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CLASSIFICATION OF TILL

By G.S. Boulton

A REPORT OF TWO MEETINGS RECENTLY HELD BETWEEN BRITISH QUATERNARY SCIENTISTS TO DISCUSS THE CLASSIFICATION OF TILL.

A meeting and field trip was held at the University of Keele on 17th-19th December, 1979, the object of which was to seek to find what level of consensus existed amongst an invited group of the most active British workers on a genetic classification of till. The following attended the meeting:

Dr. G. Boulton	Mr. E. Francis	Dr. D. Peacock
Dr. J. Catt	Dr. P. Gibbard	Mr. J. Rose
Mrs. H. Davies	Dr. M. Hambrey	Dr. J. Rice
Dr. E. Derbyshire	Dr. A. Horton	Dr. G. Thomas
Dr. M. Deynoux	Mr. M. Lee	Dr. W. Warren
Dr. N. Eyles	Dr. M. Paul	Dr. P. Worsley

Discussion ranged over three principal topics: 1) Overall structure of the classification. 2) Definition of till. 3) Appropriate sub-types.

1) Overall structure of the classification

There were considerable qualms, expressed primarily by those involved in mapping glacial sequences, about the usefulness and applicability of a purely genetic classification. This was strongly opposed by those primarily concerned with the study of processes who believed the use of a genetic classification to be an important tool in enlarging our understanding of ancient glacial sequences. One way out of this dilemma would be to develop a parallel descriptive classification for mixed grain size sediments. This would be a very useful contribution to our armoury of sediment descriptors in any case.

2) Definition of till

As a result of the disagreement about use of the concept of re-sedimented waterlain till, and the desire of some to have till defined on partially lithological grounds rather than simply by process, several definitions were produced.

- (i) Till is an aggregate whose particles have been brought into contact by the direct agency of glacier ice and which, though it may have undergone subsequent glacially-induced flow, has not been disaggregated.

This is a process definition. It excludes re-sedimented waterlain till, waterlain materials which have formed on or in the glacier and been transported and deposited (e.g. eskers and flow tills which have been remoulded by flow after underlying ice has disappeared).

- (ii) Till is a diamicton whose components illustrate that it has been deposited by glacier ice.

This is the other extreme, a descriptive definition with only a general reference to glacial deposition. It is questionable if it gives enough guidance about whether flow till or waterlain till are included within it.

- (iii) Till is a sediment in which the particles have been brought into contact by the direct agency of glacier ice. It may be deposited as terrestrial till directly by or from glacier ice, or as waterlain till in a body of water. In the latter case the glacially-derived component should dominate.

A process definition, framed in order to include re-sedimented waterlain till.

There was general agreement about the use of position of deposition (supraglacial, subglacial, proglacial) and process of deposition as bases for a genetic classification. However, there were problems about the use of supraglacial deposition. Some felt: a) that material on, or in, ice was still in transport and therefore should be termed debris, others felt: b) that an aggregated debris mass on the glacier surface should be called till. However, by analogy with other geological usage we see no reason to use the term supraglacial till as proposed at the Norwegian meeting in 1979. The term aeolian sandstone does not imply that the sandstone still undergoes aeolian action - a great deal is left unstated in geological terminology. There is no reason not to use the term supraglacial till as "deposited from a supraglacial position" by those who prefer a) above. For those who prefer b) there is no problem.

3) Appropriate sub-types of till

A discussion of the appropriate sub-types of till was discussed first as it helped to define where the boundaries of till should be drawn.

Ablation till

Whereas some workers might wish to retain this term, and it obviously should be referred to in the dictionary, there was unanimous agreement that it should not form part of a recommended classification.

There were several major objections to its use:

- i) The prefix could be applied to many glacial situations.
- ii) It was defined before our more precise knowledge of the supraglacial environment was acquired and is difficult to fit into that knowledge, and into our evolving classification.
- iii) It has tended to be synonymous with a particular lithology, and tends to perpetuate the myth that supraglacial tills are necessarily coarser and looser than others.

Flow till

It was questioned whether such material (as defined by Hartshorn) should be termed till at all. After a long discussion which was usefully illustrated during a field trip, it was unanimously concluded that it should be included in the classification. It was suggested that the point at which till ceases to be till should be the point at which zero effective interparticle stresses allow independent grain movement, as this is a physical process which allows the development of a suite of recognisable sedimentary structures.

Waterlain till

Whereas flow tills might accumulate in water bodies, and lodgement tills and melt-out tills might be deposited by glaciers grounded below a lake or sea level, these still remained flow tills, lodgement tills and melt-out tills and the fact that they were deposited beneath a water level was of secondary significance, which might be taken into account by a prefix, such as in waterlain flow till.

The principal problem was whether to allow a sediment to be till which has accumulated in water from debris particles falling from icebergs, or from an ice shelf or from the glacier roof of a subglacial cavity.

It was argued that those working on pre-Quaternary glacial sequences who used the term till for what were probably iceberg-dropped sediments would probably not change that usage. Largely in response to this opinion the meeting became strongly divided between those who felt material sedimented through water could be till and those who rejected this.

Acceptance of a re-sedimented origin meant that one criterion would be used to define when flow till ceased to be till (i.e. a disaggregation criterion) and yet disaggregation and re-sedimentation would be allowed for "waterlain till".

A meeting was held at the University of East Anglia on 1 March 1980 of those British scientists who have studied till in modern glacial environments.

There was a large measure of agreement and general conclusions of the meeting are set out below.

General Considerations

1. What is the classification for?

Although an important justification is that of standardisation of nomenclature in order to improve communication, that of itself is of little value unless there is a clear scientific aim. The aim should be to apply, via a classification, our current understanding of glacial processes to the interpretation of sediments.

On this basis, the classification MUST be a classification of sediments via the sediment-forming processes. It should NOT merely be an amalgam of old classifications and terms which may have legal precedence but do not usefully reflect modern ideas about process.

We must accept that a genetic classification will only last as long as the opinions about processes on which it is based are generally accepted. This also means that speculative ideas without a sound observational basis and which are not yet generally accepted, should not be incorporated.

2. Boundaries of taxonomic units

The process-defined boundaries of taxons should, wherever possible, coincide with readily identifiable changes in the sediment which are produced by the taxon-defining processes. However, taxons which are difficult to identify should not necessarily be ruled out if they are theoretically important (e.g. melt-out till).

It is important to define the boundaries of taxons very carefully, not merely their most common characteristics. Thus we should concentrate on: (i) when does debris become till? and: (ii) when does till cease to be till?

3. Structure of the classification.

It is important that if a particular process is used to define the boundary of till in one environment, the same process should be used as its definition in another. Thus, one way of structuring the classification is in an environment x process matrix, which can also be structured in a hierarchical fashion (Figures 1 and 2).

Detailed Considerations

1. How broad a range of genetic types of sediment do we wish to encompass in the term till?

For instance, Lawson (1979) appears to rule out flow of till after it has been directly deposited from the glacier. This would restrict till to melt-out till and lodgement till. As many of the latter probably undergo post-depositional deformation, on Lawson's definition many modern valley glaciers and even larger ice-cap and ice sheet distributories would deposit so little till (using his definition) that the term would hardly be useful. It was felt that this definition was too restrictive.

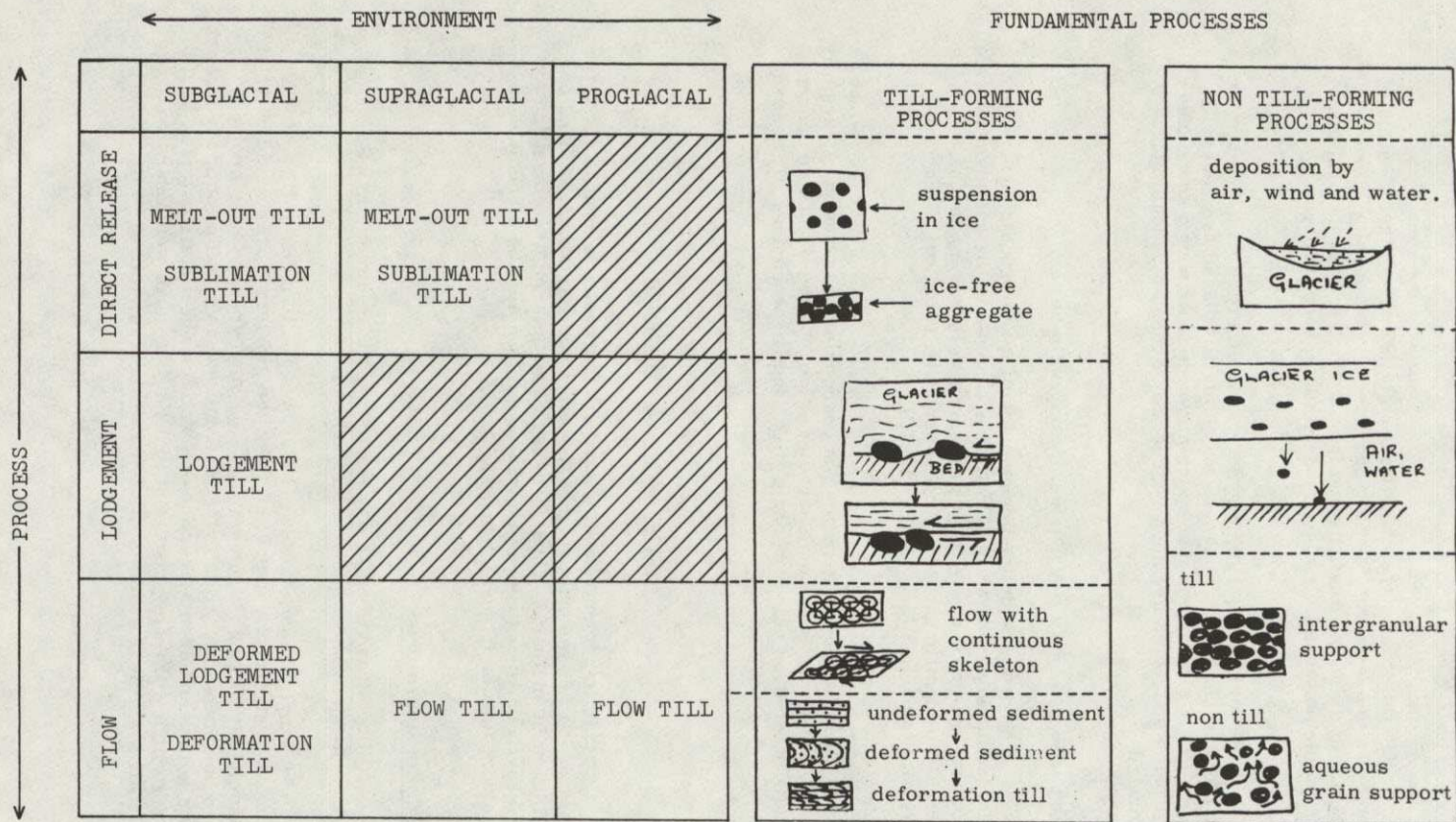
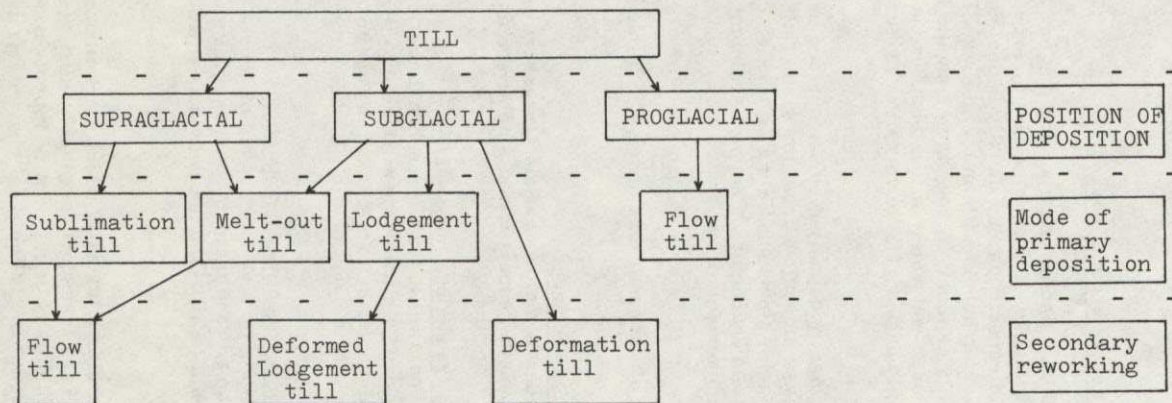


