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THE CLASSIFICATION OF TILL: A SEDIMENTOLOGIST'S VIEWPOINT

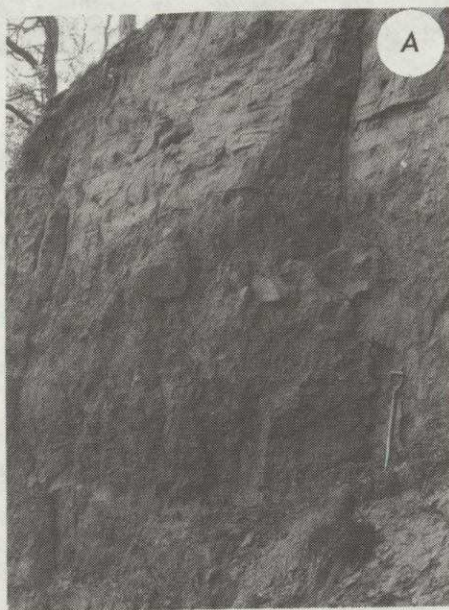
By J.H. Martin

Introduction

British workers have expressed a variety of opinions on the classification and definition of till and some have expressed their doubt about the applicability of process-related classification to the mapping of glacial deposits (see opinions in Boulton, 1980). Although objective descriptions of diamict facies have been used in the regional investigation of ancient glacial deposits (Shaw, 1969; Huddart, 1971), the interpretation of contemporary, Quaternary, and pre-Quaternary diamict sediments is still difficult (Harland *et al.*, 1966). This note is intended to provide a preliminary description of a range of Devensian sediments of varied origin from central Scotland, review a classification which seems most appropriate for the description of these sediments, and comment on the role of sedimentological investigation in the study of ancient glacial deposits. For comparison, reference is also made to work in other fields of clastic sedimentology.

Aim of classification

Diamict sediments overlie, underlie and are interbedded with sand and gravel deposits in parts of Mid- and East Lothian. In the



exploration for, and appraisal of, aggregate resources it is important to be able to predict the lateral extent and thickness of diamicton units encountered in a trench face, natural exposure, quarry face or borehole. One also wishes to know if diamicton units close to land surface are likely to overlie economically important deposits.

These questions may, of course, be answered by expensive detailed drilling or trenching programmes. However, knowledge of the mode of origin of the sediments will help in the prediction of their geometry and extent, and will allow the production of detailed facies models with wider applicability in the location of aggregate deposits. The first step in this interpretation is the erection of a satisfactory facies classification.

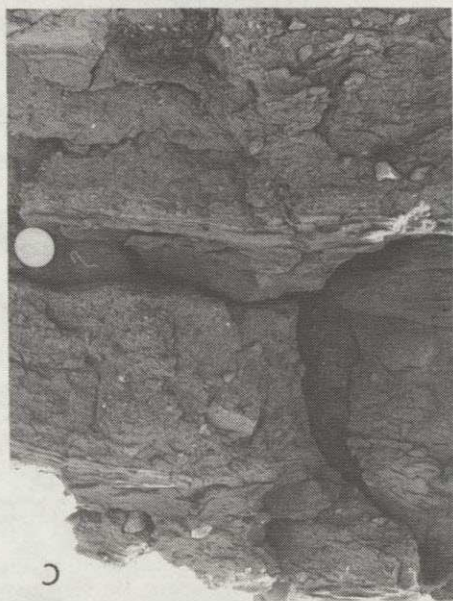
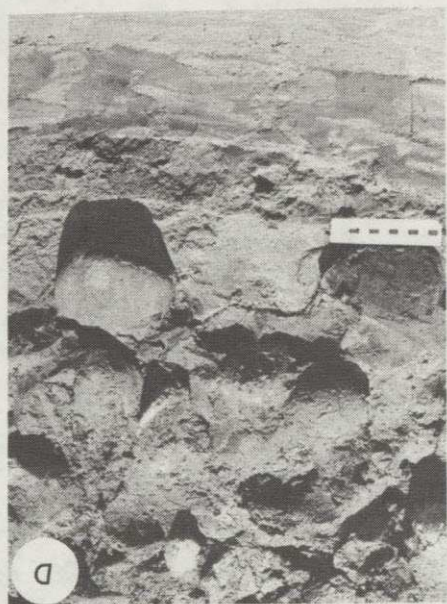
Figure 1.

