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QUATERNARY GLACIATION IN IRELAND

By F. M. Syngé

Introduction.

At Easter 1979 the Annual Field Meeting of the Quaternary Research Association was held in Ireland. It therefore seemed an appropriate time to give a brief review of the Quaternary of that country. With this aim in mind the following note has been included in the Quaternary Newsletter. It outlines views that are both well established and recently developed so that it may provide a background to those recently introduced to the problems of the Irish Quaternary and a stimulus to those involved in Irish Quaternary Research.

The whole of Ireland, with the possible exception of the highest mountains in the south-west part of the island, has been covered by an ice-sheet at least once during the Quaternary. This is testified by the presence of glacial polishing or erosion with the production of grooves or striations on bedrock surfaces and by the presence of glacial drift in all areas. The drifts include all types of material laid down directly by ice, or by meltwaters issuing from the ice, as well as glaciallacustrine and glacialmarine silts and clays.

The oldest recognizable sheet of glacial deposits is also the most extensive one, and occurs at the surface across the southern parts of the island between Cork and the central portion of County Wexford (Fig.1). Younger and less extensive spreads of drift overlies the older sheet in the central and northern parts of the island, and also in the South-west where they occur in association with an independent focus in the mountains of Kerry and West Cork.

On the basis of freshness of drift topography the limits of the last major ice-sheet have long been recognized across the southern part of Ireland (Carvill Lewis, 1894; Charlesworth, 1928). Although the original southern limit of this glacial episode, termed the South Ireland End-Moraine by Charlesworth, has been somewhat modified by more recent work, its general position remains unchanged. Evidence that the continuation of this limit from Wexford hugs the present coastline as far west as Cork Harbour suggests the exciting possibility that an enormous lobe of ice fanned south through the St. George's Channel at that time and expanded into the Celtic Sea. This idea, which will be discussed later, must be regarded as highly controversial.

The fresh drifts just mentioned are generally regarded as the equivalent of the Würm/Weichsel/Wisconsin Glaciation. These are termed Midlandian in Ireland, and correspond to the drifts of the Devensian Glacial Stage in England (Mitchell et al. 1973). However, as no reliable chrono-stratigraphic sequence can be constructed on present evidence, it is not yet possible to determine the age of the earlier drift sheet, located in south Ireland. These deposits represent the Munsterian Glacial Stage and equate either with the Riss/Saale/Illinoian (=Wolstonian in England) Glaciation or with the Mindel/Elster/Kansan (=Anglian in England) Glaciation, or even with an early phase of the Midlandian Glacial Stage.

At eight separate localities similar organic beds have been found with remains of temperate woodland dominated by rhododendron (Rhododendron ponticum) and silver fir (Abies). All these sites occur in the south or the western parts of Ireland (Mitchell, 1976); recently, however, organic beds with a similar flora have been found near Benburb, not far from Lough Neagh. These interglacial beds have been grouped together in the Gortian warm stage, named from the type site in County Clare where they outcrop on a river bank beneath Midlandian drift. Their stratigraphic relationship to the Munsterian is obscure. Originally they were thought to underlie a Munsterian till *in situ* (Jessen et al., 1959) as, on palaeoecological grounds, they were correlated with the European Holstein (Watts, 1970) which is the interglacial that separates the Elster and Saale Glaciations.

If the above correlation stands, we should expect to find a number of localities with deposits belonging to the Last or Eemian interglacial (between Saale and Weichsel) at a stratigraphically high level. Yet, in spite of an extensive search, no definite deposits from the last warm stage have been positively identified. True enough, an Eemian age has been proposed for the Shortalstown deposit, an estuarine marine sand intercalated between an upper and lower bed of Irish Sea till, containing much pollen of oak (Quercus), pine (Pinus), birch (Betula), and some of elm (Ulmus), with small amounts of ivy (Hedera), alder (Alnus), Hazel (Corylus) and spruce (Picea). This deposit has been differentiated from other Gortian beds by the presence of elm (Colhoun & Mitchell, 1971). But otherwise this deposit could just as well be Gortian (Warren, 1979).

The general absence of any interglacial deposits younger than Gortian has given rise to the idea that the Gort interglacial itself is Eemian in age (Warren, 1979). The differences in flora between Ireland, England and the Continent could be explained by the much more westerly location of the former. Ireland would likely lie in a completely different climatic zone from territories further to the east, which would be clearly expressed in its flora.

If the Gortian is Eemian in age, then all overlying drifts are Weichsel (Midlandian) in age. But the suggestion that the Munsterian drifts are also Weichsel in age seems questionable. Such drifts 'appear' to overlie a marine raised beach (the Courtmacsherry Beach) which stands at 6-8 m m.s.l. along the south coast of Ireland, identical in every way to the Eemian beach of the coasts of south England and northern France. In Ireland the beach has never been observed beneath Munsterian till that, with confidence, can be considered in situ. In every case the overlying 'till' shows all the characteristics of boulder-clay that has been redeposited from higher levels by solifluction or by cliff falls (Synge, 1977). Also the beach gravels appear to have been derived from till similar in composition to that of the 'overlying' Bannow drift in many places in South Wexford. This suggests that the beach post-dates the till and not vice-versa.

Three different interpretations of the drift succession in the south of Ireland are current to-day; these are compared in Table 1. The third column of this table presents the results of a recent revision of the succession in the light of new evidence. In this interpretation the Munsterian drifts are regarded as being much older than hitherto shown. Also the second last glacial stage is shown to be much smaller in extent than the Midlandian. Recent evidence (Synge, 1977) also suggests that only one major glacial stage was dominated by a large ice stream passing down the Irish Sea from the Clyde, in Scotland. This event occurred during the earlier part of the Last or Midlandian Cold Stage.

Table 1. The glacial succession in South Ireland.

STAGES	NORTH EUROPEAN SUCCESSION	GLACIAL SUCCESSION IN SOUTH IRELAND		
		Mitchell et al. 1973	Warren 1979	Based partly on Syge 1977
<u>COLD</u>	<u>WEICHSEL</u>	<u>MIDLANDIAN</u> (4) Advance from Midlands (Blessington Moraine)	<u>MIDLANDIAN</u>	<u>MIDLANDIAN</u> (4) <u>Blessington</u> Advance from the Midlands ----- Interstadial -----
		(3) Advance from Irish Sea (Shortalstown Upper Shelly Till)	<u>MUNSTERIAN</u>	(3) <u>Hacketstown</u> Advance from the Midlands and Glenealy Advance from Irish Sea
<u>Warm</u>	<u>Eem</u>	<u>Shortalstown</u>	<u>Gortian</u> Courtmac- sherry Beach	Courtmacsherry Beach
<u>COLD</u>	<u>SAALE</u>	<u>MUNSTERIAN</u> (2) Advance from Midlands (Bannow Till) (1) Advance from Irish Sea (Ballycroneen/Kilmore Quay Shelly Tills)	Baggotstown Till	<u>CONNACHTIAN</u> (2) <u>Slieve Bloom</u> Advance from Connemara
<u>Warm</u>	<u>Holstein</u>	<u>Gortian</u> Courtmacsherry Beach	XXXXXXXX	<u>Gortian</u>
<u>COLD</u>	<u>ELSTER</u>	(unnamed)	XXXXXXXX	<u>MUNSTERIAN</u> (1) <u>Bannow/Clogga</u> Advance from the Midlands

For simplicity, the relation between glacial advances of the main ice sheet and those from local centres is not indicated. Such relationships will be discussed later.

THE OLDER DRIFTS.

Outside the limits of the Midlandian ice sheet and the contemporaneous ice masses centred round the South West and the Wicklow Mountains, a dissected sheet of older drift extends across Munster and south Leinster. This drift sheet is Munsterian in age and would appear to constitute the oldest glacial deposit to be found in Ireland.

Further north the somewhat hypothetical Connachtian drift buried beneath thick accumulations of Midlandian drift, is also classed with the 'Older Drifts'. This drift appears to overlies the Munsterian deposits as a surface accumulation between Mallow and Kerry Head. Apart from North West Mayo this is the only part of Ireland where probable Connachtian drift can be seen at the surface.

Munsterian.

The area within which drifts of Midlandian age are exposed at the surface is roughly 7,600 sq. km, enclosed by a line running Rathluirc - Clonmel - Gorey - Hook Head - Dungarvan - Ballycotton - Millstreet - Rathluirc. Throughout this area no fresh constructional glacial landforms are to be found; instead even gentle slopes have been smoothed by widespread solifluction or the mass movement of drift and shattered rock debris. On more level ground the upper few metres of drift have been churned up by frost action. And in many places the sites of pingos or 'frost-boils' are evident.

The widespread development of periglacial landforms is such as would be expected when the northern and central parts of Ireland were subsequently covered by an ice sheet. It is therefore not surprising that moraines can no longer be recognized by their surface form but only as thick accumulations of bedded sands, gravels and till layers; but piles of well-sorted sand and gravel, by virtue of their permeability, sometimes survive as hillocks. These, however, are but the eroded remnants of larger features, either esker ridges or other fluvioglacial accumulations.

Another feature of the Munsterian drift surface is the complete absence of surface boulders or perched blocks. These have been removed by frost shattering and weathering; those boulders which can be seen in many places have been dug out of ditches or other excavations because at depth the normal blocky nature of the drift still

survives. Thick ground moraine only survives in valley bottoms and other depressions.