Figure 1. Till classification - process x environment matrix



Parallel classifications:- (1) Textural - e.g. clast dominant
matrix dominant
supraglacial morainic till

(2) Morphological - e.g. fluted lodgement till

Lithified sediments:- Add suffix - ite

Figure 2. Classification of till in a hierarchial structure

On the other hand, extension of the term till to sediments which accumulate in water bodies with a dominant component which is derived from glacier ice by gravitational settling through water would extend the term too far. It would be far broader than any other genetic term applied to sediments.

2. When does debris become till?

Debris is introduced into the glacier transporting system supraglacially from rockfalls and avalanches and subglacially by erosion of the bed. On the basis of our field experience this usually becomes disseminated in or on the ice as granular debris with an ice matrix. Pre-existing sediment incorporated basally as a unit by the glacier should be considered as a clast. The term floe, used widely in eastern Europe to describe this, is ambiguous in verbal usage. The term raft is preferred.

Aggregated material primarily deposited on the surface or in the glacier by water, or wind, or mass movement from the glacier flanks, which is not disaggregated during glacier flow, should not be termed debris, and will not become till, but should be regarded as a normal sediment produced by water, wind, or mass movement.

There were three views of the conditions under which this debris becomes till:-

- (i) When glacial transport has ceased
Glacial transport includes ii) below, but also transport of a mass that is stationary with respect to the glacier ice on which or within which it occurs.
- (ii) When glacially-induced transport ceases
Glacially-induced transport is flow down a supraglacial slope, which would include flow off a glacier ice surface into the proglacial zone; or subglacial deformation (flow) due to overriding effect of the glacier, or local differences in effective pressure.
- (iii) When disseminated debris becomes aggregated
Thus an aggregated flowing or stationary mass of debris on the glacier surface would be till and material undergoing subglacial deformation would be till, and not debris as it would be in i) or ii).

The justification for regarding a material which is stationary with respect to the glacier but which is in transport (because it still lies on or in the transporting medium, which may or may not be moving itself) as a deposited sediment, is that it has all the lithological characteristics of a deposited sediment and there is no obvious analogue between this and other transporting media where individual grains undergo transport. Also

it is often extremely difficult to know where till/debris is underlain by glacier ice or not. Thus we reject (i) above.

There was disagreement about which of definitions (ii) and (iii) should be adopted. Using the aggregation criterion (iii), a supraglacial or subglacial flowing mass would be till as would the resultant stationary sediment. Using (ii), only a mass stationary with respect to glacier ice or to another substratum would be till. A flowing mass would be a debris flow, though note the restriction recommended in 3 (ii) below.

3. When does a sediment cease to be till?

Three boundaries for till have been proposed:

- (i) Sediment ceases to be till if a melt-out (or sublimation) or lodgement orientation fabric is destroyed (e.g. Lawson).
- (ii) Sediment ceases to be till if inter-granular stresses are reduced to the point where independent grain movement occurs (for 2 (iii) above); or if this has occurred at some time in the aggregates history (for 2 (ii) above).
- (iii) Sediment ceases to be till if the component derived from the glacier directly, or by falling under gravity, is less than a certain percentage (e.g. "waterlain tills", "iceberg-dropped tills")

(i) is rejected as being too restrictive, and very difficult to identify, presumably by the relative uninformative and time consuming methods of fabric analysis.

(iii) is rejected because:-

- a) Till is defined too broadly. Workers on ancient sequences would then simply call any diamicton with glacial clasts a till or tillite, there might be no further incentive to develop more sophisticated palaeoenvironmental ideas by using modern genetic concepts.
- b) It would reflect a very unstable aspect of marine environments: i.e. the precise tracks of icebergs which depend on wind bathymetry and ocean currents, and their relationships with plumes of sediment-laden water, and would not even help in defining proximal and distal glacial zones.
- c) On this basis many proximal glacial outwash deposits would certainly be till, and the development of a workable criterion which would exclude active water transporting mechanisms would be difficult.

(ii) This is the preferred criterion, as in the continuum from melt-out till to water transported sediment it marks an important process change which leaves readily-observed lithological characters (Figure 3). It was also suggested that in practice when effective stress in tills is near

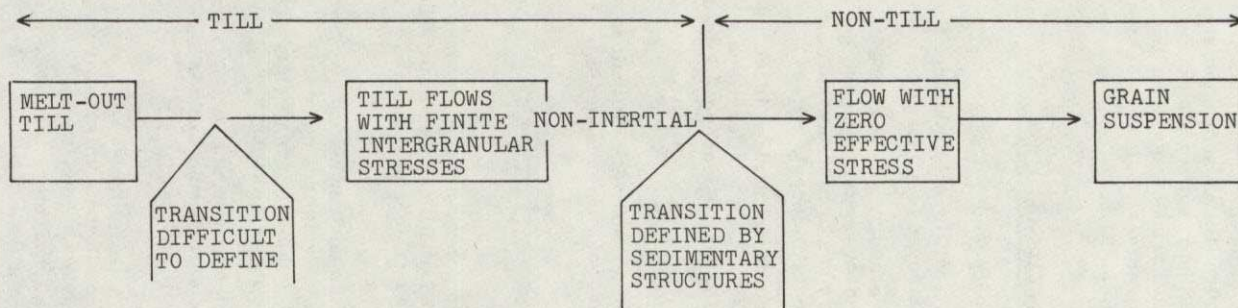


Figure 3. The relationship between till and non-till deposits.

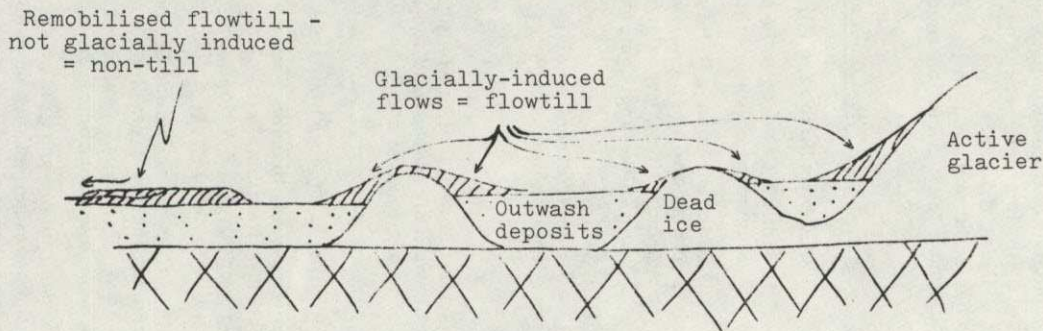


Figure 4. Illustration of the likely occurrence of flow till and remobilised till.

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New publication

THE PRE-GLACIAL PLEISTOCENE OF THE NORFOLK AND SUFFOLK COASTS

R. G. West

with contributions by P.E.P. Norton, B.W. Sparks and D.G. Wilson

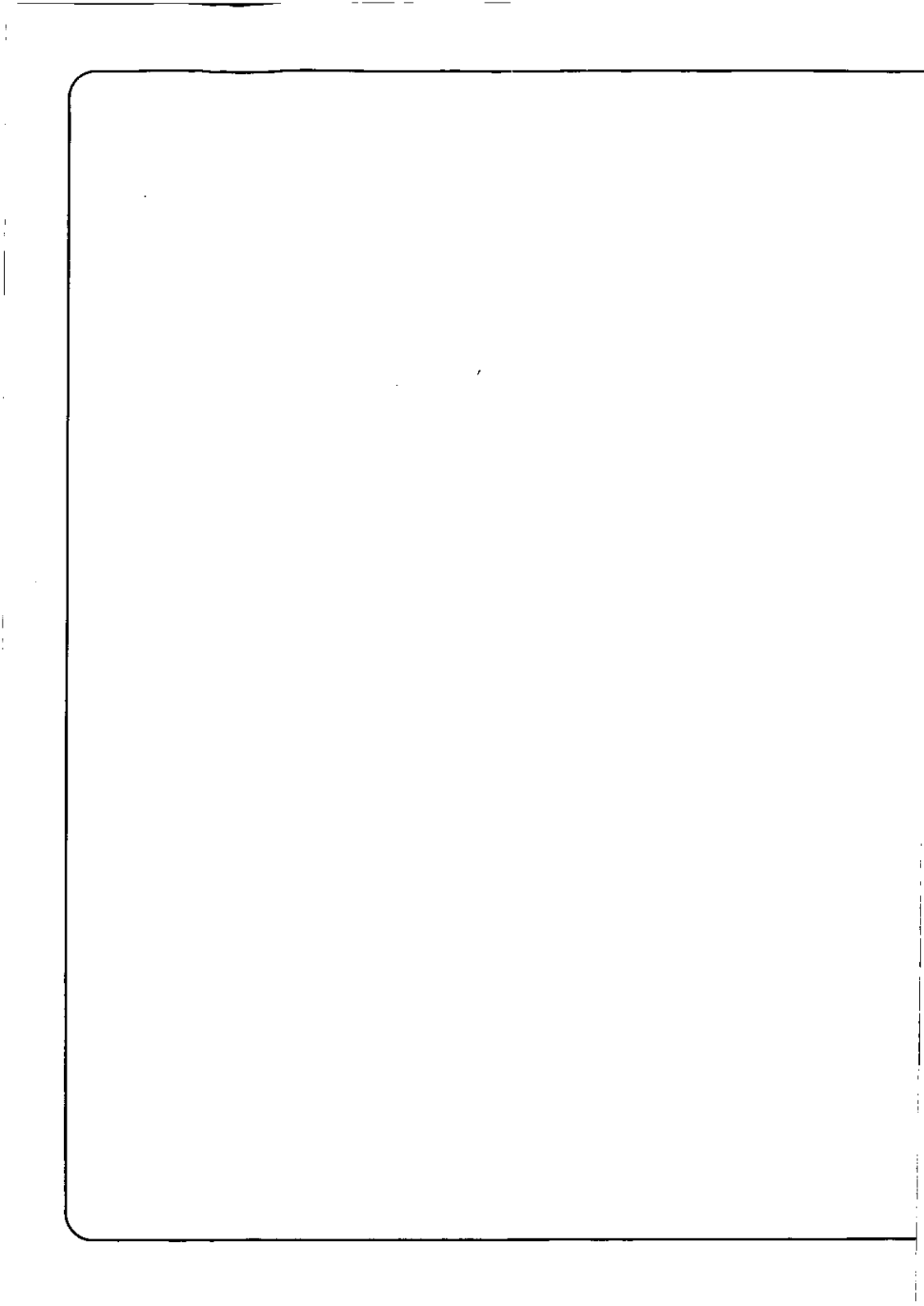
This account provides the basis for reconstructing environmental history in the immediate pre-glacial period of time. A number of climatic stages have been recognised, defined and related to the history of sedimentation, vegetation and sea-level change.