- A Facies Dm1 containing sand lenses and large boulders. Sharp upper contact with laminated sand (deformed, containing thin stringers of diamicton). Total thickness of diamicton here exceeds 7m. Bedrock is exposed in this section, although the contact is not seen.

- B Facies Dm1: detail showing compact, fissile structure. Clasts are rounded to subangular. (The Lothian area is underlain by a wide variety of sedimentary and igneous rocks. Clasts in the Late Devensian deposits undoubtedly have a complex depositional history: some are derived from Palaeozoic conglomerate units without great change of shape). Scale bar 0.1m.

- C Facies Dm2 with sharp planar contact above normal-faulted ripple-laminated fine sand. Note irregular blocky fracture; land surface is directly above field of view. Scale division 0.2m. (See also Figure 3b)

- D Facies Dsi and Gr (detail of Figure 3b). Note facies Gr below two matrix-supported units separated by laminated sand. Sequence occurs in down-faulted pocket above a probable ice-marginal fan/delta complex.

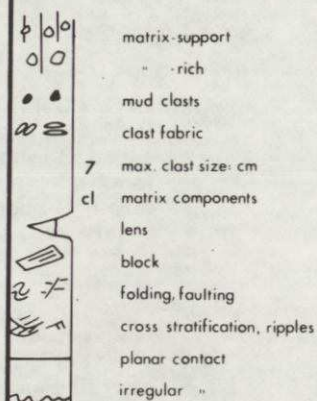
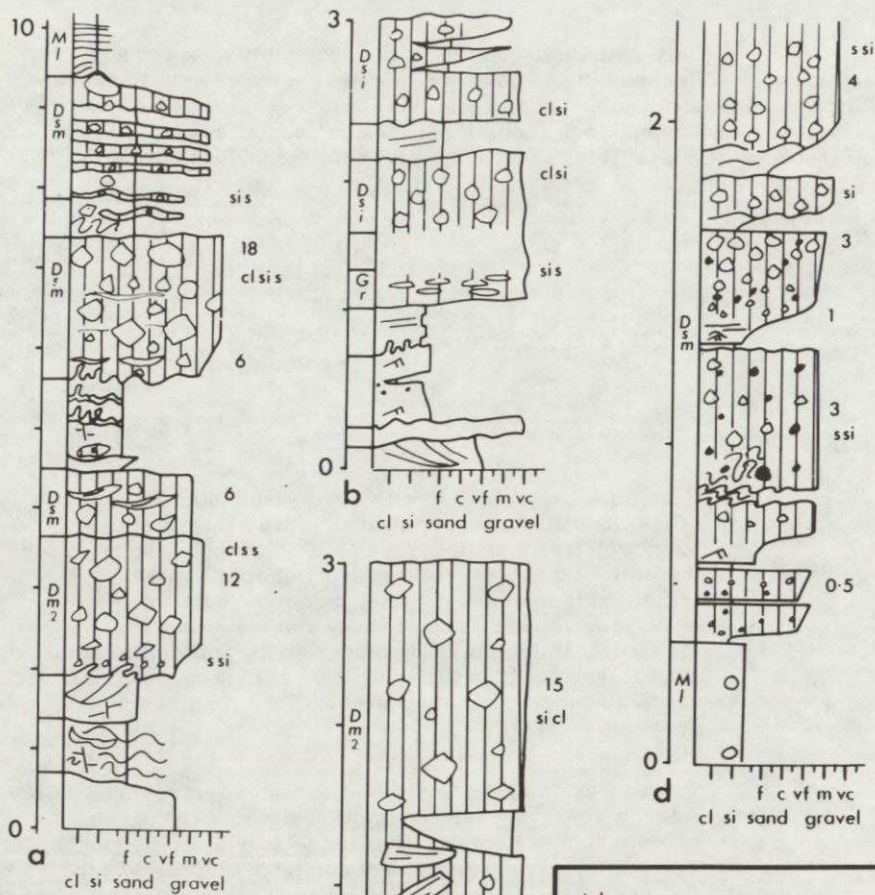


