair drumlin-like hills.

Locality 1. Loch Ardinning [NS 564 780] (Figure 33.1)

The A81 route to Strathblane skirts the eastern side of the town of Milngavie and, having passed Craigmaddie Reservoir on the left, winds through an area where drumlins may be seen on the right around Baldernock, before the road straightens between Craigmaddie House and Loch Ardinning (Locality 1), where the first major stop should be made in the lay-by on the right (eastern) side of the road c.100 m south of the loch. The summit of the conglomerate crags in the

quarry immediately to the north of Loch Ardinning provides an excellent viewpoint for the observation of a number of physical features that testify to the WNW–ESE passage of glacier ice over the surrounding area during at least one of the major cold intervals of the Quaternary period. To the south, Loch Ardinning in the immediate foreground occupies an ice-scooped hollow, whilst in the distance may be seen the large drumlin field on which much of the city of Glasgow and its environs are built. On the top surface of the conglomerate itself, poorly developed glacial striations occasionally may be observed; the quality of the striae has deteriorated recently, probably because of excessive recreational activity in the form of unauthorised motor-cycle 'scrambling. To the north is the glacially-deepened valley that extends from Strathblane to Lennoxtown, with the tributary valley of Fin Glen 'hanging above it on the southern face of the Campsie Fells. Far off to the NW may be seen the isolated peak of Ben Lomond which, although covered completely by ice in the course of the 'main' Devensian glaciation (i.e. Dimlington Stadial; (Table 33.1)), stood high above separate lobes of ice to its west and east during the later Loch Lomond Stadial.

Locality 2. Dunglass [NS 575 789]

Leaving Loch Ardinning, the A81 route continues down the hairpin bend immediately south of Stra thblane. It is at this bend that the first glimpse of the 'crag-and tail' feature represented by the intrusive mass of Dunglass (Locality 2) is to be seen but, if a more prolonged view is desired, a short digression from the main route should be made eastwards along the A891 to a point near the entrance to Ballagan House. From such a location, the steeper solid-rock 'crag' at the western end and the streamlined 'tail' of glacially-deposited debris at the eastern end of the hill show up well, although it must be said that the feature as a whole is not a perfect example of its kind.

To reach the next major stop, at Drumbeg pit (Locality 4, [NS 483 880]), the A81 should be followed from Strathblane for about 8.5 km to the crossing of the A8land B834, where a left turn into the B834, and thence westwards across the Blane Water, leads to the junction of the B834 with the A809. Here a right turn should be made NW along the A809 towards the village of Croftamie.

Locality 3. Croftamie [NS 473 860]

If desired, a brief digression may be made to the left (west) as the village of Croftamie is entered, into a minor road signposted 'Pirniehall', to visit the former railway cutting crossed by the road from Croftamie to Kilmaronock Church. Here shelly till of the Loch Lomond Stadial has been found to rest on a very thin layer of fossiliferous interstadial deposits which, in turn, rest on up to 1.5 m of till that is attributed to the Dimlington Stadial. The cutting is now largely overgrown but, 10–15 m from the southwestern side of the road and on the southern bank of the cutting, there is a small exposure of the red-coloured till of the Loch Lomond Stadial. Small fragments of shells can occasionally be found in the till. To gain access to the exposures in the cutting a low wire fence has to be straddled. There is parking space for one vehicle near the cutting, where a private farm road joins the public road.

Locality 4. Drumbeg pit [NS 483 880] (Sunday visits preferred). From Croftamie, the entrance to the Drumbeg pit is reached by first travelling northwards along the A809 to its junction with the A811, about 150 m south of the graceful red sandstone bridge that spans the Endrick Water. From the junction, ignoring the various side roads that lead off on the left, the A811 should be followed for about 1.6 km to the point where a narrow road, signposted 'Gartness' on the left of the A811 but leading off on the right of the A811, is reached. Follow this road for about 800 m to the entrance to Drumbeg pit, which is alongside the (signposted) entrance to Drumbeg farm. Visitors to the site should drive down into the pit to park. They must not leave their vehicles near the entrance to the site or on the access roads. Trucks must not be obstructed.

This is a working pit, in operation from Monday to Friday and on Saturday mornings. During working hours, permission to examine the faces should be sought from the site foreman, normally to be found in the office at the weighbridge. Permission to visit the pit outside working hours must be obtained in advance from John Wilson, Ardgowan Estate Office, Inverkip, telephone number 0475 521656, as agent for the owner. Neither the owner nor the operator can accept responsibility for the safety of any visitor. To comply with safety regulations, hard-hats must be worn while on the site, and working faces must not be approached closely because of the risk of their collapse. Wellington boots are

recommended as footwear.