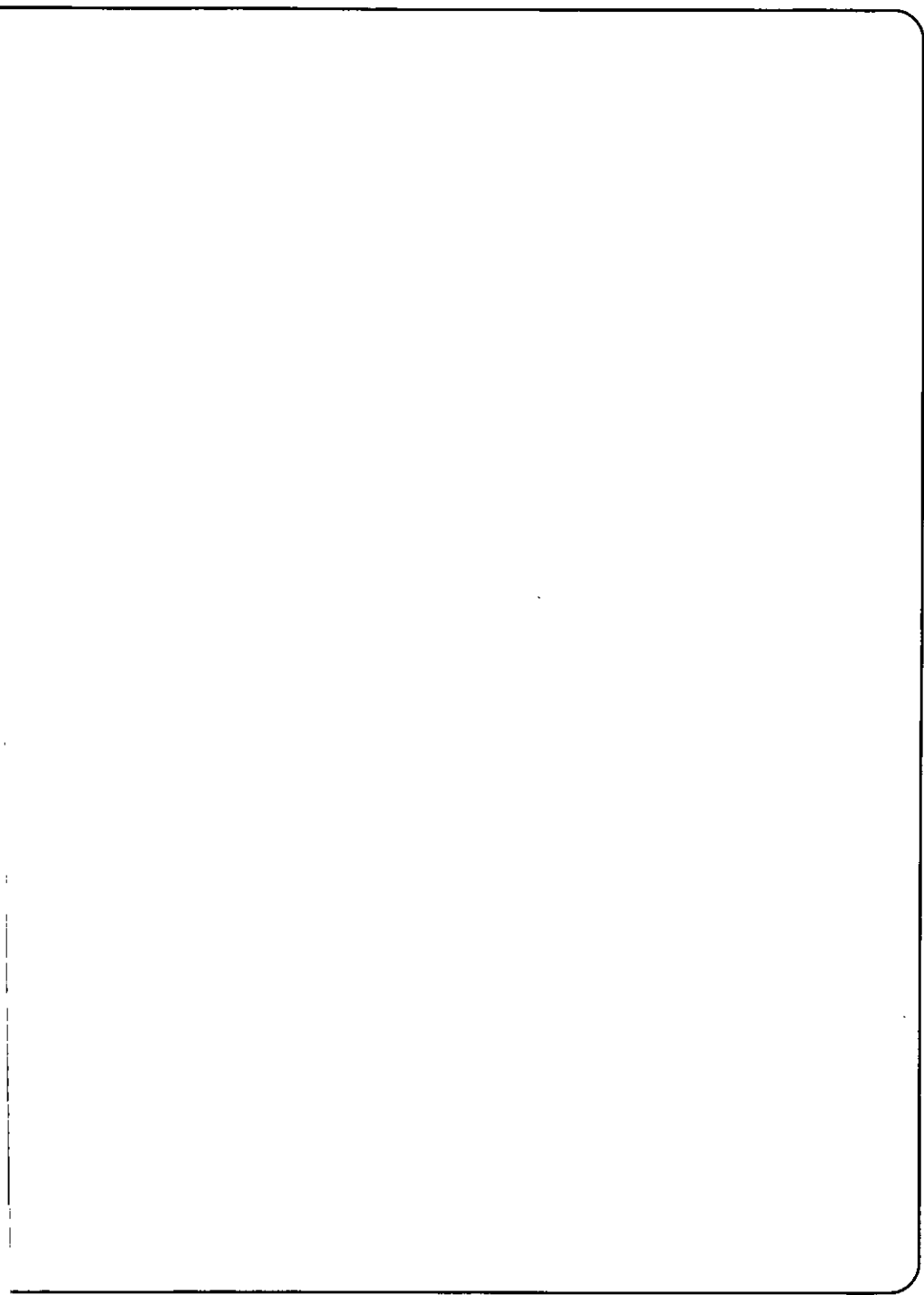
The book describes for the first time the detailed evidence for changing environments at the western, or East Anglian, edge of the North Sea basin before the first local physical glaciation of Pleistocene age in the period 300,000 to one million years ago. The changes described include climatic changes from temperate to frozen ground conditions, changes in vegetation from tundra to forest and changes in sea-level. The coastal areas of East Anglia contain the most detailed evidence in Western Europe of such changes. The volume is of particular relevance to studies of climate and environmental changes which are so important for our present civilisation.

The work is composed of entirely new material published here for the first time. It is of great originality and likely to become a classic because of the substantial basis it provides and because of the international importance and significance of the subject.



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Appendix 2. Marine mollusc faunas, by P.E.P. Norton

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The Plates

to zero, positive feedback mechanisms insure that their sedimentary properties evolve rapidly, thus defining a natural boundary at which discrimination is not difficult. Thus we place the boundary of till within what have been known as flow tills, and waterlain tills would be excluded.

4. Definition of till

Our preferred definition is:-

Till is a sediment whose components are brought into contact by the direct agency of glacier ice, and which, although it may suffer subsequent glacially induced flow, is not disaggregated.

There is an obvious problem with flow till. Is a till which flows long after the parent ice has melted a flow till? According to our preferred definition it is not. The flow must be glacially-induced. This flow could be subglacial, under the influence of pressure gradient or shearing force; or it could be supraglacial flow down an ice surface or off the flanks of a sediment covered dead ice ridge. It could not, however, be a flow of till after glacier ice had disappeared.

Good criteria to determine this do exist. For example, diamicton on a supraglacial kame summit would be flow till.

5. Grain by grain accumulations in air under gravity

Important accumulations of scree-like material frequently occur in association with valley glaciers. These may be screes that fall from flanking valley sides onto the glacier or against the glacier, or they may be screes which accumulate from debris particles which fall from a glacier ice cliff (an important component of alpine lateral moraines).

In both cases these are regarded as screes rather than till, analogous to stream-deposited or lake-deposited sediments on a glacier surface neither of which fall under our definition of till.

6. Lee-side till

It was felt that this was an inappropriate term. It is useful to note the existence of a common facies assemblage of melt-out till, flow till, lodgement till, scree, debris flow, fluvial and lacustrine material, which is often glacially deformed, in the lee of bedrock hummocks beneath glaciers. The term lee-side till for this assemblage is unnecessary when the individual components can be readily identified.

7. Deformation till

Banham (1977) argued cogently that subglacial sediment or

bedrock, of no matter what origin, that has been glacially-deformed sufficiently to overprint pre-existing sedimentary structures by penetrative deformation should be termed till. There is strong evidence for such deformation both in ancient sediments and from modern glacial environments.

We propose that Elsons (1961) term deformation till should be applied to this material. This falls within our definition of till, as in this case, the mode of aggregation of the grains is a direct result of glacially-induced strain patterns and the grains can thus be said to have been "brought into contact by the direct agency of glacier ice".

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ICE MOVEMENTS IN SOUTH-WEST IRELAND: COMMENTS ON THE SUPPOSED CONNACHTIAN GLACIATION

By W.P. Warren

The recent ideas on glaciation in Ireland proposed by Francis Synge in Quaternary Newsletter No. 28 (Synge, 1979) are, typically, new, fresh and challenging, and may yet become standard. However, at present, there is little field evidence to substantiate them in so far as they suggest the introduction of yet another glaciation, the Connachtian. This note considers the broad question of the Connachtian Glaciation, which Synge distinguishes as a new and separate glaciation on the basis of the distribution in the midlands, especially around Slieve Bloom, of Galway granite erratics, and on the occurrence in the east and south of the country of overdeepened river estuaries. However, it must be stated that there is no reason why these phenomena should not relate to the early part of the Midlandian cold period (cf. Mitchell, 1977) or to the Munsterian. Quite simply, the question must be asked: why introduce yet another glaciation, when there is yet evidence of but one interglacial?

This note will consider the opinions of Synge only in so far as they refer to south-west Ireland. It also considers the comments made by Lewis (1979) with regard to the peninsula of Corca Dhuibhne. (Dingle

Peninsula) This is done in an attempt to clarify the factual information concerning the Quaternary deposits in that area, and is based on the results of an on-going programme of mapping the Quaternary geology of south-west Ireland.