There is little doubt that the Munsterian ice was thick and gave rise to a powerful radial movement across the island from an ice shed stretching from Mayo to Tyrone. This is seen by the striae pattern in South Wicklow which maintains a perfectly uniform NW-SE orientation across a pronounced hilly landscape. As the ice travelled across the Leinster Granite outcrop, boulders of this rock were picked up and transported south-east across the present coast. Originally this movement was attributed to local glaciers from the Wicklow Mountains and termed the Clogga glaciation from the type site just south of Arklow (Farrington, 1954). But the presence of weathered pebbles of chert and silicified limestone in the drift right across this watershed to within 20 km of the coast show that a major ice sheet and not local glaciers were responsible.

A similar pattern is shown by the Bannow till of South Wexford; limestone boulders were transported SSE from the Barrow valley at Goresbridge (S 680 536) to the south coast, which is a distance of 50 km (Culleton, 1977). The calcareous nature of the subsoil in South Wexford was previously attributed to the passage of ice SE from the Irish Sea to Waterford Harbour. However, there is no evidence of an Irish Sea glacier during the Munsterian.

Further west the ice flowed due south. In county Waterford it deposited the Ballyvoyle till, while north of Cork Harbour at Watergrass-hill (W 767 845) blocks of granite from Connemara in county Galway show that the ice axis extended far to the west.

Recent evidence suggests that the Munsterian glaciation was associated with the first glacial invasion to the south of Ireland. In South Wicklow, near Tinahely (T 019 735), a conglomerate of possible Tertiary age, is associated with an erosion surface at 210-240 m and directly underlies this drift. Also striking granitic tors appear only at high altitudes above the drift limit encircling the Blackstair Mountains at 430 m. As this mountain range has the character of a nunatak and these tors appear to be preglacial Tertiary landforms, the suggestion that the drift represents the first major glacial episode appears well-founded.

Connachtian.

Boulders of Connemara granite have been found scattered throughout the Midlands as far east as the Slieve Bloom Hills (Fig. 1). Within the valleys of this isolated highland mass of Old Red Sandstone there is a concentration of these granite boulders. As no similar

boulders have been recorded any further to the east it is thought that a major ice stream emanating from Connemara terminated in the vicinity. For this reason the name 'Connachtian' has been given to this glacial event by the writer.

Meltwaters coursing from the eastern margins of the ice sheet towards the east and south coast were probably responsible for excavating the narrow rock-cut valley gorges now partially reoccupied by the present rivers Boyne, Liffey, Slaney, Barrow, Nore, Suir, Blackwater, Lee, and Bandon. These gorge-valleys have all been excavated down to about -30 m. s.l. at the mouths of the present rivers. Within the subsequent Midlandian glacial limit the valleys were completely filled with till and gravel and are only partially exhumed to-day by river erosion.

Curiously enough similarly buried valley gorges are absent from the west coast. Only the Shannon estuary occupies a series of overdeepened troughs. But these seem much more akin to fault line troughs that have been glacially overdeepened, than to features resulting from fluvial erosion. Also it may be noted that this estuary lies along a major geological structure that parallels other E-W fault zones that can be recognized in western Connacht, such as Galway Bay, Killary Harbour, Clew Bay, and the north coast of Mayo.

The absence of buried valley gorges in the West may be attributed to the fact that this part of Ireland lay beneath an ice cap which protected the rock surface from the effects of meltwater at the very time when global (eustatic) sea level was low.

Between the limits of the subsequent Midlandian ice masses in Munster, a drift covered corridor of probable Connachtian age, extends between Mallow and the western ocean. This area is 2,200 sq. km in extent and includes the lowlands of South West Clare, North Kerry, the Dingle Peninsula, North West Iveragh and the Upper Carboniferous Sandstone plateau lands of South West Limerick. The drift cover is fairly featureless although denuded eskers and moraines occur on the plains of North Kerry and lateral moraine terraces border the highlands of the Dingle Peninsula (Lewis, 1974). In the Blackwater the zone of the terminal moraine between Mallow and Millstreet is defined by a series of large gravel kames.

The direction of ice movement as shown by striae is E-W, which is quite different from the older movements (N-S) and the younger ones (NE-SW). Previously these drifts of the 'Munster Corridor' were regarded as Munsterian in age, but no explanation was given for the curious E-W movement. Was the normal southerly flow obstructed by Kerry-Cork ice so that the ice stream was forced to turn abruptly to the west? (Finch & Synge, 1966).

A more plausible explanation would be to relate these movements to a completely different glacial event with ice moving east, not west, from an ice shed running N-S across the mouth of the Shannon estuary (Fig. 1). This would explain the relative absence of boulders of Connemara granite and the abundance of limestone erratics in N. Kerry. This limestone cannot be attributed to the south-westerly advance of ice from the Fergus basin, because stone counts from the drift show a very rapid fall off of limestone content across the Upper Carboniferous Sandstones. A more suitable source would be limestone lying on the seabed between Loop Head and Ballybunnion; this would only have to be carried east for a short distance to overlie the shales and sandstones that underlie the northernmost lowlands of county Kerry.

Further south, the local ice cap that covered South Kerry and West Cork at this time, sent a stream of ice NW across Iveragh to the Dingle Peninsula. Boulders of Inch Conglomerate were transported across the peninsula and then deflected to the west by the presence of ice in Tralee Bay (DuNoyer, 1863); this evidence contradicts the idea that local ice flowing NE out of the Brandon valley was deflected eastwards towards Tralee (Lewis, 1974).

The survival of Gortian interglacial plant beds near the surface throughout the central and northern parts of Ireland can be attributed to their location close to, or beneath, the axis of the former ice shed; that is, in a zone where ice erosion would be minimal. By this definition, the ice axis passed by the Gortian beds at Fenit (Mitchell, 1970) to Castlebar (Synge, 1968) and Tyrone (Fig. 1).

THE YOUNGER DRIFTS

All the fresh constructional landforms composed of glacial material fall within the Last or Midlandian Cold Stage. But the earlier glacial advances of this stage are typified by denuded landforms because the period of most intense periglacial weathering occurred at a later date. Because of this, the separation between Younger and Older Drifts on purely morphological grounds is not adequate.

Most, but not all, investigators have placed the southern limit of the Last Ice Sheet at the southern edge of the great limestone plain of the Midlands (Charlesworth, 1928; Farrington, 1954; Synge, 1970); but others would regard Ireland as being more extensively covered by ice (Bowen, 1973; Warren, 1979).

Midlandian

The history of the Last Glaciation in Ireland is much clearer than that of the earlier ones (Fig. 2). But even within this single cold

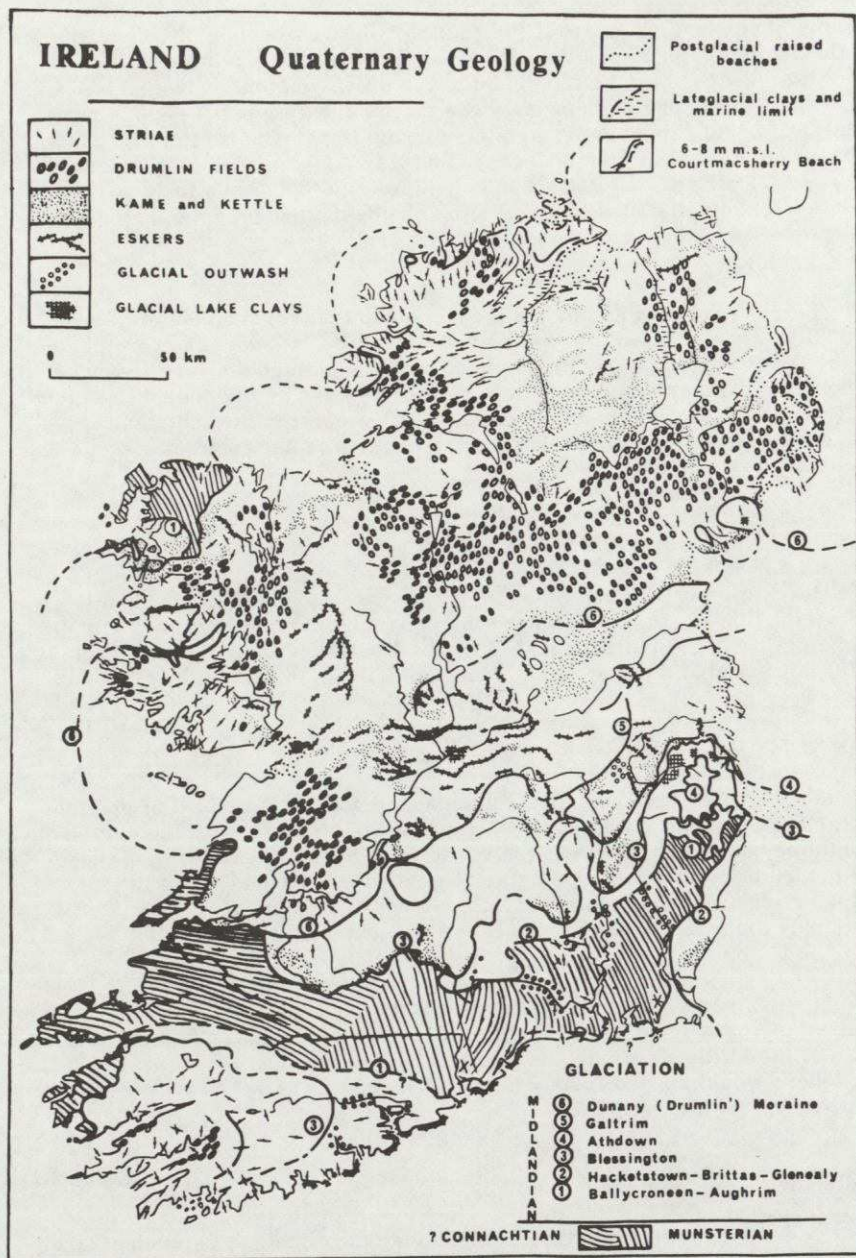


Figure 2. The Quaternary Geology of Ireland.

stage a great many different glacial events can be identified (Table 2). The presence of organic beds underlying Midlandian drift in county Fermanagh sets a maximal date for the build up of the ice sheet. Radiometric dating of these beds give 41,500 years B.P. (Hollymount Interstadial) and 30,500 years B.P. (Derryvree Interstadial). It is evident that the greatest expansion of the ice took place after 30,500 years B.P. (Colhoun *et al.*, 1972). But it is not known if there had been any extensive ice sheet earlier, during the middle and early parts of the last cold stage (Mitchell, 1976).