Range of sediment types

Only a limited selection of the sediment types encountered is shown here. Figures 1-3 do, however, partly illustrate the wide range of diamict and related sediments found in this limited geographical area. Variation also occurs on a much smaller (exposure) scale, and it is clear that a broad classification would not be useful for the purposes of the present work.

Figure 2.

- A Facies Dsi, interbedded with ripple-laminated and cross-stratified sand and gravel. Scale-bar rests on gravel-free massive clayey silt unit which drapes the bedforms below. Immediately above is sharp transition to matrix-supported diamicton containing subangular to subrounded clasts, some of which are striated. Matrix is sandy clayey silt. Subhorizontal sand lenses occur in the upper part of the bed, and the sharp planar top is clearly seen.
- B Facies Gb; laterally equivalent to facies Dsi of Figure 2a. Angular to subangular clasts of locally-derived basalt predominate. Voids are infilled by clay and silt, partly derived from overlying thin diamicton unit. Scale bar 0.1 m.
- C Facies Gsm. Three units are seen, separated by laminated silt/clay units passing up to ripple-laminated sand. Lower bed contacts are gradational, although weathering above coin (28 mm diam) emphasises ripple form. Upper contacts are sharp planar. (detail of Figure 3d)
- D Well-rounded cobble gravel with mud matrix (the base of a very large scale cross-stratified unit) overlying very fine sand. Matrix is secondary, probably formed due to the presence of silty permeability barrier beneath the gravel.



Facies classification

'Facies' is used here in the sense of "an objectively described rock unit" (Reading, 1979). The scheme (Figure 4) is based on properties that can be observed in the field: grain size (clast and matrix), bed thickness, overall geometry, contact relationships, sedimentary structures (qualitative assessment of clast orientation; grading patterns etc.) and deformation structures. It complements a classification used for gravel and sand sediments (interim version in Martin, 1980), in which there is a modified letter code system based on Miall (1977, 78). The format is based on a review of facies types within the

Figure 3.

Vertical sections through diamicton and related facies. Field observations are shown on the right, while facies designations are on the left. Scale (various) in metres. Style of matrix description follows Schermerhorn (1966).

- a Diamicton complex below laminated silt. Bed thickness within facies Dsm is variable. Base of section is an unknown distance above bedrock. Colour changes in this section are unlikely to reflect different source regions as they show strong correlation with change in matrix type and bed thickness and are more likely to be of secondary origin. This example is from the Avon Valley, Strathclyde Region.

- b Facies Dsi and Gr overlying coarse gravel. See Figure 1d.

- c Facies Dm2 overlying fine-grained equivalent of waterlain material at base of section b (100m distant). Clast-fabric measurements indicate indistinct fabric parallel to the modern land surface. See Figure 1c.

- d Facies Dsm, (thin and medium-bedded). Note small-scale overturned folds between diamicton units. This section overlies laminated silt, developed above a thick sequence of glaciofluvial gravels that in turn overlies facies Dm1. See Figure 2c.

Dalradian Jura Quartzite (Anderton, 1976). Tabulation aids the rapid comparison of sedimentary facies from different environments, although absolute standardisation of presentation would not be desirable.