The Shannon Mouth Ice-Shed

The only area of outcrop of Connachtian deposits is said to be the "Munster Corridor" (Synge, 1979), where a supposed relative absence of erratic boulders of Galway granite has, coupled with a high incidence of Carboniferous limestone erratics in the north Kerry lowland area (despite their absence in the Limerick/north Kerry upland area), suggested to Synge that a Connachtian ice-shed extended across the Shannon estuary and produced an easterly moving ice sheet in north Kerry. Mapping has shown, however, that Galway granite erratics abound in the tills on the south side of the Shannon estuary, and Charlesworth (1953, p. 202) indicated a wide spread of Galway granite erratic boulders in Munster, with no apparent discrepancy in north Kerry (Fig. 1). The apparent discrepancy in the distribution of limestone erratics in relation to an ice movement from the north-east (Synge, 1979, p. 9) is most likely due to selective post-depositional weathering in response to variations in groundwater pH levels, varying thickness and texture of the glacial deposits. For example, tills resting on Namurian bedrock in the north Kerry lowland area are leached of carbonates to a depth of 2-4 m, whereas leaching in the deposits resting on limestone is less than 0.5 m. As tills in the upland area tend to be less thick than those on the lowland they are frequently leached-through, however, calcareous till exists below a 3.5 m thick leached horizon in the Stacks Mountains 14 km east-north-east of Tralee. Furthermore, much of the recorded limestone till in north Kerry outcrops in incised stream beds and does not represent the surface deposits sensu stricto. The till overlying Namurian bedrock on the south side of the Shannon estuary is leached of carbonates to a base level controlled by the high tide mark where it is less than 4 m thick. Thus, at low tide, a calcareous till can be traced from Tarbert to the bedrock exposures south of Beal Point.

Striae on the south side of the Shannon estuary, in Kerry, run consistently NE - SW, while those on the north side have both an E - W and a NE - SW orientation. This is consistent with a single ice lobe across the mouth of the Shannon fed from the north or north-east. The striae further up the estuary relate to the retreat of this lobe.

Clearly, there is evidence in north Kerry of ice movement from the north and north-east, and erratics of southern provenance indicate that the southern part of the Munster Corridor was glaciated from the south (Warren, 1977), but there is no apparent reason why a west to east ice movement should be considered at this stage. A single occurrence of east-west oriented striae on the Kerry/Limerick border (Fig. 1) is not sufficient.

As the stratigraphy at Ballybunnion indicated (Warren 1980b), some of the tills in the Munster Corridor seem to be older than Midlandian, but, as the location of the Midlandian ice limit is doubtful, the extent of the

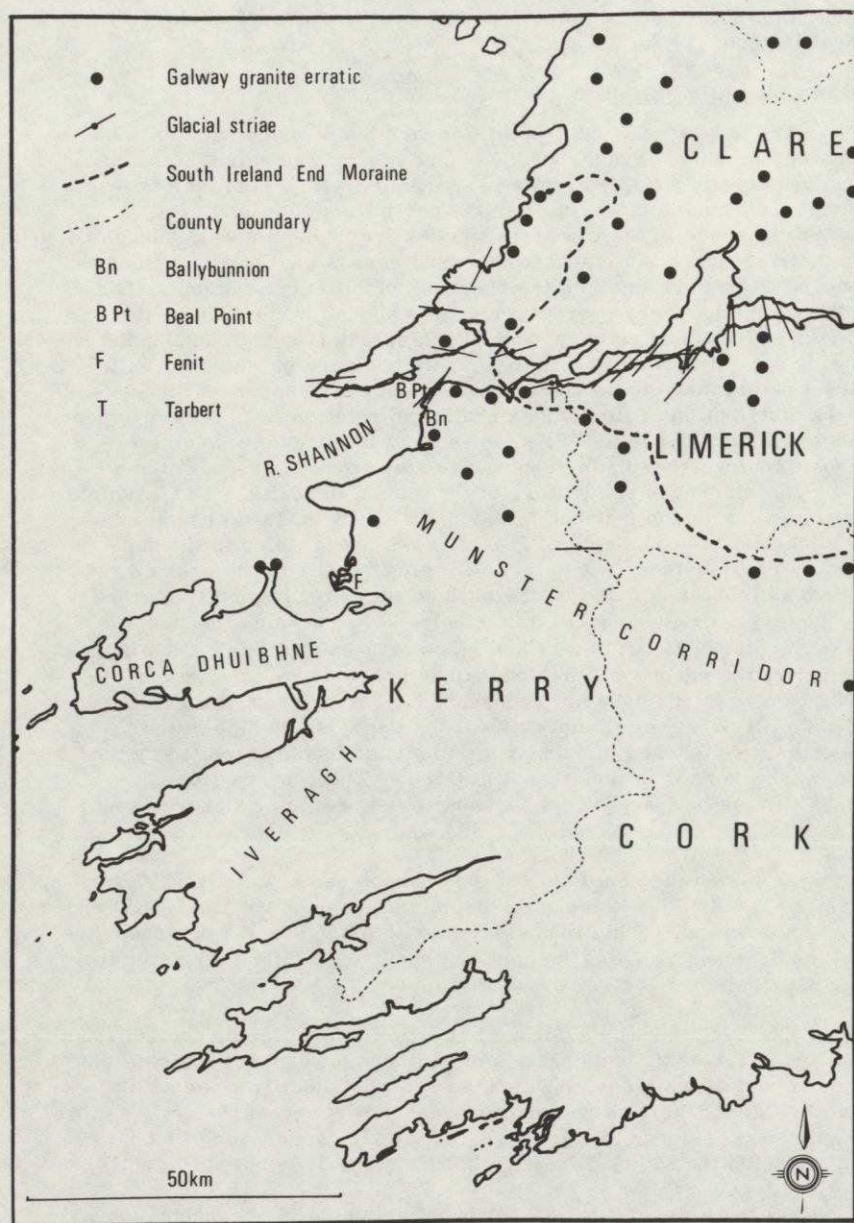


Figure 1. Distribution of Galway granite erratics in Clare, west Limerick and north Kerry. Based on maps from the Farrington Collection and manuscripts in the Geological Survey of Ireland.

older till has not been determined. The north Kerry deposits between Fenit and Ballybunnion may be regarded as Munsterian, that is, the penultimate glaciation, but there is no evidence in the area of a third glaciation.

Corca Dhuibhne (often misnamed the Dingle peninsula)

The problem of the erratic occurrence of Inch Conglomerate fragments (Synge 1979, Lewis 1979) is not a simple one, and, if nothing else, illustrates the dangers inherent in using a single tracer erratic to interpret patterns of former ice movement. However, a number of points with regard to its distribution should, and can, be appreciated:

1. The Inch Conglomerate Formation outcrops for more than 90% of its extent on the south side of the watershed of the peninsula (Fig. 2, Horne 1974), but its occurrence in the tills on the north side is extremely common and widespread.
2. Not only is this erratic common in the tills exposed on the north coast of Corca Dhuibhne, along Tralee Bay, but, on the south coast of the peninsula, along Castlemaine Harbour, it is common in torrent gravels, and occurs in great numbers in the modern beach and occasionally in till.
3. Ice is not the only means of erratic carriage. Undoubtedly, there were many gravel fans and scree cones with high Inch Conglomerate content already in erratic positions on the preglacial landscape, just as there are now.
4. On Fig. 2 the relief is indicated by the 400 m contour and clearly shows that south - north moving ice, pushing against the mountains of Corca Dhuibhne, would most easily breach them between Caherconree and Stradbally Mountain, and carry Inch Conglomerate erratics over precisely the area of Inch Conglomerate erratic occurrence indicated by Lewis (1979) on the north coast.

With regard to the other erratics mentioned by Lewis - fresh limestone and Silurian "slates" (properly, mudstones), the following should be noted:

1. The limestone erratics are of uncertain provenance; they are as likely to have come from the south as from the north, for the carriage distances are similar, considering the erratics occur on either side of the watershed, in the Finglas and the Emlagh valleys.
2. The Silurian "erratics" at Caheracrutera, on the southern side of the peninsula cannot be used as tracers, for the Silurian mudstones here are most commonly regarded as basically in situ inliers (Capewell 1951, Horne 1980), and, bearing in mind their highly localised occurrence, this seems the most reasonable interpretation. The alleged erratic character of these rocks is based on circular reference; Lewis (1974) refers to Parkin (pers. comm.) as his source, and Parkin (1976) refers to Lewis (1974) as his source.

There is also some question as to the mode of carriage of the so-called Galway granite erratics of the area. These are found exclusively in coastal areas, and, in Corca Dhuibhne, are not found in situ in tills, and may have been ice-rafted into position. There is also considerable doubt as to the provenance of some of these "granite" erratics.

On balance, there is a very strong argument for a general south - north movement of ice over the peninsula (Devonian erratics at

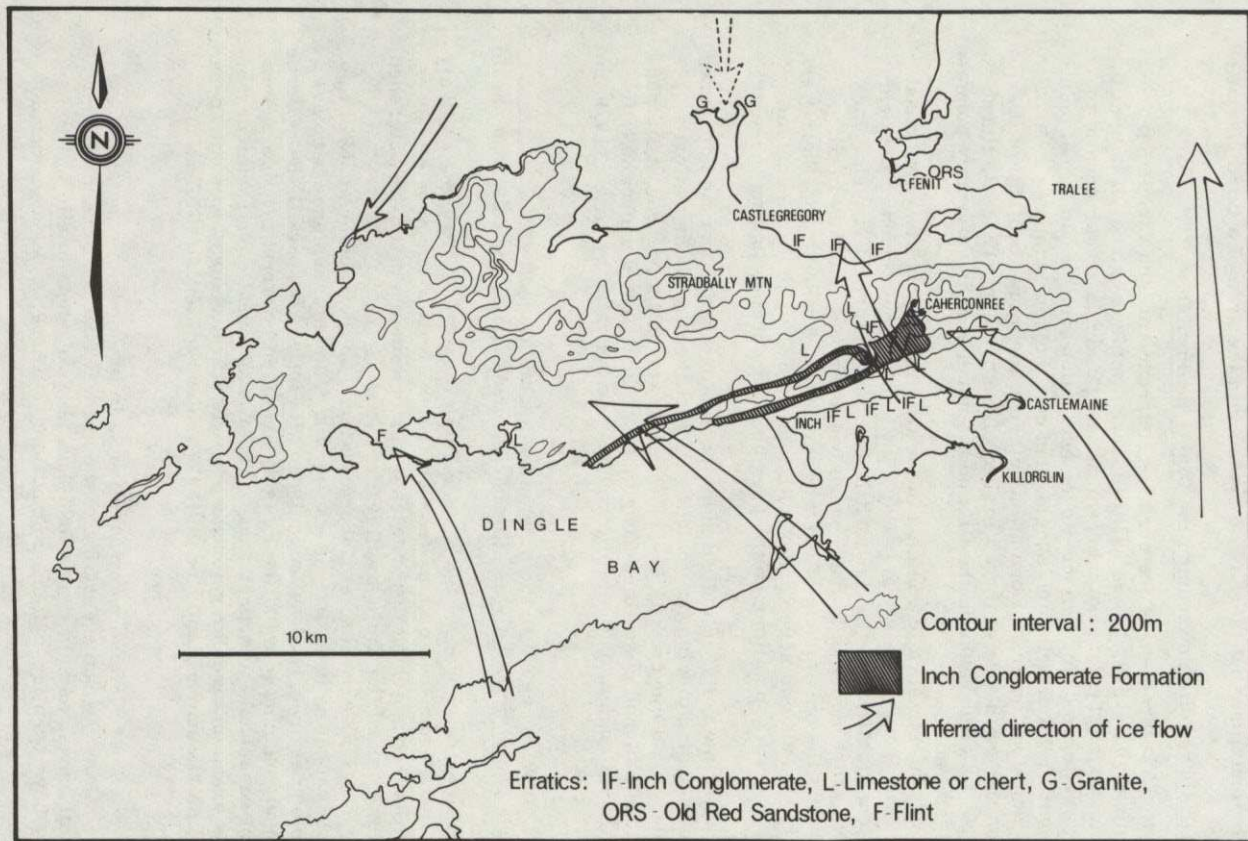


Figure 2. Inferred directions of main ice movement over the peninsula of Corca Dhuibhne (Dingle).