The stratified sediments exposed in the Drumbeg pit are part of a complex of morainic and meltwater deposits that accumulated at several locations close to the southern margin of the lobe of ice that occupied the Lomond basin during the Loch Lomond Stadial (c. 11, 00–10, 000 years B.P.). The sediments exposed in the pit vary as work progresses, but thicker layers of sand and thinner layers of gravel may be seen. The sediments occasionally exhibit structures typical of glacial meltwater deposits: unconformities, top-set and fore-set bedding and cut-and-fill structures. Shell fragments are found occasionally within these deposits (see section iv of the text above).

Locality 5. Muirland School [NS 348 867]

The route from Drumbeg pit to Locality 5 takes the Quaternary geologist back to the T-junction of the A811 and A809 south of Drymen. From thence, the A811 should be followed southwestwards towards Balloch, attention being paid, on the right (western) side of the road c. 2.5 km beyond the village of Gartocharn, to the deep dry valley that extends for several hundreds of metres parallel to the road. The channel is thought to have been cut by glacial meltwaters that were flowing from approximately north to south, either sub-glacially or close to the margin of the ice lobe that occupied the Lomond basin during the Loch Lomond Stadial.

In Balloch, signposts showing the route to Luss and Crianlarich should be followed. These take the traveller, via two major roundabouts, to the new northward-leading A82 road, which should be followed for 6–7 km to a point near Duchlage Farm [NS 350 871], where care should be taken to turn left on to the old B832 road rather than the newer road a short distance north of the B832. Vehicle parking is not easy on the B832, but it may be possible near Muirland School (Locality 5, [NS 348 867]). The purpose in stopping here is to examine at close quarters the narrow sinuous ridge of gravel that occurs discontinuously near the western margin of Loch Lomond in this area. This esker, formed by the meltwaters of ice that occupied the Loch Lomond basin, is seen well as a prominent ridge a few tens of metres east of Duchlage Farm, and a similar distance SSW of Muirland School. Occasionally the stratified nature of the gravel is to be seen in small exposures.

Locality 6. Highfields Muir [NS 323 857]

About 2 km south of Muirland School, the B832 meets the B831 at a crossroads. Turning right, the B831, leading towards Glen Fruin, should be followed for c.1.5 km to the point near where a track on the left (SW) side of the road leads to Inverlauren farm and, on the right beyond a gate, a recently-metalled but non-surfaced private road leads northeastwards on to Highfields Muir (Locality 6, [NS 323 857]). There is limited parking on the NE side of the B831. The private road has been constructed on a small, but typical, end-morainic ridge, which was produced at the margin of the Loch Lomond Stadial ice lobe. The ridge extends for several kilometres to the north of the B831 as a narrow 'ribbon' oriented approximately SW-NE, parallel to the previous part of the route along the B832. In the autumn, vegetational variations make the ridge especially conspicuous and, after leaving Muirland School, its presence may be noted on this basis on the way to Highfields Muir. The approximate altitude of the ridge, at around 125 m above the present water level in Loch Lomond but at a level well below the crest of the hill that the ridge flanks, is a useful reminder that, although ice occupied the Lomond basin during the Loch Lomond Stadial, there were large areas of the surrounding higher ground that contemporaneously were ice-free. In such areas, severe frost action was in progress at that time (c. 11, 000–10, 000 years B.P.).

Locality 7 . Geilston [NS 341 777]

The best route from Highfields Muir to the next potential stop, at Geilston (Locality 7) near Cardross, is by returning on the B831 to its junction with the B832 and thereafter taking the B832 road southwards into Helensburgh. The Geilston stop is recommended to only the keenest and ablest-bodied Quaternary geologists, since the exposure at this locality has deteriorated greatly since it was described in detail by Rose (in Jardine 1980), and access to the site is not easy if the water is high. Wellingtons (or better, waders) are recommended. This, however, is one of the few localities, or perhaps the only locality, in the Glasgow district where Clyde Beds are (semi-)permanently exposed. From Helensburgh, the A814