Initially a great glacier passed down the Irish Sea from the Clyde (Tullyallen, Ballycroneen, Kilmore Quay and Glenealy phases), carrying a suite of Scottish erratics including Ailsa Craig microgranite. There is a suggestion that sea level was still high as the ice advanced, depressing the rock basement isostatically under its own weight. This progressive deepening is indicated by the presence *in situ* of a deep cold water marine fauna to flourish in the Boyne estuary at Mell (0 074 764) near Drogheda (Colhoun & McCabe, 1973). The considerable height of these marine beds at 29-40 m O.D. has given rise to the suggestion that they were transported inland as a frozen erratic by the Irish Sea glacier. However, the height of this deposit lies within the range of expected isostatic recovery (Synge, 1977). Also the discovery of other marine silts, apparently *in situ*, at the base of the Irish Sea till sequence along the east coast of Wexford adds weight to the arguments in favour of the presence of marine waters during this ice advance (Huddart, 1977).

At the same time the inland ice was in contact with the Irish Sea glacier in county Louth, as can be seen by the interbedding of the two tills at Drogheda (McCabe, 1973). But to the south the two ice bodies were quite separate. Irish Sea extended as much as 25 km west of the present coastline to the Meath lowlands. As the ice advanced south a large lake was impounded in the Liffey basin and drained south by ice-marginal drainage through the rock gorges of the Scalp, Glen of the Downs and Deputy's Pass. At the same time a swollen valley glaciation engulfed the Wicklow Mountains. During this Aughrim phase an Avonbeg glacier flowed south to Aughrim, and the Avonmore glacier reached Woodenbridge (Fig. 3).

Eventually the Irish Sea glacier reached the St. George's Channel and probably commenced to deposit morainic debris on the sea floor between Ireland and Wales. Traditionally this channel has always been considered to mark the terminus of the ice during the last cold stage. Many would see the discovery of great thicknesses of drift on the sea floor as confirmation of this idea (Garrard, 1977). However, this does not disprove the evidence suggesting that the ice did advance considerably further, once the possibility of shelf ice is admitted. The bulk of the glacial load would be deposited in the Channel in the zone where the glacier snout would be just starting to float. But further out

¹⁴ C Age B.P.	Limits of <u>INLAND ICE</u> in <u>East Leinster</u>	<u>IRISH SEA ICE</u> in <u>East Leinster</u>	<u>WICKLOW ICE</u>	<u>KERRY-CORK ICE</u> in <u>Munster</u>
10000 - 11000	----	----	<u>Nahanagan</u> (Cirques)	(Cirques)
11000 - 11500	Interstadial			
	<u>Kilsaran</u> (limit of drumlins) Ice from NW	----	(Cirques) ?	Drumlin substage in Bantry Bay Ice from SW
	<u>Dunany</u> , Ice from NW	----		
	----	<u>Togher</u> , Ice from NE		
18000 - 19000	Interstadial			
	<u>Galtrim</u> , Ice from NW	----		
	<u>Colbinstown</u> , Ice from NW	----		
	<u>Blessington</u> , Ice from NW	----	<u>Atthdown</u>	<u>Killumney</u> , Ice from W
	Interstadial weathering			
22000	<u>Hacketstown</u> Ice from NW	<u>Glenealy & Screen</u> Ice from NE	<u>Brittas</u>	<u>Cloyne</u> , Ice from W
	Interstadial - Marked periglacial weathering			
	----	<u>Kilmore Quay</u> , Ice from NE	----	<u>Garryvoe</u> , Ice from W <u>Ballycroneen</u> , Shelf Ice from E
30000	<u>Drogheda</u> , Ice from NW	<u>Tullyallen</u> , Ice from NE	<u>Aughrim</u>	
30500 41500	Derryvree Interstadial Hollymount Interstadial			

Table 2. The Midlandian Succession.

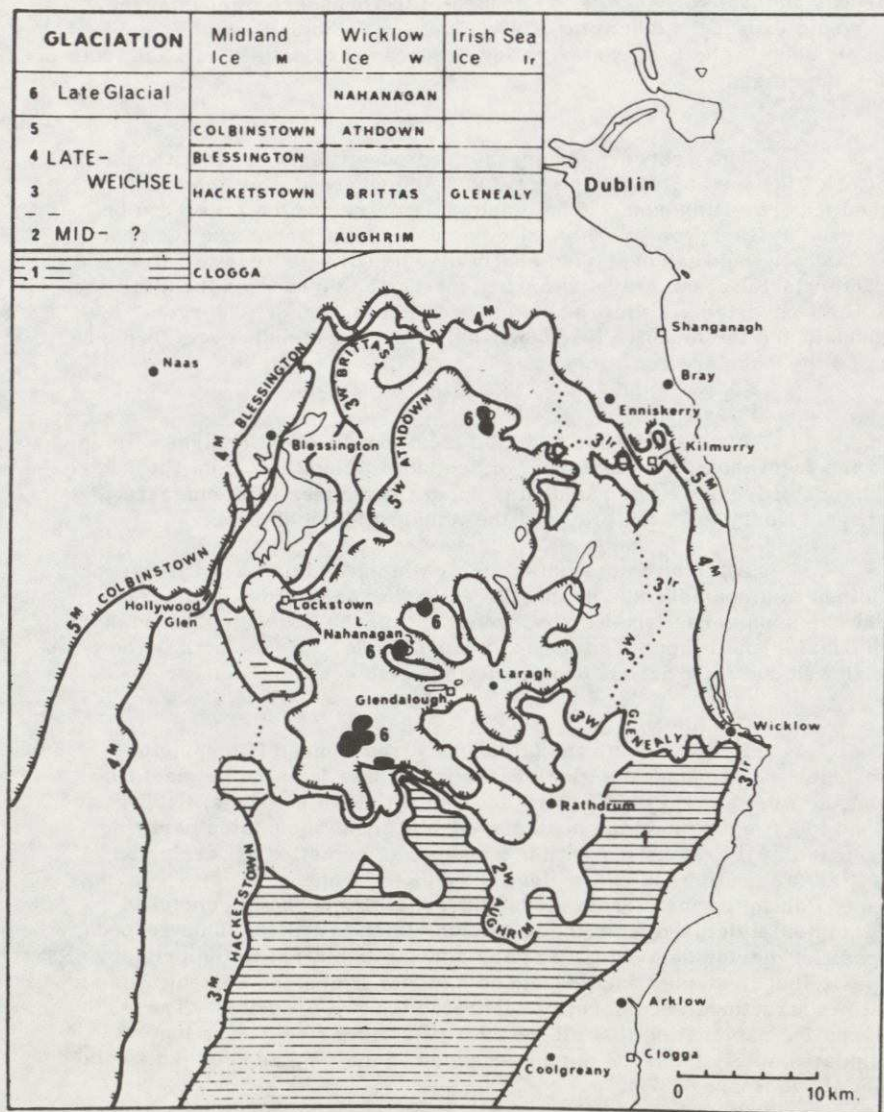


Figure 3. The main glacial advance limits of south-east Leinster. The shaded area represents terrain that may have been unglaciated during the last (Midlandian) glaciation.

the glacier being composed of shelf ice would only be capable of eroding the shallow inshore zone, where it would thrust shelly clays on to the coast. This explains why the coastal till is only restricted to a very narrow zone along the top of the coastal cliffs between Waterford Harbour and Ballycroneen. Because of the presence of coastal ice one would expect the damming of river valleys. Such damming is clearly seen in the Blackwater valley in terraces of deltaic outwash from the inland ice.

The westward progress of this shelf ice was arrested east of Cork Harbour at Ballycroneen (W 906 613) where it met local land-based ice travelling east. The maximum advance of the latter can be observed at Garryvoe (W 998 672) as a rubbly local sandstone till resting on shelly outwash overlying shelly marine till. The latter sits on an interglacial beach gravel (Farrington, 1954). When sea level fell the ice limit reverted once more to a position across the St. George's Channel, and the massive kame-and-kettle Screen Moraine was formed behind the Rosslare end-moraine.

At this time ice radiated from six different centres - Irish Sea ice from the S.W. Highlands of Scotland; inland ice from the Midlands of Ireland; and radial flow from the centres in Connemara, Donegal, Kerry - West Cork, and the Wicklow Mountains.

After an interstadial during which the Irish Sea tills were oxidised to a considerable depth, the extension north-eastwards of the Irish ice shed across the North Channel cut off the source of the Irish Sea Glacier and it ceased to play a dominant role. Henceforth Clyde ice flowed due west across Kintyre to the north coast of Donegal.

Further south the Midland ice readvanced (Blessington substage) and impounded a glacial lake which was fed also by glaciers from the west side of the Wicklow ice cap (Athdown substage). The inland ice swept around the northern edge of these mountains carrying quantities of limestone across the Palaeozoic formations (Farrington, 1944) as far south as Wicklow Head (Davies & Stephens, 1978). In county Dublin the ice stream moved SE gradually becoming enriched with material derived from the underlying Irish Sea till. This secondary deposit of marine derived till is very similar in matrix to the primary deposit, but is stonier and possesses a higher limestone content; also a distinct structural unconformity separates the two deposits. The alternative explanation that all coastal tills of marine derivation originated solely from ice moving onshore to the SW has been put forward (McCabe & Hoare, 1978).