Fenit and Inch Conglomerate and sandstone erratics in the till on the northern coast of Corca Dhuibhne), and little or no evidence for a movement in the opposite direction. Undoubtedly, as Lewis (1974) pointed out, the local picture is somewhat complicated by a general radial dispersal of local ice from the cirques.

The Raised Beach

Lewis asserts that no one has provided "acceptable evidence" that the raised beach "on the south coasts (sic) of Ireland" (Lewis, 1979) is younger than the Munsterian (i.e. that it is last interglacial). Reference should be made to Bowen (1973), Synge (1977) and Warren (1977a, 1977b, 1979, 1980a, 1980b). The support that this interpretation receives objectively in the field can be gauged from Bryant and Quinn (1979). Lewis is concerned that discussion of the stratigraphic position of the raised beach might lead to circular argument. However, the only circular argument regarding this beach is the traditional one: "The glacial deposits directly overlying the raised beach are Munsterian (because it is pre-Munsterian). The raised beach underlies Munsterian deposits. Therefore, the raised beach is pre-Munsterian." This is ultimately the basis of Lewis's argument, and is, of course, a classic example of the logical fallacy of petitio principii or begging the question.

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AN EARLY DEVENSIAN GLACIATION IN EASTERN ENGLAND REITERATED

By A. Straw

My previous note in Quaternary Newsletter No. 28, 1979) has fulfilled part of its purpose in provoking at least one response. Dr. J. Catt however (Quaternary Newsletter No. 30, 1980) prefers to take a relatively narrow view, challenging specific aspects rather than looking at the broader issues, and defends what I mischievously called 'the fashionable view'.

It is unfortunately necessary, before returning to the central issue, to discuss these specific aspects again in this note to refute the

misrepresentations and reveal the apparent misconceptions that Catt's note contains.

Catt grossly misrepresents my views in the paragraph that links pages 6 and 7 of his article. In the first instance my argument was structured deliberately to draw attention primarily to features, stratigraphic and geomorphic, that could not easily be accommodated within the Late Devensian glaciation. It is the nature, scale and significance of these features which enforce postulation of an Early Devensian glaciation, an exercise that formed a conclusion to, not the substance of my note. Second, my point about reliability of the Dimlington radiocarbon dates was misconstrued. What was called in question was not their precision with respect to the age of the mosses (Penny et al, 1969), but the reliance that can be placed on their use, in the total British context, to define the maximum age for all Devensian tills. Finally, my statement that petrographic techniques should complement traditional geological and geomorphological ones can hardly be taken to imply that they should be subordinate. All types of evidence should be taken equally into account, though it is manifestly Catt's opinion that geomorphic evidence is less equal than other types.

Two glacial stages

It was interesting to read that my main geomorphological argument for two Devensian glaciations is based on contrasts in glacial morainic topography in Lincolnshire and Holderness. Such contrasts are only one component of a complex model. Meltwater channels, drainage patterns, river terrace sequences, borehole data, periglacial features and lacustrine phenomena, together with examination of many exposures of surficial deposits have been the concern of fieldwork over eastern England and of contemplation in a variety of models for some 25 years. Much of this work has been incorporated in a comprehensive scenario for Pleistocene events in eastern England (Straw, 1979b). While difficulties of interpretation have been met in all those aspects mentioned above when only a Late Devensian glaciation is envisaged, they have been eased when an Early Devensian glaciation also is considered as a substantial event in eastern England.

Age of the glaciations

Several particular situations in eastern England bear on the age of the glacial stages, some of which were discussed previously and must perforce be commented on again.

To dwell on the relative ages of elements in the derived faunas of the Marine Gravels of east Lincolnshire and Holderness is to ignore the more important considerations of the stratigraphic position and geographic location of the gravels themselves. Catt agrees that the latter comprise outwash from Late Devensian ice, but he does not explain why they occur

only in east Holderness and in outwash trains immediately west of and parallel to the Killingholm and Hogsthorpe moraines. Why do they not occur along the Devensian maximum limit (especially if it is Late Devensian) in outwash materials which exist at Winteringham and Horkstow west of the Humber gap, at Kirmington (on the south side of the interglacial deposits), at South Elkington west of Louth, and at Stickney in the Fens? The presence of the shells only eastward of the Devensian maximum limit and in gravels that overlies tills emplaced by ice that advanced to this limit indicates either that somehow they became available between two closely-timed stadial stages of the Late Devensian glaciation (appropriate circumstances being very difficult to envisage), or that the earlier advance was considerably older than Late Devensian, with a long interval (Middle Devensian?) of changing and complex environmental conditions being available for the primary shell-bearing deposits to be exposed and/or deposited before the Late Devensian.

Catt's comments on the Kirkby Moor Sands near the mouth of the Bain valley reveal some unfamiliarity with the locality. I reiterate that these Sands are spatially and lithologically separate from and older than the Tattershall Gravels and their extensions at Kirkby-on-Bain. It is marginally possible that the Sands are late Wolstonian, but they would then have to be separated stratigraphically from the aggradational Hemingby Terrace gravels because the latter certainly did not accumulate until erosion of the middle Bain valley (a late Wolstonian initiation) had proceeded into Lower Cretaceous rocks below a thick sequence of Wolstonian drifts (Straw, 1966). The Hemingby Terrace gravels are at least seven metres thick and consist of cross-bedded seams and lenses of gritty sands and flint gravels deposited by an aggrading, braided stream system under cold climatic conditions. This aggradation certainly gave way to erosion which carried the floor of the Bain valley well below the base of the Hemingby Terrace gravels before renewed deposition produced the Tattershall and Kirkby-on-Bain Gravels, so what processes does Catt envisage in his vague phrase 'a short period of intense periglacial incision'? The most plausible explanation for both the Hemingby Terrace aggradation and the subsequent incision is the rise and fall of the level of Lake Fenland acting as local base-level for the Bain valley, rather than any dramatic change in environmental conditions. Catt is quite wrong in his statements that the Tattershall Gravels overlie Middle Devensian organic horizons and that these horizons do not indicate the age range of the Gravels. The organic horizons comprise discrete lenses at different levels within the Gravels and related deposits at Kirkby-on-Bain, have provided a range of radiocarbon dates between 44,300 and 30,800 b.p. (BIRM-448, 250, 450, 398, 409, 341, 408), and contain evidence of at least one episode of considerable warmth (Girling, 1974; Coope, 1977).

Catt touches briefly on the problem of dating Lake Humber and clearly places as much faith in the solitary ^{14}C date reported by Gaunt (1974, 1976) as he does in the Dimlington dates. Yet how does this date of 21,835 \pm 1660 b.p. (IGS C14/96; St. 3903), obtained on an unidentifiable fragment of bone found 3.05 m below the surface in a temporary section at

or near the base of a sand and gravel deposit near Brantingham (SE 93852918), stand in relation to the two dates on the Dimlington mosses? If the latter are taken at face value then it seems very unlikely, in view of Dimlington's location, that Devensian ice could have closed the Humber and Wash gaps effectively before that time and the maximum level of Lake Humber could not have been achieved before about 18,000 b.p. Gaunt, allocating the sand and gravel deposit to his Older Littoral Sand and Gravel largely on geomorphic and altitudinal criteria, claims no more than that the Brantingham date puts an older limit to Lake Humber. But what was happening to that piece of bone for almost 4,000 years before burial in the sands and gravels, and how reliable therefore is the date based on it?

Broader issues: pro-glacial lakes and an Early Devensian glaciation

Catt's discussion makes no serious attempt to resolve the very important and far-reaching question of the age of maximum Lake Humber, a question which in my view is critical for the Devensian sequence in eastern England, and which overshadows any parochial argument over glacial morainic topography in Lincolnshire.

The recent work by Gaunt (1976; Gaunt *et al.*, 1972) confirms not only the presence of strandline deposits of local character ranging up to 33 m O.D. which he ascribed unequivocally to the high-level stage of Lake Humber, but also that these deposits are quite separate, spatially and stratigraphically, from the 25-Foot Drift of the Vale of York and its marginal sands laid down during the low-level stage of Lake Humber.

There seems little doubt that Lake Humber once reached about 30 m (100 feet) during the Devensian. Equally there is little doubt that the Lincoln gap through the Jurassic cuesta existed by the Devensian with sufficient depth to ensure that when Lake Humber reached 30 m O.D., either a comparable body of water occupied the Fen region or the gap was closed by ice. Because Devensian ice approached no closer than 37 km to Lincoln, a Lake Fenland must have existed. However, no worker on Fenland Quaternary deposits or landforms has ever brought forward evidence for Late Devensian strandline features up to 30 m O.D., even though claims abound that high-level Lake Humber was a Late Devensian phenomenon. This impasse will persist as long as the maximum Devensian ice advance and high-level Lake Humber are considered to be Late Devensian. It does not exist if these events were Early Devensian. Strandline features ranging up to 30 m O.D. are present in the Fen basin but can be shown, for example at Kirkby Moor, to be older than Middle Devensian, and a claim has been lodged elsewhere (Straw, 1979a; Straw, 1979b) that the higher strandline features of the Humberhead area are considerably older than the Late Devensian.

Extensive though the conjoint Lakes Humber and Fenland were, their significance in regional Quaternary history goes beyond strandline features and bottom deposits. For a time they not only provided a higher

base-level for all streams flowing into them but all subaerial geomorphic processes were suppressed over the submerged areas. Their shapes and water-levels were controlled not only by the ice plugs in the Humber and Wash gaps, but also by the pre-existing physiography and especially the gaps at Lincoln, and at Lopham in East Anglia, and as they drained away so fluvial processes were reactivated, though not always along pre-lacustrine lines.

The lakes therefore loom large in the Devensian history of eastern England, the problem of their age influences our perception of this history and alternative models should be assessed dispassionately. In my first note I questioned the degree of success of that model which incorporated only a Late Devensian glaciation, and finding it deficient, introduced an alternative which is discussed more fully elsewhere (Straw, 1979b).