coast road should be followed eastwards to Geilston, at the western end of the village of Cardross. As soon as the built-up area is entered a stone-built hall (resembling a church) will be seen set back about 25 m from the left (northern) side of the road. It is preferable to park vehicles in the small lay-by on the other (southern) side of the road. Very close to this parking place, the Geilston Burn flows under the A814. The site is located on the eastern bank of the Burn c.150 m south of the A814. The geologically most interesting route to the site is to walk southwards on a footpath that enters a narrow wood to the west of the bridge over the Geilston Burn. The path leads down to the low ground of the Flandrian raised beach. By skirting fields located on the sands and gravels of the raised beach it is possible to reach the western bank of the lower reaches of the Geilston Burn. A faintly-defined footpath leads northwards upstream, but at some point the burn has to be crossed to arrive at the site described in detail by Rose (in Jardine 1980, pp. 25–29). The site is best visited when vegetation is at its minimum. The Clyde Beds consist of sticky grey clays containing fragile marine fossils of bivalves (*Arctica* and *Mytilus*) and gastropods. A spade may be necessary for excavation. Lodgement till and beach gravels are also exposed.

Locality 8. 500 m east of Cardross [NS 354 767].

The final scheduled stop is located c. 500 m east of the eastern end of the village of Cardross (Locality 8). Vehicles can be parked off the A814 on the left (northern) side of the road where a farm road joins the A814 about half way along a stretch of the main road that is bordered on the left by fields backed by red sandstone cliffs. The cliffs, together with a rock platform at their foot (a platform which is now covered with stratified sand and gravel deposits), probably are the equivalents of similar features that are thought by many authors to be the products of severe shore erosion during the Loch Lomond Stadial, by combination of frost riving and marine action. An alternative suggestion is that initial formation of the cliff and rock platform pre-dated the Loch Lomond Stadial, and the sea re-occupied a former position of the marine shoreline during the Loch Lomond Stadial (cf. Jardine 1986, p.37). The sand and gravel sediments resting on the platform are thought to date from a time later than the time(s) of formation of the platform, being deposited around 7, 000–6, 000 years B.P., when the culmination of the Flandrian marine transgression again led to the former shoreline position being reoccupied by the early Holocene sea. Since then, isostatic uplift of the land has led to the sand and gravel shore-zone sediments (together with the underlying platform and adjacent cliff) being raised to their present position, a few metres above present mean sea level (equivalent to Ordnance Datum, O.D.).

Return to the starting point via Dumbarton and the A82, which passes through Anniesland Cross. Note at Dumbarton that, whereas the River Leven now flows on the western side of Dumbarton Rock, at some (unknown) time during its Quaternary history it flowed on the eastern side of the Rock; the buried channel (to –68 m O.D. or lower, Jardine 1986, p.31) is located on that side.