Further west the outer limit of the Midlandian glaciation becomes younger in age owing to the progressive migration westwards of the axis of the ice shed. In south Limerick the limit is as young as the

Blessington substage and is clearly displayed at Ballylanders. Here, both the landforms and the drift material indicate a very abrupt limit (Fig. 1). The greater weathering of the older drift to the south, of Munsterian age, has resulted in the widespread disappearance of limestone erratics.

After the ice margin had receded from the highlands in Wicklow retreat appears to have been rapid. The lobe of ice that had protruded into the Irish Sea basin eventually disappeared as sea level rose and flooded the depressed crust that had not yet recovered from ice loading. This rapid retreat was checked by a very significant readvance which gave rise to the formation of the drumlins and embraces the three substages of Togher, Dunany, and Kilsaran (McCabe, 1973). During this readvance the till was piled up in the form of elongate hillocks or drumlins and moulded by the moving ice. Because of their mode of formation they are good indicators of direction of ice movement. Eskers, on the other hand, do not relate solely to this readvance, but were deposited during the decay of the ice as delta-like masses of sand and gravel near the mouths of subglacial rivers. They grew year by year in length as they extended upstream to keep pace with the receding ice border.

During the Drumlin Substage the ice shed had shifted much further to the west to become the outermost Midlandian limit in west Clare. Here both drumlins and striae show that the ice moved SW and W, and also S to fan out to south of the Shannon estuary. But in south Mayo complex movements resulted from the interaction between ice flowing north from the Connemara centre, and west into Clew Bay from the main inland ice.

But eskers of east Mayo and north-east Galway show that the waning ice mass possessed a northward and NE flow pattern as the margins shrank back to the Connemara highlands. But the main ice shed extended north-east from Castlerea to Lough Neagh, from which the ice streamed SE to Dundalk Bay and Strangford Lough and NW by Lower Lough Erne and round to the SW in Donegal Bay under the influence of the local North West Ice Cap. Ice also flowed N from the Lough Neagh basin down the Bann valley and along the Main to Armoy where a slightly later advance of Scottish ice from NE truncated the drumlins (Stephens *et al.*, 1975).

The final dissolution of the Irish ice sheet took place in Tyrone where the greater part of the county is covered by a chaotic mass of gravel hillocks and kettle holes which form a typical 'dead-ice' landscape.

Cold conditions returned between 11,000 and 10,000 years B.P.

and small glaciers reappeared in the mountain cirques of Kerry, Wicklow, Mayo and Donegal, and other highland areas. But the amount of ice involved was very limited and no extensive glaciers were formed during this Nahanagan substage.

Conclusion

This account gives the general succession of glacial events and ice movements that are recognized in Ireland. In places the direction of glacial movement are clear, notably Wicklow, Kerry, Connemara, Donegal and east Ulster. But in other areas the pattern is far from simple, particularly beneath the migrating ice sheds in various parts of the Midlands. The simple SE or NW pattern does not apply in these areas.

Interaction between the Connemara ice mass and the main ice sheet were particularly complex. According to the pattern of eskers and the few striae recorded, the ice mass in the central part of the Midlands resulted in an ice flow due east to the Bog of Allen. Yet when the ice margin lay in the vicinity of Galway a movement to the NE was apparent. Further north, it is somewhat of a mystery to relate flowage NNE in Lough Mask to one SW into Clew Bay and the valleys of South West Mayo.

Problems such as these may be resolved eventually by the identification of erratics with their source and the relating of stone counts to particular geological formations.

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AN EARLY DEVENSIAN GLACIATION IN EASTERN ENGLAND?

By A. Straw

By contrast with the Vale of York, the maximum limit reached by Devensian ice inland of the coast between the North York Moors and Norfolk is reasonably well defined. A major issue, however, along the east coast is the extent of Late Devensian ice, and if raising this as an issue evokes some surprise, then one of my points has already been made.

It is currently the fashion to ascribe Devensian glacial deposits in Britain to the Late Devensian (Shotton, 1977; Shotton et al., 1977) and it may well be that west of the Pennines and in the north-west Midlands Late Devensian ice was the most extensive and was largely successful in obliterating earlier Devensian materials. However, it is believed that this was not necessarily the case in eastern England, and in spite of the recent paper by Madgett and Catt (1978), some major questions still need to be explained before we can accept that all Devensian glacial features and sediments in this area were created between about 19,000 and 15,000 years B.P.

In this note I wish to elaborate two proposals - first that two discrete stages of Devensian glaciation can be recognized in eastern England, and second that the earlier and more extensive of these was probably Early Devensian.

Two glacial stages

In east Lincolnshire two stages are clearly defined and have been described elsewhere (Straw, 1957, 1958, 1961). At its maximum extent Devensian ice penetrated the Humber gap to the Horkstow moraine, reached high onto the Lincolnshire Wolds and entered the Fen basin as far as the Stickney and Heacham moraines. In the second stage, although ice rose again onto the central part of the Lincolnshire Wolds, it failed to reach both north Norfolk and the Humber gap, terminating at the Hogsthorpe and Killingholme moraines respectively. This interpretation has been criticized for having a geomorphological basis, but the point has been overlooked that the geomorphological evidence, fascinating in itself, merely reflects a geological situation revealed in field mapping of drifts and examination of some hundreds of borehole logs, many more than appear in the Old Series Geological Memoirs. In a recent paper, Madgett and Catt (1978) have carried out careful mineralogical studies of Holderness and Lincolnshire tills, conclude that Drab-like assemblages of resistant heavy minerals characterize the tills from Holderness to Norfolk, and deny the existence of two stages of glaciation in Lincolnshire. I have raised objections to some of their conclusions in the discussion to their paper, and I would only stress here that petrological techniques can only complement, not replace, traditional geological and geomorphological ones, and that all types of evidence should be carefully assessed to gain a reasoned interpretation.

The two-stage model is not restricted to Lincolnshire. Numerous workers have drawn attention to the landscape contrasts east and west of the River Hull in Holderness. Madgett and Catt dismiss these real morphological contrasts as having no significance in terms of multiple glaciation, but others equally will lack confidence in their explanation of them as the local superimposition of one layer of glacial sediment partly over another by shearing within a single icesheet. Why should melt-out from the sheared ice be so different from the unsheared (presumably west of the Hull)? Carruthers' model of a tiered ice sheet gains no greater glaciological credibility by being reduced from four layers to two, and it does not answer the question, if Purple till ice was rafted wholly on top of the Drab till ice south from Teesdale, whence derives its contained chalk and flint?

The two stages recur around the eastern end of the Vale of Pickering. The Cayton - Speeton moraine, which closes the eastern end of the Vale has a complex form similar to eastern Holderness and the Hogsthorpe moraine. At this stage, north from Cayton, ice covering the Scarborough area pressed against the Corallian scarp of Irton and Silpho Moors, with meltwaters draining south through Mere and Forge

valleys to build the Seamer and East Ayton gravels into a Lake Pickering that from strand-line evidence in the Staxton area had a water level at about 45 m O.D. However, 9 km west of Cayton, the striking kame terrace and gravel moraine around Wykeham marks an earlier advance into the Vale contemporaneous with a proglacial lake at 70 m O.D. As discussed elsewhere (Straw, 1979) Forge Valley meltwater channel was probably initiated in this stage, but enlarged to its present form during the Cayton stage. North of Scarborough the second stage ice seems to have overlapped the limit of the earlier stage.

Turning briefly to the Vale of York, ice standing at the York - Escrick moraines has generally been associated with initiation of the Malton gorge of the River Derwent, but I would suggest that this is not the case. The York - Escrick moraines do not rise onto the Howardian Hills, yet the gorge does not cross these hills at their lowest point. An ice advance earlier and more extensive than the York - Escrick stage is indicated, to which the Linton - Sutton gravels on the west side of the Vale of York may conveniently be related. Such an advance beyond the Escrick moraine is clearly envisaged by Gaunt (1976), who however carries it as far south as the latitude of Doncaster. Such a limit however raises far more difficulties than it solves and it is more likely that the ice never reached further south than Selby.

This summary and selective review is perhaps sufficient to indicate that a two-fold Devensian glaciation model has some substance, and concerned persons should examine carefully some of the older literature before accepting uncritically the conclusions of the newer.

Age of the Glaciations

There seems little doubt that the second stage glaciation took place within the Late Devensian. The east Holderness tills are bracketed between about 18,000 and 13,000 years B.P. on ^{14}C dates, which would also apply by extension to the Hogsthorpe - Killingholme, Cayton - Speeton, and York - Escrick moraines. But are the two dates on the Dimlington mosses so reliable, or alternatively, are we so certain that we can accept without question that there are no Devensian tills older than 18,000 years B.P. anywhere else in Britain? I doubt it, for there are circumstances in some parts of eastern England (and perhaps elsewhere?) that do not fit happily into the fashionable framework.