I do not find Dr. Catt's defence of the 'Late Devensian glaciation only' model convincing and will continue to look favourably on an Early Devensian glaciation until incontrovertible evidence against it is forthcoming and convincing answers (alternative to my own) are given to the questions of detail which I have raised in these two notes.

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QUATERNARY SHORELINES IN MALLORCA

By O. Davies

I have read with care the report in Quaternary Newsletter No. 29 (November 1979) relating to Quaternary shorelines in Mallorca. I am much interested, as I have been collecting evidence on Eem shorelines from all over the world, particularly in view of the warm fauna which we get at that time in the South Cape of Southern Africa. There is abundant evidence from the Mediterranean, but it seems hopelessly confused and contradictory, largely owing to failure to standardize terminology and to grave doubts on the published U/Th dates on molluscs.

The Quaternary Research Association Study Course to Mallorca (Crabtree *et al.*, 1978; Rose and Maizels, 1979) seems to have relied largely on the work of Butzer (1975), who constructs his sequence from the unreliable dates of Stearns and Thurber. He finds Strombus bubonius in the Mediterranean in two and probably three interglacials (probably Stages 5, 7 and 9), without explaining what happened to this warm fauna during the intervening peak-glaciations when the Mediterranean received much cold melt-water and the Atlantic incoming water also was probably very cold. The best evidence for pre-Eem Strombus bubonius in the Mediterranean is that of Bigazzi and Bonadonna (1973), who do not use U/Th. But no one except Meco (1977) has considered possible confusion with Strombus coronatus.

Mediterranean work seems largely marred by several faults, which can be summarized as follows.

- a) failure to correlate with other parts of the world;
- b) failure to recognize more than one peak of Eem age;
- c) failure to distinguish Strombus in growth-position (-10 m) from Strombus washed up on a beach;
- d) tendency to accept high radiocarbon-dates on carbonates and so often to equate Neotyrrenian with intra-Würm;

e) failure to take account of the theories of Hollin (1977), which are at present considered suspect, but in view of certain figures from the South Cape and from Lebanon deserve more consideration.

The visit of the INQUA Shorelines Commission to Sardinia in April 1980 strongly suggested that there had been a fluctuation during the transgression to the peak of Eem I (Stage 5e) with two marine deposits separated by a short terrestrial episode. There may have been a similar sequence in southern Tunisia as described by Paskoff and Sanlaville and there is a more definite description from the Kerkennah Islands off Sfax by Delteil and Lamboy. I have recognised a similar sequence in the eastern Cape Province of South Africa, which will be published shortly. Sardinia has produced no reliable evidence for Strombus bubonius or other Senegalese fauna in an interglacial before the Eemian.

I would strongly agree that Mallorquin shorelines would be an excellent subject for further study, but it must consider in detail the whole genus of Strombus with considerable attention given to evidence from the rest of the Mediterranean.

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EXTENDED ABSTRACT OF A PAPER READ AT A DISCUSSION MEETING ON:

OFFSHORE AND ONSHORE QUATERNARY OF
NORTHWEST EUROPE - THE SCOPE FOR CORRELATION.

This meeting was held at the Institute of Geological Sciences, Murchison House, Edinburgh on January 4th and 5th 1980.

THE DEVENSIAN LIMIT IN ENGLAND:
GENERAL CONSIDERATIONS

By E. A. Francis

It has long been recognized that the surface of the drift in England could be differentiated into two contrasting types of topography. The placing of the line separating these has changed in detail over the years, but it has generally approximated to what is now referred to as the Devensian limit, although the emergence of such a conclusion has not been a simple process.

Following the general acceptance of the glacial theory, the extent and character of the glacial drifts were widely studied. Ramsay was aware of their distribution over most of the country almost as far south as the Thames. James Geikie (1874) commented upon the different kinds of glacial materials in Scotland, and was clearly convinced that moraines were formed from material that was directly derived from the bounding valley sides, while till had quite a different origin, being derived from the bedrock over which the ice moved. Geikie also remarked that other stony clays were found in certain districts, and though these were sometimes quite impossible to distinguish from "true or typical till", there were lithological differences, and he therefore used a different term for these materials: 'boulder-clay'. Geikie believed that boulder-clay was "the conjoint production of the ice-sheet and the sea — consisting partly of true moraine profonde and partly of the nature of a submarine terminal moraine". Thus till and boulder clay were not synonymous.

Geikie described also the succession in N.W. England in similar terms. Upon bedrock lay true till, but at low levels the till was overlain by stony clay of contrasting lithology but strongly resembling the Scottish boulder-clay and interpreted as having been deposited "along the seaward edge of the ice-sheet at a time when this was melting and slowly retreating inland". Above this boulder-clay were up to 200 feet of sand and gravel interpreted as marine, and these in turn by another clay known as the "upper boulder-clay" interpreted as having been

accumulated by the scattering over the sea-bottom of material transported by detached masses of coast-ice breaking off from the shore. At still higher levels, gravels occurred in the valleys and when traced upstream became "coarser and earthier" and appeared to pass into moraine debris. The drifts of N. East Anglia were mainly interpreted similarly in terms of a marine origin, it being visualized that "large bergs and ice-rafts, launched from the shores of Scandinavia, sailed across the North Sea and dropped their boulders over what is now dry land". But Geikie claimed on the basis of the shells in the associated deposits, that the East Anglian glacial beds were older than those in other parts of Britain such as Scotland and Lancashire. Rather different conclusions were reached by Carvill Lewis in papers read in 1887 and published in 1894. "The task of attempting to gain a conception of the history of the glacial period in England by reference to literature is, as I know by some experience, a hopeless one. Many excellent geologists have given up the attempt to explain the phenomena of the glacial epoch in England, regarding the whole subject as a puzzle, the key to which has not yet been found." Lewis also wrote, "The great principle upon which I shall firmly insist is that every glacier at the time of its greatest extension is bounded and limited by a terminal moraine." The boulder clay and gravels outside of these moraines can be explained as the result of floating ice and flowing water". According to Lewis, "the largest of [the British] glaciers started in the west of Norway, flowed south and southwest into the North Sea, where it was joined by other glacial streams coming from Norway and Scotland, until the North Sea was completely filled by it. It reached the shore of England at Holderness. The terminal moraine which this glacier formed, where it ended at the coast of Yorkshire, is both in form and in composition as typical a moraine as any in Switzerland. It is a conspicuous feature of the landscape, marked as a line of drift hills, sometimes of till and elsewhere of stratified sand and gravel".

The great moraine could be traced in a nearly straight line along the western flank of the Pennine Chain to Macclesfield and through Congleton to Madeley and thence southward to Wellington, where North Welsh rocks appeared in it as the result of a glacier coming east from the Snowdon region. The medial moraine between these two was seen (or rather "beautifully exhibited") at Ellesmere.

To Lewis, the margin of the directly glaciated region was clear. Beyond this, the country was partially covered by boulder-clay, deposited in water. By 1914 the picture was not so clear. Wright realized that the strong contrast between the area of East Anglia and the southern Midlands on the one hand, and the north on the other, implied a difference of age, and he referred to the former as covered "by a monotonous sheet of boulder-clay with but little associated gravel, and scarcely any original diversity of surface", whereas in the central plain of Ireland, as an example of more recently glaciated country, although boulder-clay plains occupy great stretches of country, they are interrupted by areas of

drumlin topography, "are strewn over with isolated mounds and moraine debris and traversed by innumerable winding eskers". However, although there was a clear distinction between the two types of topography, Wright also wrote that "it is impossible to draw a definite line separating the older and newer drifts".

On the western side of England, the boundary has moved north from Lewis's margin at Wellington and was for some time located at the Madeley-Whitchurch line. This was regarded as a Newer Drift margin, and there was a general implication that it marked the ice limit during what we would now call the Late Devensian, somewhere between about 25,000 and 13,000 years ago. Boulton and Worsley (1965) stated that this line "must belong to the maximum of the last glaciation", though Poole (1966) in reply wrote that it had been clearly demonstrated that this "moraine suite is considerably older than 40,000 years and cannot be a product of the last or late Weichselian glaciation". Soon after this, Shotton (1967) concluded that the limit lay at Wolverhampton because till derived from the Irish Sea Ice was seen to overlie and therefore to postdate gravels at Four Ashes which contained organic lenses dated up to at least about 30,500 B.P. Periglacial structures affecting the till in the area were probably formed before 13,500 B.P. (Morgan, 1973).

On the eastern side of England, the boundary has moved south from Lewis's position to north Norfolk. Madgett and Catt (1978) have recently propounded the view that the Hesse Clay is the weathered surface of underlying tills, and in this connexion it is interesting to note that Lewis (1894) wrote as follows: "The Hesse 'Clay' — probably only a weathered purple clay". Madgett and Catt (1978) have adopted the suggestion made by Boulton et al. (1977) that the southward extension of the Devensian sediments along the east coast was caused by a rapid glacial surge. However, if the limit in this area is seen as representing the western distal margin of ice in the North Sea basin rather than the lateral margin of a narrow lobe moving south, the absence of a marked gradient can be explained, and the invocation of a surge may then be unnecessary. The sediments at present provide no support for deposition from a surging, or surged, glacier, but little is known of the character of such deposits, and even this is largely if not entirely derived from valley glaciers.

Thus, although the existence of a boundary separating two contrasting types of drift cover in England has been recognized for over one hundred years, realization that this implied a difference in age rather than in environment of deposition took over forty years to emerge. The general difference between the two contrasting areas is more clearly appreciated than the definition of a dividing line, and consequently, there have been many revisions of opinion on the question of the precise placing of the margin. Although further important changes in position are not expected, it cannot be supposed that the detailed placing of the Devensian limit has yet reached stability. Even if this should be achieved, there will still be room for considerable discussion on the reasons for the particular position of the limit.

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BOOK REVIEWS

The Pre-glacial Pleistocene of the Norfolk and Suffolk Coasts. By R.G. West, 1980. Cambridge University Press, 230 pp, 49 tab., 36 plates, 54 figs. Price: £40.

The pre-glacial deposits of the Norfolk and Suffolk coasts, well-known in Quaternary stratigraphy since Clement Reid's studies at the end of the 19th century, have been re-studied by Professor Richard West over the last twenty years, in the field and by means of palaeobotanical research in the laboratory. His results, the main outlines of which were familiar to workers in Quaternary stratigraphy and to those who participated in one of the unforgettable excursions along the coasts of East Anglia (e.g. during the last INQUA Congress in 1977), are now presented in an excellent monograph.

In using the pollen analytical record of past change in vegetation and its palaeoclimatical implication as a framework Professor West has shown the presence of two temperate stages (Pastonian and Cromerian) preceding the first (Anglian) glaciation of the area, and following a "Pre-Pastonian" cold stage, which in its turn post-dates the Early Pleistocene.