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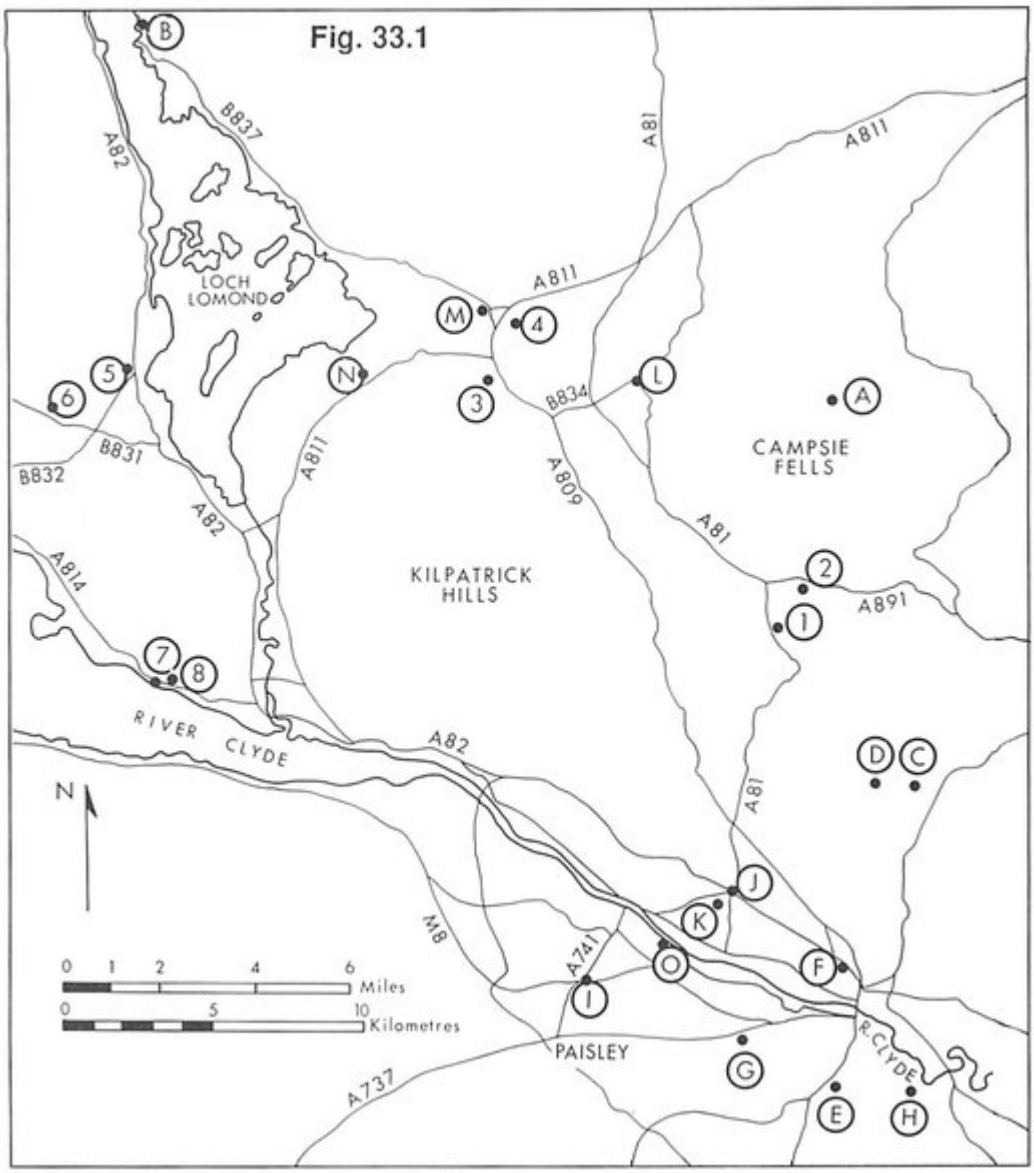
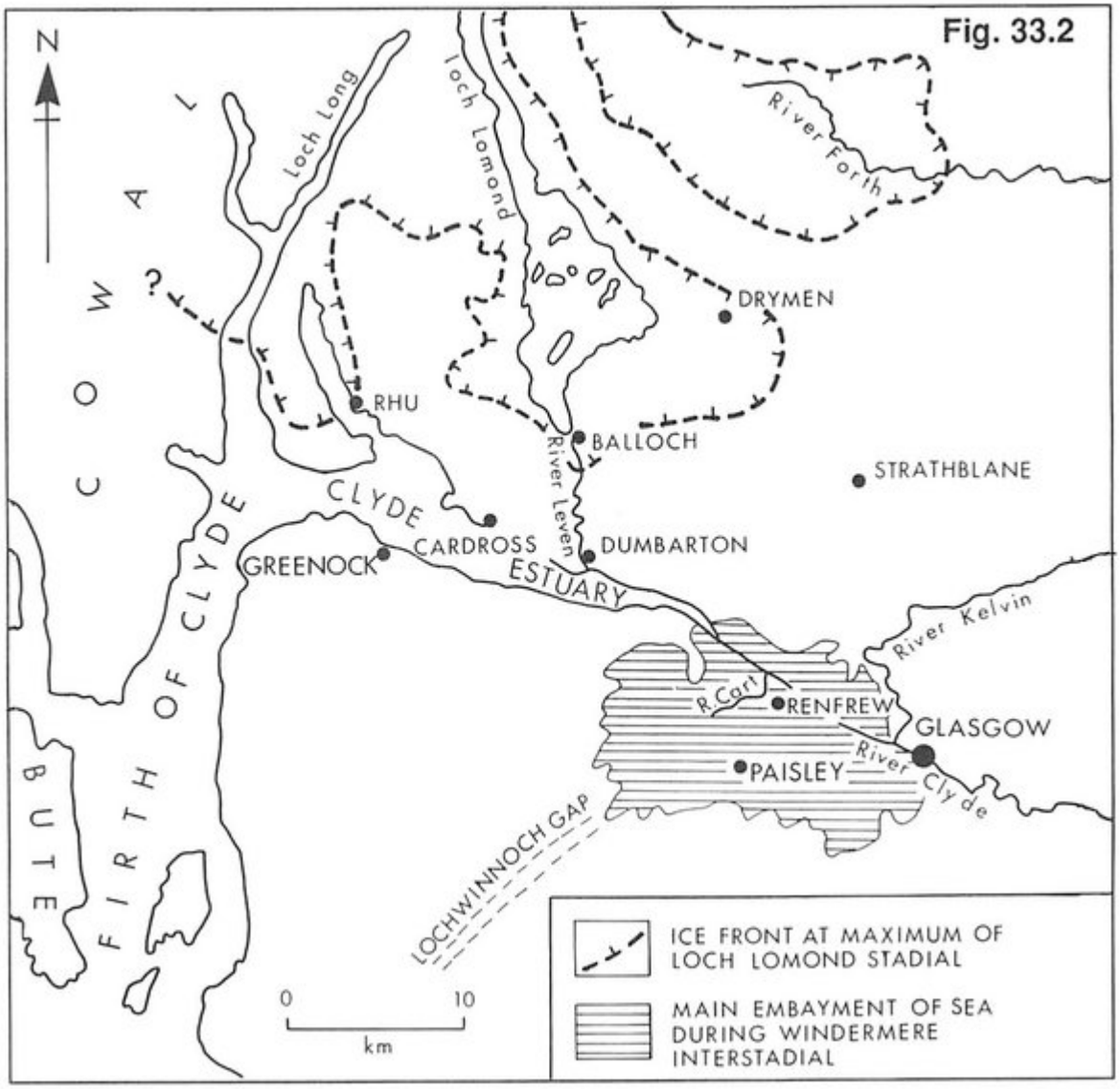
Table 33.1