In east Lincolnshire, outwash gravel trains lie immediately west of both the Hogsthorpe and Killingholme moraines. Detailed field mapping reveals close relationships to meltwater channel systems in the Wolds (Straw, 1961), nowhere are they overlain by weathered tills as Madgett and Catt would claim, but they contain enough derived molluscan shells to be referred to in the Old Series Geological Sheet Memoirs as 'Marine Gravels'. These highly chalky gravels were deposited by melt-

waters draining from the Wold channels parallel to the ice fronts as well as from the ice fronts themselves, and Madgett and Catt seem to have misconstrued the nature of the outwash situation. Of great interest is the fact that the molluscan assemblages of these gravels, which lie on a Devensian till, are similar to those at Kelsey Hill and Keyingham in Holderness. The latter are also derived faunas, distinctive in the large numbers of Corbicula fluminalis and some cold as well as temperate marine elements. Madgett and Catt suggest that the cold elements are Late Devensian, but was not the southern North Sea dry 25,000 to 10,000 years B.P.? The most plausible explanation is that shells in the Kelsey Hill - Keyingham and 'Marine' gravels accumulated originally in or near a Middle Devensian Humber estuary, within which older shell beds had probably been exposed. Late Devensian ice subsequently crossed the estuary site and carried shells south into Lincolnshire. To dismiss the 'Marine Gravels' in Lincolnshire as just fortuitous exposures of intra-till layers and the shells as glacially re-worked Ipswichian elements when the gravels lie eastward of the buried cliff of the Wolds and above a Devensian till is not squaring with the facts.

At the south end of the Wolds, around the lower Bain valley at Tattershall, an expansive tract of fluvial terrace gravels protrudes into the Fen basin. Described most recently in the INQUA handbook, the gravels were referred to briefly by Girling (1974) and by Shotton *et al* (1977). Apart from one short-lived period of considerable warmth, they were aggraded under cold environmental conditions through the Middle and into the Late Devensian, and although they lie within 13 km westward of the Devensian Stickney moraine, they contain no evidence of direct glacial or lacustrine influence. West of the lower Bain valley over Kirkby Moor, gravelly sands disposed in flat-lying seams and lenses but with some cross-bedding and erosion planes, spread widely with their surface at 22 - 25 m O.D. Altitudinally higher than the Tattershall gravels, they rest on the pre-Devensian till into which the Bain valley is incised. Both the Kirkby Moor Sands and the correlative Hemingby Terrace up the Bain valley are older than the Tattershall gravels and their upstream terrace, and the Sands appear to have been deposited by an ancestor of the River Bain where currents slackened on the margin of a water body, best interpreted as a pro-glacial lake (Lake Fenland). The latter can only have existed when Devensian ice closed the Wash gap, and because of the antiquity and depth of the gap through the Jurassic limestones at Lincoln, it must have co-existed and equalized with pro-glacial Lake Humber at its 30 m level. Lake Fenland on this reckoning existed well before 45,000 years B.P. It was probably a relatively short-lived episode, predating and therefore not represented in the Middle Devensian gravels of the Fen margins. Clearly the status of the Kirkby Moor Sands is crucial, but an alternative depositional environment to the head of a lacustrine delta must be demonstrated if a late Early Devensian ice advance to the Stickney moraine is to be discounted.

Finally, strand-line deposits and features between 12 and 24 m

O. D. of Lake Humber have recently been described in the Doncaster area by Gaunt et al. (1972), and although altitudinally higher they are regarded as younger than extensive spreads of fluvial gravels, the Older River Sand and Gravel. Also in the Doncaster area, and extending widely over the southern Vale of York, is the 25-Foot Drift, comprising laminated clays, silts and sands, also of lacustrine origin, lying generally below 8 m O.D. Whereas the 25-Foot Drift is represented within valleys of the Idle, Don and rivers further north as low accordant terraces, the higher strand-line materials lie on spur ends and other open situations between valleys. Gaunt (1976) regards the two groups of lacustrine sediments as marking different levels of a single Lake Humber that existed in Late Devensian time. It is difficult however to reconcile the contrast in attitude of the higher strand-line deposits and of the 25-Foot Drift and the intervening valley-deepening which it implies, with the drop from one lake level to the next and the short period of time which that implies. A longer intervening period such as the Middle Devensian between two separate lake episodes is an equally valid interpretation, and this leads me to ask why the Humberhead and Fenland basins are apparently so different in their Devensian histories. Why are Early and Middle Devensian fluvial gravels so extensive on the Fen borders, and why is there no Fenland equivalent of the 25-Foot Drift? Why must Devensian sediments (and events) in the Humberhead area be compressed into the Late Devensian? Simply to conform with the fashionable view?

I suggest that in fact Early and Middle Devensian fluvial gravels are present around the Humberhead area, for example, the Older River Sand and Gravel spreading from the Don and Idle valleys has much in common in its distribution and character with the Wretton, Bain and Ouse gravels in the Fens.

Gaunt et al. (1972) relate the 25-Foot Drift with a low-level stage of Lake Humber and the absence of similar drift from the Fens might be explained by Lake Fenland draining completely through a re-opened Wash gap while the Humber gap remained ice-bound. But why had materials like the 25-Foot Drift not been deposited up to the higher strand-line of Lake Humber, or put another way, why was 25-Foot Drift deposited only at the low-level stage of the same Lake Humber?

The simplest answer to these geological and geomorphological difficulties may be as follows. The first and highest Lake Humber together with Lake Fenland was impounded by the advance of ice to Norfolk toward the end of the Early Devensian. A fairly short-lived event, littoral features were weakly developed and relatively little fine material was deposited over the lake floors. Withdrawal of the ice from both the Wash and Humber gaps allowed drainage of the lakes, and through most of the Middle Devensian periglacial fluvial sands and gravels accumulated in suitable areas around the Fen and Humberhead basins until suppressed in the latter area by the rising waters of the second (and lower-level)

Lake Humber, impounded when Late Devensian ice effectively closed the Humber gap a second time by reaching the central Lincolnshire Wolds between the Killingholme and Hogsthorpe moraines. While the 25-Foot Drift was being deposited in the Humberhead area (possibly because a higher proportion of fine material was being received from the Trent valley and in meltwaters from the York - Escrick ice fronts), a relatively low base-level in the Fens controlled a measure of incision into the Early and Middle Devensian gravels inhibiting further deposition.

This paper is intended to provoke discussion, and to establish a case for considering seriously an Early Devensian glaciation of eastern England more extensive than the Late Devensian one. This two-stage model derives from identification of two glacial advances, two Lake Humbers, and complex terrace developments on many rivers (including also the Trent (Straw, 1963), and it avoids many of the difficulties that arise if Devensian glacial and glacially-related events in eastern England are compressed entirely within the Late Devensian.

I should like to see these difficulties explained satisfactorily before I cease to entertain the concept of an Early Devensian glaciation. I hope at least therefore that some contributors to the impending conference at Sheffield will be open-minded enough to consider critically and even challenge the fashionable 'one-glaciation' model, and to recognize that a lot of problems remain to be solved.

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THE CHALKY TILL IN BARRINGTON QUARRY, CAMBRIDGESHIRE

By P.G. Hoare and E.R. Connell

The Barrington area has attracted the attention of Quaternary workers since Fisher's discovery (1879) of highly mammaliferous river terrace deposits subsequently dated as Ipswichian zone IIb (or zone III) (Gibbard and Stuart, 1975). The chalky till in the nearby Rugby Portland Cement Company's chalk quarry (TL 393512) has also been the subject of considerable debate (Sparks, 1952; West and Donner, 1956; Norris, 1962; Perrin, Davies and Fysh, 1973). As a result of Norris's study, the Barrington site became one of only a very few exposures in East Anglia that had been shown, with apparent conviction, to contain two chalky tills; it therefore assumed considerable importance in the Quaternary stratigraphy of that area and farther afield. Partly in response to Bristow and Cox's revision (1973) of East Anglia's glacial history (including their suggestion that only one chalky till underlies the region), the present authors undertook a reinvestigation of the drift section in the Barrington pit during the winter of 1976-1977. The work was designed primarily to study the nature of the fabric of the till(s) and to explain a discoloured zone at the base of the exposure.

Sixteen macrofabrics were measured in the field and meso-fabrics were determined in the laboratory on six further samples; all locations lie within a restricted area at the western end of the 460 m

long face. The fabric evidence suggests that only one till exists and that the entire thickness (some 14 m) was deposited by lodgement; the mean resultant vector derived from the macrofabric results ($176-356^{\circ}$ True) lies almost at right angles to that obtained by West and Donner (1956) at Barrington from a single set of measurements, and none of our sixteen sites resembles their data. Clast dips tend to be antipodal and are of little value in clarifying the direction of ice movement.

An interesting feature of the till is a mottled, but predominantly brown horizon, 2 m thick, developed at the base of the dark grey unit where it rests directly upon chalk bedrock. This zone appears to have been slightly decalcified, is oxidized and has within it large authigenic selenite crystals which encrust glacially-striated chalk clasts. Thin sections of this lower material show the effects of both oxidizing and reducing conditions (C.P. Murphy, pers. comm.) which probably accompanied a fluctuating ground water table level. This layer is almost certainly that which Norris (1962) mistakenly identified as the severely weathered remnants of the earlier of two tills he recognised at the site. We therefore agree with Perrin, Davies and Fysh (1973) who said of the Barrington exposure "... the entire thickness of till down to the chalk was found to be mechanically and mineralogically identical and clearly part of the Lowestoft Till".

On geomorphological grounds the Barrington chalky till predates the Ipswichian terrace gravels immediately to the south. Further, the till is apparently laterally continuous with the glacial complex recorded by Horton (1970) in the St. Neots-Biggleswade area, and with that described by Gibbard (1977) in the Hitchin-Stevenage Gap. These glacial sediments are overlain by Hoxnian biogenic deposits at Fishers Green (TL 224260) and Hitchin (TL 188277) (Gibbard and Aalto, 1977), 31 km to the south-west of Barrington, indicating an Anglian age for the drift. By implication, the Barrington chalky till also dates from the Anglian Cold Stage.

A more detailed description of the Barrington exposure is in preparation.

Acknowledgement We should like to thank the manager of the Rugby Portland Cement Company's quarry at Barrington for his permission to enter the site and for assistance with excavations.