Intervening between the two earlier mentioned temperate stages was another cold stage, named Beestonian. In using biostratigraphy as yardstick the author has unravelled the extremely complicated lithology of the coastal sections and has assigned them to their proper chronological and environmental position. Two formations are formally discerned: a lower Norwich Crag Formation and an upper Cromer Forest-bed Formation.

From the above mentioned studies it has appeared that the scheme of lithological succession of Cl. Reid, still quoted in many textbooks, cannot be generally applied as previously believed. Even the "Upper Freshwater Bed", containing the Cromerian stratotype at West Runton, and of Cromerian age at several other sites, may be of quite different age at some others. A very useful comparison of new and old terminology is shown in table 43.

Each major site, starting, as may be expected, with the one at West Runton, is treated in a separate chapter. Each site is documented with photographs, drawings, pollen diagrams and tables showing macroscopic plant-remains. Other chapters are dealing with marine sediments and the relative land-/sea-level changes, environmental history and correlations. Land-sea relations seem to have been complicated. Transgressions occurred in the temperate phases as may be anticipated; another transgression, however, took place in the Beestonian cold stage. Also in the Pre-Pastonian cold stage predominantly marine conditions prevailed.

Several breaks are present in the succession; the time interval of these breaks are difficult to estimate. In particular between the earlier part of the Pre-Pastonian and the later part of the succession a major gap may be present, and also the time gap between this particular substage and older, Lower Pleistocene deposits is unknown. Problems of correlation with continental deposits resulting from these observations are discussed at length.

It is clear that the Cromerian, as presently defined, may be recognized on the continent in several places, where it includes for instance the uppermost interglacial (IV) of the Pre-Elsterian in The Netherlands. Identification of the Pastonian within the continental sequence still presents difficulties, although Interglacial III of the "Cromerian-complex" sequence in The Netherlands may present a good candidate for a correlative stage.

At any rate, in your reviewer's opinion, it is evident that the name Cromerian should be used henceforth only in a clearly defined way, referring to that particular interglacial stage which has been defined at the stratotype of West Runton. Use of this stage name in another sense, even written between inverted commas (as commonly used in The Netherlands) should be avoided.

The book has been well edited, printed and bound; however, the case containing the separate booklet with figures, is so tight that the booklet is difficult to handle.

This monograph on a classical area will certainly remain a classical book itself.

W. H. Zagwijn

Studies in the Lateglacial of North-west Europe. Edited by J. J. Lowe, J. M. Gray and J. E. Robinson. 1980, 215 pp. Pergamon. Price £17.00.

Most of the papers included in this volume were presented at a Quaternary Research Association Symposium in January 1979, and constitute either valuable new material, useful reviews, or new thoughts on old problems such as radiocarbon dating. However, of the 15 authors only one (Jan Mangerud) is from outside the British Isles, and 7 of the 13 chapters deal with British sites and specifically British problems - so it might well be asked whether the title of the book is unduly pretentious. Certainly there must be many European workers, of long experience and the authors of major original contributions to the subject, who would disagree strongly with what is presented in a final chapter by two of the Editors, as "a suggestion for a general stratigraphic scheme, applicable to N.W. Europe as a whole".

The subjects covered by the papers include most aspects of research on the palaeoenvironment of the period c. 14,000-10,000 B.P. Two review contributions, by W. A. Watts and J. E. Robinson, represent informative summaries of the interpretation of climate from respectively palynological and ostracod evidence. Professor Watts ranges over most of Europe and emphasises the wealth and diversity of the information now available on vegetation history; in a shorter contribution Dr. Robinson stresses how work on ostracods in coastal sections round Britain and the North Sea coasts is in an early stage and full of promise. New work on biostratigraphy and its climatic implications is presented from i) 3 sites in Scotland, where it is mainly palynological, by C. J. Caseldine, J. B. Macpherson and J. J. Lowe & M. J. C. Walker ii) the well-known coastal

site at St. Bees, Cumbria, for which G.R. Coope & M.J. Joachim give a full account of the Coleoptera and iii) the North Sea area, for which A.R. Lord describes benthonic assemblages of foraminifera.

Geomorphology in relation to palaeoclimate is the subject of 3 papers. J. Mangerud uses the many available ^{14}C dates for the Scandinavian moraines (13,000-10,000) to trace successive positions of the ice-front, emphasising the importance of topography on the response to climatic change of a large ice-sheet. In a striking paper J. B. Sissons develops his ideas on reconstruction of Younger Dryas climate in northern Britain from glacier morphology. A.G. Dawson attributes to periglacial shore erosion in Younger Dryas time the well-developed raised shore platform of parts of the Inner Hebrides.

Subdivision and correlation within this period of sudden changes in biota and lithology (interpreted as indicative of rapid climatic change) depend on ^{14}C dating. Problems encountered with respect to dates of deglaciation in Scotland form the basis of a discussion by D.G. Sutherland of the errors likely to affect the accuracy of basal radiocarbon dates in newly deglaciated terrain. This is an interesting and thought-provoking contribution, but it would be regrettable if readers were to conclude that there is no profit in trying to date organic deposits of this period. In its second paragraph there is a dangerous suggestion that ^{14}C dates may be suspect (i.e. grounds may be sought for disbelieving them) if they are not consistent with a preconceived pattern. This recalls the incredulity which greeted the early ^{14}C date from Loch Droma among those who thought that the Younger Dryas moraines were out in the Minch. This book is another milestone along the road which has been travelled during the last 20 years, but undoubtedly the period in question still has many surprises in store; the last word has not been said on the Late-glacial.

W. Tutin

FORTHCOMING PUBLICATIONS

Culture and Environment in Prehistoric Wales: Selected Essays.
 Edited by J.A. Taylor. 1980. British Archaeological Reports
 Special Publication.

This volume attempts to achieve a dialogue between archaeologist and geographer through an integrated appraisal of cultural and environmental changes which have taken place in Wales over the past 12,000 years or so. Each of the nine essays is an individual inter-

pretation of the culture or the environment or both for a specific period such as the Upper Palaeolithic, the Holocene, the Mesolithic, the Neolithic, the Bronze and Iron Ages. Some chapters present a broader discussion of the prehistoric successions of Wales in the British and sometimes the European, context. An Appendix is included which lists details of all radio-carbon dated sites in the Principality. Although intended primarily for the academic market the book should appeal to a general readership also. It contains a wide range of maps and diagrams and some photographic illustrations. The book should be of especial interest, as a reference work (both for undergraduates and researchers), to archaeologists, geographers, palaeobotanists, prehistorians and the growing range of scientists concerned with the reconstruction of palaeoenvironments and methods of dating the past.

OBITUARIES

Professor Gordon Manley

It is with regret that we have to report the death of Professor Gordon Manley on 29th January 1980.

Gordon Manley's abiding interest in the Quaternary arose from several sources. Not least among these was his love of landforms shaped by ice. His knowledge of and respect for the wilder parts of Britain and above all the fell country of north west England coloured his writing and speech at all times. He also strenuously affirmed the need for free and fruitful interaction between studies of contemporary environmental processes and the longer term changes to which they contribute and which form their context. This belief was one of the cornerstones of his own research whether on Quaternary themes or on recent climatic change. He sought to foster a meeting in the real world between theoretical and model based insights and those, often confusing and intransigent inferences which empirical observation yields to the most patient student through the written record and the landscape itself. Coupled with his respect for and extraordinary skill in painstaking empirical research was a delightful capacity for stimulating and imaginative speculation. His own unique blend of the two made for memorable conversations full of flavour and provocation, as well as a splendidly distinctive style of writing. His concern with the Quaternary and related themes is well justified in words he used in his Inaugural Lecture at Lancaster: - "The study of movement and of process and of change in the physical world, whether on the geological time-scale or on that of the recent storms, seems to me a logical necessity". Gordon Manley graced that "logical necessity" with work of imaginative distinction. Later in the same paper he states "The Ice Age, in N.W. Europe, represents the greatest of the environmental changes that have

affected man: and its explanation provides one of the greatest problems that this world has to offer. Anything we can do towards solving it may throw light on the reasons for the smaller climatic fluctuations that are occurring today". His lively interest in and concern for individuals as students and colleagues provided invaluable stimulus and support for many who have followed him. All those who share with him a keen taste for the Quaternary and its many mysteries will remember him with gratitude and affection.

F. Oldfield

Professor Leonard Johnson Wills

Professor Wills died at his home at Romsley, north Worcestershire, on December 12th 1979, within sight of his 96th birthday. After serving the University of Birmingham for 36 years (19 as a lecturer and senior lecturer and 17 as professor and head of the Department of Geology), he retired in 1949 but only to continue in research and publication almost until his death. His last great work was a map and memoir on the structure of England and Wales beneath the Upper Old Red/Carboniferous cover, published by the Geological Society when he was 94.

Wills was an amazingly versatile stratigrapher and palaeontologist and though students of the Quaternary will think of him for his work on the Severn valley, they should not forget that this was only a small part of his output, though it must have necessitated years of fieldwork. He wrote on the Lower Palaeozoics, he was an expert on the stratigraphy, palaeontology and hydrology of the Midland Trias. He made delicate preparations of Triassic and Carboniferous scorpions, of the Carboniferous eurypterid Authraconectes and of ostracoderms from the Downtonian and interpreted their anatomy. In contrast to this fine-scale work was the way in which he could switch his mind to consider the deeply buried structure of the country in a way for which posterity, in search of mineral wealth, may well be grateful.

Wills's first Pleistocene publication, whilst he was still a member of the British Geological Survey, was a paper in the Q. J. G. S. on "Late-Glacial and Post-Glacial changes in the Lower Dee Valley". Then followed what appeared to be a long period of inactivity in this field which ended in 1937 when, as President of Section C of the British Association, he read a paper on "The Pleistocene history of the West Midlands". This was a portent of what was to appear in great detail a year later, "The Pleistocene development of the Severn from Bridgnorth to the sea". This was truly a masterly piece of work. Critics have objected to some of his conclusions, sometimes as vehemently as they have disagreed amongst themselves, but Wills was the first to accept reasoned modifications to his original ideas. Nevertheless, the broad interpretation of the Severn terrace sequence, the Ironbridge

Gorge and the concept of Lake Lapworth still holds good, even though some details have been modified.

Wills's influence on Quaternary geology was not bounded by his own work. He was an inspirer of others, in particular of the late Dr. Mabel Tomlinson, who did for the Warwickshire Avon and its tributaries the same sort of pioneer work which he did on the Severn, and in later years of our own member, Sara Peake.

"Jack" Wills was a delightful person to know, but accounts of his gentle kindness, his generosity, his dry sense of humour, his love of nature and his sense of family may be left to the telling of his many friends, who include all his old colleagues and former students.