Age/Stage	Minor Climatic Divisions	Ice Advances	Text para.	Deposits of the Glasgow District
FLANDRIAN			v	Lower group raised marine/estuarine deposits and shore-lines bordering the River Clyde and its estuary
	10,000 radiocarbon years before present			
DEVENSIAN (cold) Last Glaciation	Loch Lomond Stadial	Loch Lomond Readvance	iv	End-morainic deposits, Loch Lomond and Lake of Menteith areas
	c. 11,000 years B.P.			
	Windermere Interstadial		iii	Upper group of marine/estuarine deposits and shore-lines:Paisley, Renfrew, western and central Glasgow
	c. 13,000 years B.P.			
	Dimlington Stadial	Main Devensian ice advance (c. 25,000 to 14,000 years B.P.)	ii	Tills (boulder clays) of Glasgow and environs
	Un-named and undefined stadials and interstadials		i	sands, gravels and tills, of uncertain ages, filling the buried channels underlying the Rivers Clyde, Cart and Leven.

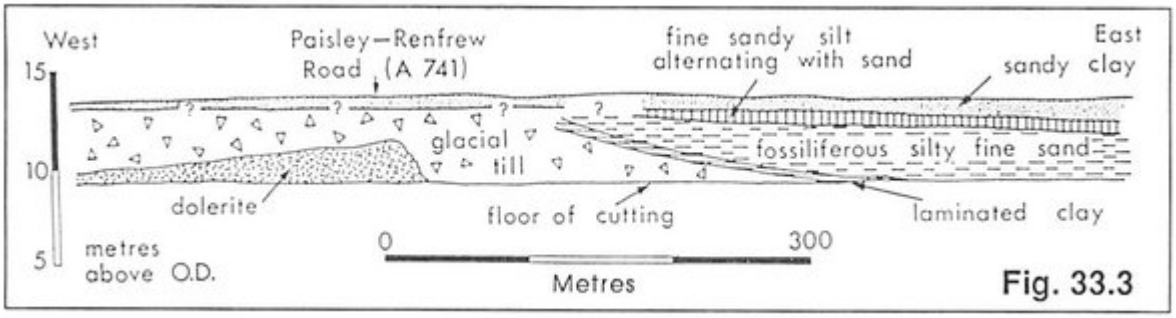
(Table 33.1) Summary of the sequence of events in the Glasgow district during the Quaternary Period.



(Figure 33.1) Location map for Excursion 33. The localities denoted by numbers are those included in the excursion. Other localities mentioned in the text are denoted by capital letters.



(Figure 33.2) Map of the area to the NW of Glasgow, showing locations mentioned in the text of marine deposits of the Windermere Interstadial and on the Loch Lomond Stadial; adapted from Jardine 1986, figure 3.



(Figure 33.3) Composite W-E section formerly exposed at Junction 27 on the M8 motorway near Paisley, showing a roche moutonnee (of dolerite) overlain by till which, in turn, is overlain by laminated clay and fossiliferous marine sediments (Clyde Beds) deposited during the Windermere Interstadial. The overlying layer of fine sandy silt alternating with sand probably represents land conditions. The conditions under which the uppermost bed, of sandy clay, accumulated are uncertain. Adapted from Aspen & Jardine 1968, Figure 1.