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ABSTRACT OF A PAPER READ AT A DISCUSSION MEETING
ON "THE LATEGLACIAL ENVIRONMENT OF THE BRITISH
ISLES AND POSSIBLE CORRELATIONS WITH NORTH WEST
EUROPE"

This is an abstract of a paper presented at a meeting held at University College, London, on January 5th and 6th 1979.

GLACIAL HISTORY, VEGETATIONAL DEVELOPMENT
AND MARINE FAUNA IN NORWAY DURING THE LATE
WEICHSELIAN.

By J. Mangerud.

Ice front variations of the Scandinavian Ice Sheet between 13,000 - 10,000 y B.P. are examined with the main emphasis on the

Allerød and Younger Dryas chronozones. In Finland, Sweden and eastern Norway there was a great net retreat, in south-western Norway the ice front oscillated back and forth and in the north-western part of southern Norway the ice front retreated during the Allerød and halted during the Younger Dryas. The differences are interpreted in terms of different topography and therefore different glacial response to climatical changes.

The rates of erosion associated with Younger Dryas cirque glaciers located outside the inland ice sheet were outlined and discussed on the basis of cores from a lake beyond the Younger Dryas moraine. (Mangerud et al., in press).

A short review of the pollen stratigraphy emphasized the continuous sequence back to 18.000 B.P. described by K.D. Vorren (1978) on Andøya.

The history of the marine fauna of the Norwegian coast was described. These observations were used to illustrate the changes in the position of the Atlantic Current in the region (Mangerud, 1977; T.O. Vorren et al., 1978).

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POSSIBLE INTERGLACIAL DEPOSITS AT LINCH HILL, OXFORDSHIRE

By D. Briggs

Recent excavations at Linch Hill, near Stanton Harcourt, Oxfordshire, have revealed rich biogenic deposits believed to relate to an interglacial phase of the Upper Pleistocene.

The deposits fill a channel cut into Oxford Clay below the Summertown-Radley Terrace of the Thames. They consist of inter-bedded sands, silts and gravels and contain a varied fauna and flora, including remains of the vertebrates Elephas primigenius, Panthera leo and Ursus sp., the temperate non-marine bivalve Corbicula fluminalis and a thermophilous insect fauna.

The channel deposits are overlain by 4-5 m of terrace gravels which show clear evidence of aggradation in a periglacial climate. The gravels contain intra-formational ice-wedge casts and cryoturbation layers and silt lenses which include a cool-climate molluscan fauna.

The site is of particular interest because of the implications it has for the Quaternary sequence in this area and elsewhere. Previous reports by Sandford and others have demonstrated the presence of interglacial deposits lying on top of the Summertown-Radley Terrace in this area, and these have generally been ascribed to the Ipswichian Interglacial. The channel now exposed at the base of this terrace is clearly separated from these so-called Ipswichian materials by a major cold period, yet there are a variety of stratigraphical reasons for believing that the channel postdates the Wolstonian Glaciation. If the channel deposits do prove to be true interglacial materials, therefore, they raise a number of questions about the accepted Quaternary interpretation of the Oxford area.

The site is currently being investigated by Dr. Roger Beck (Open University, Plymouth), Dr. David Briggs (Sheffield University), Dr. Russell Coope (Birmingham University), Dr. Andrew Currant (British Museum, London), Dr. David Gilbertson (Sheffield University), Dr. Eric Robinson (University College, London) and Dr. Derek Roe (Oxford University). It is supported by a small grant from the British Geomorphological Research Group. It is proposed to visit the Linch Hill site on a short one-day meeting on Saturday, 7th July 1979. Details of this meeting are given in the Circular issued with this Newsletter.

A NOTE ON THE INDUSTRIAL MINERALS ASSESSMENT UNIT OF THE INSTITUTE OF GEOLOGICAL SCIENCES - WITH A LIST OF DRILLING PROJECTS FOR 1979, AND LIST OF PUBLISHED REPORTS

By M. R. Clark.

On behalf of the Department of the Environment, staff of the Industrial Minerals Assessment Unit (of the Institute of Geological Sciences) have for some years been conducting borehole drilling surveys, as part of a national assessment of sand and gravel resources. The results of these surveys, which include a 1:25000-scale resource map, are published in the Mineral Assessment Report Series and to date 32 reports are available (listed below). They may be obtained from IGS or HMSO bookshops.

The boreholes, usually of 6" or 8" diameter, are drilled using shell and auger rigs, modified for a dry drilling technique. A detailed log of the Drift deposits is made, and bulk samples are taken of any sand and gravel present. These bulk samples are used for particle size analysis and for a limited number of compositional analyses and physical tests on the aggregate. Samples of material of particular geological interest (for example peat or shelly silts) are also collected for further study.

In the coming drilling season, new surveys will be conducted in parts of Cambridgeshire, Essex, Lincolnshire, Suffolk, West Midlands and Yorkshire as well as in North Wales and Central and Southern Scotland. Further details may be obtained from Dr. R.G. Thurrell, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Keyworth, Nottingham, NG12 5GG.

Reports of the Institute of Geological Sciences

Assessment of British Sand and Gravel Resources

- 1 The sand and gravel resources of the country south-east of Norwich, Norfolk: Resource sheet TG 20. E.F.P. Nickless. Report 71/20 ISBN 0 11 880216 £1.15
- 2 The sand and gravel resources of the country around Witham, Essex: Resource sheet TL 81. H.J.E. Haggard. Report 72/6 ISBN 0 11 880588 6 £1.20
- 3 The sand and gravel resources of the area south and west of Woodbridge, Suffolk: Resource sheet TM 24. R. Allender and S.E. Hollyer. Report 72/9 ISBN 0 11 880596 7 £1.70

- 4 The sand and gravel resources of the country around Maldon, Essex: Resource sheet TL 80. J.D. Ambrose. Report 73/1 ISBN 0 11 880600 9 £1.20
- 5 The sand and gravel resources of the country around Hethersett, Norfolk: Resource sheet TG 10. E.F.P. Nickless. Report 73/4 ISBN 0 11 880606 8 £1.60
- 6 The sand and gravel resources of the country around Terling, Essex: Resource sheet TL 71. C.H. Eaton, Report 73/5 ISBN 0 11 880608 4 £1.20
- 7 The sand and gravel resources of the country around Layer Breton and Tolleshunt D'Arcy, Essex: Resource sheet TL 91 and part of TL 90. J.D. Ambrose. Report 73/8 ISBN 0 11 990614 9 £1.30
- 8 The sand and gravel resources of the country around Shotley and Felixstowe, Suffolk: Resource sheet TM 23. R. Allender and S.E. Hollyer. Report 73/13 ISBN 0 11 880625 4 £1.60
- 9 The sand and gravel resources of the country around Attlebridge, Norfolk: Resource sheet TG 11. E.F.P. Nickless. Report 73/15 ISBN 0 11 880658 0 £1.85
- 10 The sand and gravel resources of the country west of Colchester, Essex: Resource sheet TL 92. J.D. Ambrose. Report 74/6 ISBN 0 11 880671 8 £1.45
- 11 The sand and gravel resources of the country around Tattingstone, Suffolk: Resource sheet TM 13. S.E. Hollyer. Report 74/9 ISBN 0 11 880675 0 £1.95
- 12 The sand and gravel resources of the country around Gerrards Cross, Buckinghamshire: Resource sheets SU 99, TQ 08 and TQ 09. H.C. Squirrell. Report 74/14 ISBN 0 11 880710 2 £2.20

Mineral Assessment Reports

- 13 The sand and gravel resources of the country east of Chelmsford, Essex: Resource sheet TL 70. M.R. Clark. ISBN 0 11 880744 7 £3.50
- 14 The sand and gravel resources of the country east of Colchester, Essex: Resource sheet TM 02. J.D. Ambrose. ISBN 0 11 880745 5 £3.25
- 15 The sand and gravel resources of the country around Newton on Trent, Lincolnshire: Resource sheet SK 87. D. Price. ISBN 0 11 880746 3 £3.00
- 16 The sand and gravel resources of the country around Braintree, Essex: Resource sheet TL 72. M.R. Clark. ISBN 0 11 880747 1 £3.50

troversial, and at time impassioned. What might be called the traditional view, as set out for instance by Mitchell (1970) is that the Courtmacsherry raised beach (6 - 8 m O.D.) is of Gortian age, and that this interglacial is in turn equivalent to Hoxnian in Britain. Glacial and periglacial deposits resting on this beach are referable to the Munsterian (penultimate) and Midlandian (last) glaciations, although in this framework no deposits which are unequivocally of last interglacial status have yet been found. However, Warren (1979, in press) argues that the logical interpretation of the situation is that the Gortian interglacial is in fact the last interglacial in Ireland and hence that all glacial and periglacial deposits resting on the 6 - 8 m beach are of Midlandian age.

The first site visited was at Boleynneendorish, near Gort, where a brief homage was paid to the type site of the Gortian interglacial. Only about 2 m of organic deposits are presently exposed. It was seen to be overlain by one till unit, although Farrington (1959) has suggested that nearby two post-Gortian tills are present. The second stop was the strand at Ballybunion, where Frank Mitchell demonstrated a wave-cut till platform recently discovered by him. It is overlain successively by a raised beach and an upper till. Nearby a rock platform was also seen. Several points of dissention emerged. Were the two platforms part of the same feature? Willie Warren promised to instrumentally level the section in the coming field season and let us know. Was the upper till in situ? If the beach belongs to the last interglacial then an in situ upper till would indicate that Midlandian ice reached as far as Ballybunion.