F. W. Shotton.

WESTBURY - SUB - MENDIP

Wanted: photographs of the Pleistocene site

As part of the work on Westbury-sub-Mendip we are trying to reconstruct the original shape of the cave and establish the distribution of the cave sediments. Therefore we would be very grateful for the chance to see any photographs or slides of the Westbury site, taken before 1974, including any taken during the Q.R.A. visit in 1971. Anyone who can help should contact Dr. Chris Stringer, Department of Palaeontology, British Museum (Natural History), Cromwell Road, London, SW7 5BD.

C. B. Stringer.

MSc IN QUATERNARY STUDIES

This part-time course, run jointly by North London and City of London Polytechnics, is still thriving, and is now recruiting its third intake. Further information and application forms may be obtained from Dr. R. H. Bryant, Department of Geography and Geology, Polytechnic of North London, Holloway Road, London, N.7. The closing date for applications is September 1st, 1980.

R. H. Bryant.

26th INTERNATIONAL GEOLOGICAL CONGRESS - PARIS

July 7th - 17th 1980

This Congress includes a Session S.08: Quaternary - Geomorphology convened by Drs. H. Faure, P. Rognon and J. M. Soons. This includes symposia to consider: 08.1.1. The speed of surface mechanical and geochemical processes in the Quaternary; 08.2.1. Correlation between the evolution of temperate and cold regions in the northern and southern hemispheres; 08.2.2. Reconstruction of Quaternary palaeoclimates in intertropical regions; 08.2.3. Variations in sea-level and their consequences for littoral morphology; 08.2.4. Geomorphology and Neotectonics; 08.3.1. Quaternary stratigraphy in Western Europe; 08.3.2. Differential erosion in plutonic bodies; 08.3.3. Vertical movements responsible for the genesis of first-order reliefs in the context of plate tectonics; 08.3.4. Palaeohydrology and Quaternary lake levels; 08.3.5. Graben systems and their influence on Quaternary stratigraphy; 08.3.6. Correlation of palaeoclimatic data between Quaternary continents and oceans.

The meeting is preceded and followed by Field Excursions (June 26th - July 7th 1980 and July 18th - 27th 1980). A total of 145 papers on Quaternary and Geomorphology problems will be read and these will be included in the Congress Volume of Abstracts. The meeting is being held at the International Center Palace of Congresses - Porte Maillot. Further details can be obtained from Secrétaire Général du 26^e Congrès International, Maison de la Géologie, 77-79, rue Claude-Bernard, F 75005, Paris.

AMQUA SIXTH BIENNIAL MEETING

The Structure of an Ice-Age

August 18th-20th 1980

This meeting has been arranged in conjunction with pre- and post-conference field trips to review the recent developments in the understanding of ice-ages. It comprises five sessions: i) Primary input from fluctuations in ice volume, sea-levels, sea-surface temperatures and salinities, ii) Primary input from terrestrial precipitation cycles and vegetation responses, iii) Second stage reconstruction and modelling of organic and atmospheric circulation, growth of marine and terrestrial ice sheets, iv) Driving mechanisms including solar variations, orbital geometry and feedback from ice-sheets, oceans and volcanic activity, v) Human actions and reactions in the past, present and future.

The meeting will take place at the University of Maine, Orono, and the programme chairman is Dr. Bill Farrand, Quaternary Research Laboratory, Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan, 48104, U.S.A.

QUATERNARY RESEARCH ASSOCIATION PUBLICATIONS FOR SALE

Quaternary Newsletter

Nos.	Price to Members		Price to Non-members
1-3	10p		40p
4-9	out	of print	
10-13	30p		60p
14-22	40p		80p
23-26	50p		£1.00
27-28	out	of print	
29-31	50p		£1.00

Quaternary Research Association Field Guides

<u>Title</u>	Date	Editor/Compiler	Price to Members	Price to Non-members
Clacton	April 1973	J. Rose & C. Turner	£1.00	£2.00
Exeter	Easter 1974	A. Straw	£1.00	£2.00
Aberdeen + Quaternary Studies in North East Scotland	April 1975	A.M.D. Gemmell	£2.00	£4.00
Oxford Region	April 1976	D. Roe	£1.00	£2.00
Bristol	Easter 1977	K. Crabtree	£1.00	£2.00

Keele	April 1978	E.A. Francis	£2.00	£3.00
Vale of St. Albans	June 1978	J. Rose & P.L. Gibbard	£2.00	£3.00
Mallorca	December 1978	K. Crabtree, J. Cuerda, H.A. Osmaston, & J. Rose	£2.00	£3.00
East Central Ireland	April 1979	A.M. McCabe	£2.00	£3.00
Glasgow Region	Easter 1980	W.G. Jardine	£2.00	£3.00
Inverness Region	May 1980	F.M. Synge & J.S. Smith	£1.00	£2.00

Any of these publications can be obtained by writing to the
Hon. Sec. Mr. J. Rose, Department of Geography, Birkbeck College,
University of London, 7-15 Gresse St., London W1P 1PA.

CALENDAR OF MEETINGS

June 29th- July 6th 1980	V. International Palynological Conference, Cambridge. Information can be obtained from Mrs. G.E. Drewry, Geology Dept., Sedgwick Museum, Downing Street, Cambridge, CB2 3EQ.
July 7th-17th 1980	26th International Geological Congress, Paris, at the International Center Palace of Congresses - Porte Maillot. Section 08 is devoted to Quaternary Geology. Further details can be obtained from Secrétariat Général du 26 ^e Congrès International, Maison de la Géologie, 77-79, rue Claude-Bernard, F 75005, Paris, and a note is included in this Newsletter.
August 18th-20th 1980	AMQUA. Sixth Biennial Meeting. The Structure of an Ice Age. Orono, Maine, U.S.A. Further details can be obtained from Professor W.R. Farrand, Quaternary Research Laboratory, Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan, 48104, U.S.A. and a note is given in the Newsletter.
September 1st- 5th 1980	Annual Meeting of the British Association for the Advancement of Science. University of Salford. Details can be obtained from Dr. L.B. Halstead, Dept.

of Geology, University, Reading, RG6 2AB. This meeting includes a consideration of 'Geology and Conservation' on Tuesday 2nd Sept., 'Red Beds' on Thursday 4th Sept. and 'Ice Ages through Time' on Friday 5th Sept. The ice age session includes lectures by W.B. Harland, N.J. Shackleton, D.Q. Bowen and P. Worsley.

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| September 1st-11th 1980 | INQUA Sub-Commission on shorelines of North West Europe. Field Excursion based on Oban, Glasgow, and Lancaster. Approximate price £220. Further details can be obtained from Dr. W.G. Jardine, Dept. of Geology, University of Glasgow, Glasgow, G12 8QQ. |
| September 18th-21st 1980 | Quaternary Research Association Short Field Meeting to West Cornwall under the leadership of Prof. N. Stephens and P. Sims. Further details and a Registration Form are given in the Circular issued in February 1980. |
| October 24th-26th 1980 | British Geomorphological Research Group. Magnitude and Frequency Concepts. Liverpool. Further details can be obtained from Dr. A. Harvey, Department of Geography, University of Liverpool. |
| January 5th-6th 1981 | Quaternary Research Association Discussion Meeting to consider the findings of the I. G. C. P. /UNESCO Project 24 Sub Committee on Glaciations in the Northern Hemisphere. |
| January 5th-8th 1981 | British Geomorphological Research Group/Institute of British Geographers. Materials in Geomorphology. University of Leicester. Further details can be obtained from Dr. V. Gardiner, Department of Geography, University of Leicester, Leicester, LE1 7RH. |
| March 25th-26th 1981 | Geological Society of London /British Geomorphological Research Group. Residual Sediments. At the Geological Society. Further details can be obtained from Dr. C. Wilson, Geological Society, Burlington House, Piccadilly, London, W1V 9HG. |
| March 20th-29th 1981 | British Geomorphological Research Group - International Meeting. Mega-Geomorphology. At London School of Economics/Kings College, London. Further details can be obtained from Dr. D. Brunson, Department of Geography, Kings College, Strand, London, WC2R 2LS. |
| April 12th-15th 1981 | Quaternary Research Association Annual Field Meeting and Annual General Meeting to the East Midlands, |

based on Leicester, under the organisation of Dr. R.J. Rice. Further details will be given with the November 1980 Circular.

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| May 1st-4th
1981 | Quaternary Research Association Short Field Meeting to study glacial and periglacial features in North Wales under the leadership of Dr. J.M. Gray, J. Ince, J.J. Lowe and S. Lowe. Further details will be given in the November 1980 Circular. |
| May 15th-18th
1981 | Quaternary Research Association Short Field Meeting to East Cumbria, under the leadership of J. Boardman, J.M. Letzer, and J. Rose. Further details will be given in the November 1980 Circular. |
| August 17th-21st
1981 | Sub-Commission of the International Society of Soil Science. International Working Meeting on Soil Micromorphology. University College, London. Further details can be obtained from Dr. P. Bullock, Soil Survey of England and Wales, Rothamsted Experimental Station, Harpenden, Herts, AL5 2JQ. |
| August 26th-
September 9th
1981 | Quaternary Research Association Overseas Study Course to Finland, organised by P.L. Gibbard. Full details are given on a separate form issued with this and the February 1980 Newsletter. The closing date for this meeting is the last day of July 1980, and any member wishing to attend should contact Dr. P.L. Gibbard, Sub-department of Quaternary Research, Botany School, University of Cambridge, Downing Street, Cambridge, CB2 3EA as soon as possible. |
| September 1981 | Quaternary Research Association Short Field Meeting to Central and South-eastern Grampians and Lowland Perthshire, based on Crieff. Leaders: Dr. J.J. Lowe and Dr. M.J.C. Walker. |
| September 21st-
25th 1981 | Second International Conference on Fluvial Sediments: Modern and Ancient Fluvial Systems. University of Keele. Further details can be obtained from Dr. J.D. Collinson, Department of Geology, University of Keele, Keele, Staffs., ST5 5BG. |
| October 1981 | British Geomorphological Research Group. Environmental Change in Tropics and Deserts. Manchester. Organizer: Professor I. Douglas. |
| May 1982 | Quaternary Research Association Short Field Meeting to Suffolk. Leaders: P. Allen and P. Coxon. |
| May 1982 | British Geomorphological Research Group. Landforms in East Anglia. Leader: Dr. L. Martin. |

- Summer 1982 Quaternary Research Association Overseas Study Course
to North France. Leader: Dr. J.P. Lautridou.
- September 1982 Quaternary Research Association Short Field Meeting
to South Kerry. Leaders: Dr. R.H. Bryant and
Dr. W.P. Warren.
- Summer 1983 Quaternary Research Association Overseas Study
Course to Galicia, Spain. Leader: Dr. J. Vidal
Romani.
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