Any facies classification suffers from some overlap, and there will be instances where the unambiguous allocation of a unit to a particular category is not possible. The classification is a simplification of complex data, and original detailed observations should be presented if possible. It is best regarded as a convenient 'summary', as in a classical application of the facies concept (de Raaf et al., 1965). The scheme could be further subdivided or extended in the light of detailed laboratory investigation (McGown and Derbyshire, 1977), increased field experience, or observations made by other workers.

The role of matrix in classification of diamicton and related sediment types

The term 'diamicton' as defined by Flint et al. (1960a, b) encompasses sediments which are poorly sorted and contain a wide range of grain sizes: they need not necessarily be matrix-supported. However, it has been found convenient to include matrix-supported sediments within the diamicton facies group, while clast supported sediments containing approximately 2-10% mud are included within the matrix-rich facies group (Figure 4). More detailed consideration of clast/matrix proportions has previously been used in classification (McGown and Derbyshire, 1977). As the facies scheme is designed for field use, absolute values of mud proportion have not been determined: in any case clast size, shape and sorting affects the percentage of mud required for matrix-support.

Figure 4.

Facies classification of diamicton and related sediments. It is difficult to assign suitable names to differentiate facies Dm1 and Dm2.

Other facies types which are defined include

facies M1 : laminated mud (containing dropstones)

Mm : (massive mud (passes laterally into facies Dsi; also occurs as thicker units with scattered clasts)

facies Dsm can be divided into two subfacies: parallel-bedded (laterally persistent beds with gradational bases: Figures 2c and 3d), and non-parallel-bedded (very irregular lensoid beds with blunt or interfingering terminations: not illustrated here).

TYPE		GRAIN SIZE (see notes)	T1	T2	EXTERNAL CONTACTS	INTERNAL STRUCTURE	GEOMETRY
MATRIX - SUPPORTED DIAMICTON FACIES							
Dm 1	massive facies 1	mc/gtl. Max. clast size up to boulder. Matrix silty clay to sandy silt. Homogeneous, or minor sand lenses.	0.5 10	- -	U: sharp irregular or erosive L: erosive irregular (commonly overlies rockhead)	Stiff, compact, with rare inclined shear planes. Structureless or indistinct clast long-axis orientation. Clasts sub-angular to well-rounded; some striated.	Sheet/sheet drape p1 > 100?
Dm 2	massive facies 2	mc/gm. Max. clast size up to cobble. Matrix silty clay to sandy silt.	1 2	- -	U: not seen or sharp undulatory L: sharp planar or undulatory with local erosion	Soft on initial exposure. Commonly badly weathered. Random clast orientation. Clasts sub-angular to well-rounded. Some striated. Rare deformed lenses. Normal faults below base.	Sheet/sheet drape p1 > 50?
Dsi	stratified, isolated	mc/gtl. Max. clast size up to boulder. Matrix sandy clayey silt.	0.1 1.5	- -	U: sharp irregular L: sharp or erosive undulating	Soft on initial exposure. Irregular sand lenses and stringers. Clasts sub-angular to well-rounded, may overlie thin gravel-free unit. Striated clasts seen.	Sheet drape, wedge or lens p1 < 50
Dsm	stratified, multiple	mc/gtl. Max. clast size up to v.c. gravel. Matrix silty clay to sandy silt. Interbedded with thin units of clay/silt/sand.	0.1 4.0	0.02 0.5	U: gradational interbedded or sharp irregular L: gradational interbedded or sharp planar	Parallel undulatory or irregular bedding. Common small-scale overturned folds and normal faults. Beds sharp-based, rarely normal or inverse clast-graded. Sharp upper contacts. Striated clasts not seen.	Sheet/sheet drape p1 20 - 100 p2 10 - 50
Dsr	stratified, reworked	Matrix med/coarse sand.	0.05 0.01	0.05 0.1	U: sharp planar or gradational L: sharp planar or gradational	Close-packed angular to rounded clasts of mud and diamicton.	wedge p1 < 50
MATRIX - RICH FACIES							
Gr	matrix-rich gravel	mcG. Max. clast size cobble gravel. Matrix clayey silty sand to silty sand.	0.3 2	- -	U: sharp undulatory or gradational L: sharp undulatory or planar	Structureless, or indistinct subhorizontal clast orientation (rare imbrication). Clasts rounded to sub-angular. Diamicton clasts and lenses common.	Sheet/basin fill p1 10 - 50
B	boulder gravel	G. Max. clast size large boulder. Subordinate muddy sand matrix.	1 15	- -	U: sharp irregular L: sharp irregular	Structureless, or highly deformed (normal faults). Rounded to sub-angular clasts.	Sheet, wedge or lens p1 10 - 50
Bb	breccia	G/lstG. Max. clast size up to boulder. Subordinate muddy sand matrix.	0.5 2.0	- -	U: sharp planar or irregular or gradational L: sharp planar/irregular	Angular clasts, subhorizontal or imbricated clast-fabric. Openwork, some secondary matrix development.	Wedge p1 5 - 20