The examination of the coastal section at Fenit on the north side of Tralee Bay on the morning of the second day proved to be most illuminating. Here the party observed a long section whose sequence has been described by Mitchell (1970) as: shore platform, raised beach, peaty muds and silts, lower head, glacial deposit (Devonian erratics), upper head. In this paper he suggested that the erratics were indicative of a glaciation of Munsterian age which reached Fenit from the south, and that the peaty deposits were laid down two interglacials ago. Warren (1979) proposed that the beach is of last interglacial age and that the overlying deposits are a solifluction unit. Considerable discussion about the upper part of the section, with contributions from inter alia Eddie and Sybil Watson, Dick Bryant, Frank Mitchell and Willie Warren, resulted in general agreement that all the deposits above the silts could be best interpreted as the product of one cold stage, the last glacial, the erratics being derived secondarily from upslope. Since the peats and silts appeared to pass up conformably into the lower head, this would seem to imply that on lithostratigraphic grounds the organic deposits at Fenit were of last interglacial age. Nevertheless Charles Turner forcibly contended that on biostratigraphic grounds the deposit could be older. Later that day the long cliff exposure at Rossbehy on the south side of Dingle Bay (Warren 1977) was inspected. Again, a beach was observed resting on a raised rock platform, and overlain by

head and till. Willie Warren pointed out an extremely weathered till low in the section which he interpreted as being of sub-beach age, although nowhere was the beach actually seen resting on it. More room for argument.

The following day provided a change of theme. Refreshed by bouts of heavy rain as a change from Guinness, the party turned its attention to features of mountain glaciation in the Killarney area. This included a trek in the Behy Valley, where moraines, cirques and tors were observed. Some members sought out walls buried by peat and were rewarded by finding a rock-carving similar to those seen earlier at Newgrange during the annual field meeting.

No visit to the south-west would be complete without a visit to Howe's Strand, on the south coast of Co. Cork, described by Wright and Muff (1904), the type site for the Courtmacsherry raised beach and this constituted the first stop of the fourth day. The section has changed its appearance in recent years, and participants expressed their regret at the loss of the famous 'stack' which was eroded during 1976. After a salubrious lunch at Kinsale, the first of two afternoon stops was at Ringabella on the west side of Cork Harbour. Here a raised platform was observed to be grooved and striated which seemed to reflect ice movement from a north-west direction, although the possibility that they were slump marks was also discussed. Overlying the platform, a succession of beach cobbles, sandy facies and head containing erratics and lenses of what appeared to be a till-like diamicton, was observed near the car park, but further east in the section, a diamicton rested directly on the platform. Slumping made it difficult to determine the precise relationships in the section, but Francis Synge proposed that the raised beach was overlain by a local head which in turn was overlain by the diamicton, which he interpreted as a till in primary position. Willie Warren contended that since we could not actually see those relationships, the diamicton might equally as well predate as postdate the beach. The final stop was at Garrvroe in the centre of Ballycotton Bay, east of Cork Harbour, where Ballycrooneen till of eastern provenance (Irish Sea Ice) was seen to overly head. In places, head was observed overlying pockets of beach gravel on the platform beneath.

The group spent the last night in Cobh and returned to Dublin the following day via the Rock of Cashel (Norman cathedral) and Cahir (Normal Castle). Sincere thanks were expressed by all to Willie Warren for a most enjoyable and stimulating meeting.

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INTERNATIONAL GEOLOGICAL CORRELATION PROGRAMME,
PROJECT 24- STRATIGRAPHIC AND PALAEOMAGNETIC CORRELATION
OF QUATERNARY GLACIATIONS IN THE NORTHERN HEMISPHERE

Leader: Professor V. Sibrava, Prague

Establishment of a subsidiary Working Group to consider the problem of "The Interglacials after the Hoxnian".

The Correspondent for the U.K. Working Group of Project 24 is Professor F.W. Shotton.

During the meeting of this body on May 31st, 1978, a subsidiary working group was set up to consider the problem of "The Interglacials after the Hoxnian". Its members are: Professor F.W. Shotton, Dr. D.Q. Bowen, Dr. R.S. Harmon, Dr. N.J. Shackleton, Dr. C.B. Stringer, Dr. A.J. Sutcliffe (Convenor), Dr. C. Turner, Professor R.G. West and Mr. J. Wymer.

The first meeting of this subsidiary group was held on December 8th, 1978. It was agreed that, with the problem of marine-terrestrial Quaternary correlations currently attracting so much interest, it would be valuable to re-examine the period of time after the Hoxnian in the British Isles and to debate whether more than one interglacial is represented among the deposits labelled as Ipswichian in the correlation of the Geological Society.

With so many relatively new methods of obtaining absolute dates (for example uranium/thorium dating of travertine) now available, dates for sites in the British Isles were beginning to mount up and it

should soon be possible to reconstruct the climatic events of this period of time in some detail. An important purpose of the subsidiary working group should therefore be to check out possible means of obtaining a more detailed chronology of the period of time in question and to stimulate relevant surveys by drawing attention to the nature of the problem.

Since the Hoxnian is the Interglacial which precedes the period under study, it is important to identify the marine oxygen isotope stage equivalent of this interglacial. Kukla (1977) has argued that the Holsteinian is probably equivalent to stage eleven. If the Hoxnian is equivalent to the Holsteinian and if the Ipswichian proves to be equivalent to stage 5, then it would follow that stages 7 and 9 are currently unrecognised in the British terrestrial sequence. Even if the Hoxnian proves to be stage 9, 7 may still be unrecognised.

The end of the Hoxnian needs a clearer definition. Dr. Turner agreed to investigate a means of defining this, based on the pollen sequence at Marks Tey.

It is also important to try to identify terrestrial deposits in Britain, especially fossiliferous deposits, equivalent to oxygen stages 9, 7 and 5; also for the subdivisions of 5. 5e is known from both marine and continental evidence (for instance at Grande Pile) to have been warmer than 5c and 5a. Was this the time when the hippopotamus was so very abundant in Britain, spreading as far north as Stockton? Can deposits of stage 5c or 5a be identified in Britain and, if so, were they of interglacial or interstadial status?

There are so many potentially critical Quaternary sites in the British Isles that it is difficult to choose any of these as being more important than others for study of the above problems. For a beginning three areas and one special line of study were identified as being worthy of special attention.

1. The Ipswich area. Bobbitshole is the type site for the Ipswichian Interglacial. There is some controversy concerning whether some other nearby apparently Ipswichian but slightly more high lying sites (notably Stoke Tunnel, Stutton and Harkstead) represent parts of the same interglacial as Bobbitshole or a different one. It was agreed that the further investigation of these sites and others in the same area such as Brundon required urgent attention; and that means of furthering such attention should be investigated. Dr. Turner is in the course of conducting a palynological study of cores obtained from Stoke Tunnel.
2. The Gower sea caves (Minchin Hole and Bacon Hole). An opportunity

to try to relate the two raised beaches and mammalian assemblages of these caves to the marine sequences by means of altitudinal studies and uranium/thorium dating of stalagmite. Excavation by British Museum (Natural History); stalagmite dating by Dr. H. Schwarcz (MacMaster University) is in hand.

3. The Thames estuary. There is controversy concerning whether the the apparently Ipswichian deposits of Trafalgar Square and Ilford represent different parts of the same interglacial or different interglacials. Dr. C. B. Stringer is available to watch for any new sections at Ilford which may be revealed by building development.
4. A broad programme of uranium/thorium dating of stalagmite from cave sites is likely to provide one of the most ready means of obtaining absolute dates for deposits including fossiliferous deposits of the period of time under consideration. Dr. Harmon is coordinating work in this field, with special interest in the period about 200,000 years ago.

Members of the subsidiary working group would be grateful for information about important sites with an established stratigraphy (for example sites with fauna and/or flora, with carbonate suitable for investigation by U/Th method, or for which absolute dates have already been obtained) which may have bearing on the above problem. Anyone interested should contact Dr. A.J. Sutcliffe, Department of Palaeontology, British Museum (Natural History), Cromwell Road, London, SW7 5BD.

Reference

- Kukla, G.J., 1977. Pleistocene Land-Sea Correlations, 1. Europe. Earth Science Reviews, 13: 307-374.

QUATERNARY STUDIES IN WALES

A gazetteer is presently being compiled on present day active Quaternary research in Wales. Contributions are invited from research workers in archaeology, biology, geology, geomorphology and soil science. The success of such a compilation obviously depends upon the response from those involved in these topics and any associated subject, and it is intended that the list will be included in the November 1979 issue of Quaternary Newsletter. Those interested should send their name and address, along with a brief outline of their topic and region of study

to either: John Ince, Geography Section, City of London Polytechnic, Calcutta House Precinct, Old Castle St., London, E1 7NT; or Stephen Lowe, Department of Geography, Queen Mary College, University of London, Mile End Road, London E1 4NS.

AMQUA

The next AMQUA (American Quaternary Association) meeting will be held on August 18-20th, 1980 at the University of Maine, Orono, ME 04473, USA. The topic for the meeting will be 'Changes in the environment during the last interglacial-glacial cycle'. Topics discussed will include the dynamics of ice-sheet growth, land-sea coupling, differentiation of interglacials and interstadials, evaluation of palaeontological and geochemical evidence from long cores from continental areas and the response of prehistoric human groups to environmental changes.

The AMQUA Council produces, prior to the meeting, a booklet containing all the solicited papers on the conference topic and also other contributed abstracts. This is available free to members and can be purchased by non-members for about \$4.00.

Membership of the Association costs \$4.00 per annum and permits subscription to the journal Quaternary Research at a reduced cost of \$23.00 per annum. This compares very well with the personal subscription price available in this country.

While it is unlikely that many QRA members would be able to attend the Conference in person they might be interested in obtaining the book of AMQUA abstracts. If so they should write to either the Secretary, Professor W.R. Farrand, Department of Geology and Mineralogy, University of Michigan, Ann Arbor, MI 48109; or the Treasurer, Dr. J.E. King, Illinois State Museum, Springfield, IL 62706.

THE BILL BISHOP MEMORIAL TRUST



Nearly two years have passed since Bill Bishop died and his loss is still keenly felt by all who knew him. There is an additional loss,

however, that we may be able to do something about; this is the loss to geology and human evolutionary studies, and to the postgraduate students that he did so much to encourage.

At the Pan African Congress held in Nairobi in September 1977 an informal group of his friends and colleagues met and resolved to try and help continue his work and his support of research students. The outcome has been the founding of the Bill Bishop Memorial Trust the aims of which are as follows:-

- a) To support research by postgraduate students in the subject of geology and related sciences in the field of :
 - (i) Cenozoic stratigraphy, palaeoenvironments and chronology in relation to hominid evolution;
 - (ii) British Quaternary stratigraphy, palaeoenvironments and geomorphology.
- b) To support the two-way interchange of postgraduate students working in the fields outlined in (a) (i) above between Institutions in the United Kingdom or the United States of America and Institutions in East Africa, namely Tanzania, Uganda and Kenya.
- c) To support such other projects that the Trustees, or their Committee of Management may approve.

We realise that in these inflationary times that there are many calls on all our pockets but it is for this very reason that we feel that the needs of research and research students are most pressing. In his early days Bill was helped by two private Trusts at a crucial point in his career, and indeed this must apply to a great many of us. Could we ask you, therefore, to support us in this venture and help to create a living memorial to Bill Bishop that will be of continuing value to the subjects that he loved and to students in the years to come.

Contributions should be sent to: Professor M. H. Day,
Department of Anatomy, St. Thomas' Hospital Medical School, Lambeth
Palace Road, London, SE1 7EH.

RECENT PUBLICATIONS AND CIRCULARS

Loess Letter. Published by D.S.I.R. Soil Bureau, on behalf of the Western Pacific Working Group of the INQUA Loess Commission.

Loess Letter is the informal newsletter of the Western Pacific Working Group of the INQUA Loess Commission. It includes news and short notes of work in progress. For instance, No. 1 issued in April 1979 includes a review of the history of the INQUA Loess Commission and its aims; a note on recent publications and proposed publications related to Loess; notice of meetings such as the ANZAAS Meeting at Auckland on 26th January 1979 concerned with Quaternary Airborne Dust, Loess Commission in Hungary in August 1979, and a Research Report related to work done on Mass Movement Erosion in part of the North Island of New Zealand.

It is intended that two issues will be produced each year and anyone wishing to be on the circulation list or contribute to this newsletter should write to Dr. Ian Smalley, D.S.I.R., Soil Bureau, Lower Hutt, New Zealand.

Sea-Level. Information Bulletin of I.G.C.P. Project 61. Edited by M.J. Tooley.


No. 1 of Sea-Level was issued in January 1979 as an Information Bulletin of I.G.C.P. Project 61. It contains a series of short articles, a summary of reports from national representatives, a calendar of events and a list of news items.

The articles in Issue No. 1 consist of a statement of the aim of the Bulletin by M.J. Tooley; summaries of I.G.C.P. Sea-Level projects in the Netherlands by O. van de Planche, in Germany by H. Preuss and H. Streif, and in Brazil by A. Bloom. In addition it includes a report on the Seminar on Sea-Level Indicators organised by the I.G.C.P. 61 group at Paris in December 1978, and articles by J.A. Clark on 'Sea-level data most useful for improving isostatic models', and I. Shennan on 'Statistical evaluation of sea-level data'.

Future issues are intended to follow a similar format and it is proposed to issue the Bulletin twice a year: in January and July. Anyone interested should contact Dr. M.J. Tooley, Department of Geography, Durham University, Science Laboratories, South Road, Durham, DH1 3LE.

Quaternary Research Association Field Guide. East Central Ireland, April 1979. Edited by A. M. McCabe. Published by the Quaternary Research Association, 63pp. Price: £2.00 to Members, £3.00 to non-members.

This Guide Book was produced for the recent Annual Field Meeting in Ireland. It includes an introduction which reviews the major aspects of the Quaternary of Ireland and outlines some current problems, and three sections devoted to the field programme for each of the three main days of the meeting. Day 1 is concerned with the glacial stratigraphy and raised beach features of the East Coast and Lower Boyne Valley. Day 2 covers the glacial forms near Trim; Ballivor Bog and the archaeology around Newgrange. Day 3 deals with the glacial succession in Co. Wicklow.

Contributions are by J. M. Cohen, R. F. Hammond, P. G. Hoare, C. Lewis, A. M. McCabe, G. F. Mitchell, M. O'Meara, F. M. Synge, W. Warren, and W. A. Watts. Copies can be purchased from the Secretary of the Quaternary Research Association, J. Rose, Department of Geography, Birkbeck College, University of London, 7-15 Gresse Street, London, W1P 1PA. 

CALENDER OF MEETINGS

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| July 7th 1979 | Quaternary Research Association one day field meeting to Linch Hill, Stanton Harcourt, Oxfordshire. The party will assemble at Linch Hill at 11.00 a.m. Those wishing to attend should contact Dr. David Briggs, Department of Geography, University of Sheffield, Sheffield S10 2TN, tel: Sheffield 78555 or Barnsley 763612 (home). Further details are given in this Newsletter and the Circular issued with this Newsletter. |
| July 8th-14th 1979 | International Conference on climate and history to be held at the University of East Anglia, Norwich. Information can be obtained from the Conference Secretary, Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ. |
| July 9th-14th 1979 | South African Society of Quaternary Research, Conference with field excursions. Principal theme: Hominid sites in southern Africa. Venue: Bernard Price Institute, University of Witwatersrand, |

Johannesburg. Details can be obtained from Prof. T.N. Huffman, Dept. of Archaeology, University of Witwatersrand, Johannesburg 2001.

- August 6th-13th 1979 INQUA Commission on the genesis and lithology of Quaternary deposits. To be held in Norway. Further details can be obtained from Sylvi Haldorsen, Department of Geology, Agricultural University of Norway, Box 21, N-1432 Ås-NLH. A brief outline is given in Quaternary Newsletter 27.
- August 22nd-September 1st 1979 Geologists Association Meeting to study the Quaternary History of East Anglia. This will be under the leadership of P. Cambridge and others and further details can be obtained from R.A.D. Markham, Geology Dept. Ipswich Museum, High St., Ipswich, Suffolk.
- September 13th-23rd 1979 Joint Quaternary Research Association/British Geomorphological Research Group Study Course to the Alps to consider Glacial and Periglacial Features of High Alpine areas. Details are given in the February 1979 Circular of the Quaternary Research Association and further details can be obtained from Dr. B. Whalley, Department of Geography, Queen's University, Belfast, BT7 1NN.
- September 17th-23rd 1979 International meeting on Holocene Sedimentation in the North Sea Basin. To be held at Texel, Netherlands. Details are given in Quaternary Newsletter 26.
- September 19th-23rd 1979 Fourth meeting of the Geological Societies of the British Isles. To be held at Sheffield. The Q.R.A. will contribute a series of lectures and a field meeting related to the topic of the limits of the Last Glaciation in England on Friday 21st Sept. and Sunday 23rd Sept. respectively. Further details are given in the Circular issued with this Newsletter and an application form that is enclosed.
- September 24th-28th 1979 Quaternary Research Association Short Field Meeting to the Channel Islands under the leadership of Dr. David Keen, Department of Geography, Lanchester Polytechnic, Priory St., Coventry, CV1 5FB. Further details are given in the Circular issued with this Newsletter and an application form is included in the February 1979 Circular of the Quaternary Research Association.
- November 7th-9th 1979 I. G. U. Commission on the Coastal Environment Atlantic Regional Conference to be held at

Newport, Rhode Island, U.S.A. Further details can be obtained from John Fisher, Conference Chairman, Department of Geology, University of Rhode Island, Kingston, Rhode Island, 02831, U.S.A.

- January 4th-5th 1980 Quaternary Research Association Discussion Meeting to be held at Murchison House, Edinburgh. This is concerned with Offshore and Onshore Quaternary of North West Europe and the Scope for correlation. Further details are given in the Circular issued with this Newsletter and can be obtained from Dr. N.G.T. Fannin, Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh, EH9 3LA.
- April 6th-10th 1980 Quaternary Research Association Annual Field Meeting and Annual General Meeting, Glasgow. Preliminary notice is given in the Circular issued with this Newsletter.
- May 22nd-25th 1980 Quaternary Research Association Short Field Meeting in the Inverness Region under the leadership of Dr. J.S. Smith and F.M. Syngé. Preliminary details are given in the Circular issued with this Newsletter.
- September 18th-22nd 1980 Quaternary Research Association Short Field Meeting to West Cornwall under the leadership of Dr. R. Beck and Professor N. Stephens. Preliminary notice is given in the Circular issued with this Newsletter.
- August-September 1981 Quaternary Research Association Overseas Study Course to Finland organised by Dr. P.L. Gibbard. Preliminary details are given in the Circular issued with this Newsletter.
- September 1981 Quaternary Research Association Short Field Meeting to the Central and South-eastern Grampians and lowland Perthshire under the leadership of Dr. J.J. Lowe and Dr. M.J.C. Walker. Preliminary details are given in the Circular issued with this Newsletter.
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Compiled and printed for circulation to Quaternary Research Association members and others by the Honorary Secretary to the Quaternary Research Association, Mr. J. Rose, Department of Geography, Birkbeck College, University of London, 7-15 Gresse St., London W1P 1PA, England.