Notes: T1 overall thickness range (m)
T2 bed thickness range (m)
P1 overall length/height ratio
P2 bed length/height ratio

G = gravel
mcG = muddy gravel
msG = muddy sandy gravel (Folk et al. (1970)
gtl = gravelly mud

Modal clast sizes are quoted

Figure 4. Facies classification of diamicton and related sediments.

Flint *et al.* (1960a, b) make no distinction between primary and secondary matrix. However, it can be shown that up to 30% by weight of certain muddy gravels is silt and clay infilling voids within an originally openwork clast framework (Figure 2d). Walker *et al.* (1978) demonstrate that the matrix in first-cycle desert alluvium can be of similar origin. Field evidence does not in all cases distinguish between primary and secondary matrix (Figure 1d). Some muddy gravels may be flood deposits (Eyles, 1979); other mechanisms for the incorporation of primary matrix have also been suggested (Saunderson, 1977). In the cases where matrix can be shown to be of secondary origin, muddy gravel should not be classified using the scheme shown here. However, in some less compact sediments that are included in the scheme, secondary matrix-enrichment cannot be ruled out.

Discussion

It may not be possible to directly identify the processes responsible for the deposition of various facies types. Vertical sequences and lateral relationships must also be considered, either by statistical methods or informally (Miall, 1973; Elliott, 1974). Comparison of sequences leads to the production of facies models, while generation of models from studies of modern sedimentary environments (e.g. Hine and Boothroyd, 1978) is of great importance. Detailed facies models are now available for some modern glacial environments (Boulton and Eyles, 1977; Eyles 1979), and others have been deduced from ancient successions (e.g. Shaw, 1979).

The facies classification is used as a base (Figure 4). It incorporates criteria discussed by McGown and Derbyshire (1977), Boulton (1976) and others, to interpret diamict and related sediments in the Lothian area (Martin, in preparation). The differentiation of sediments formed by 'till-forming processes' and 'non till-forming processes' (Boulton, 1980: Figure 1) is aided by the facies classification, because lithological criteria (which reflect process changes) form the basis of the scheme. However, it is unwise to proceed directly from initial investigation of sediment type to environmental interpretation; classification of facies is a necessary intermediate step. For example, Evenson *et al.* (1977) and Gibbard (1980) present well-argued interpretations of observations on the Catfish Creek till, although arriving at differing hypotheses. The sediment descriptions provided by these workers do not differ fundamentally, indicating the necessity of considering multiple hypotheses. Therefore objective description is preferred to simply 'labelling' a sediment, and sufficient detail should be provided to allow possible re-interpretation should this prove necessary in the light of further research.

Ideally, observations that may reflect the process of deposition of a diamicton should be considered separately from those that may reflect its stratigraphical position or provenance. Definition of stratigraphic units by direct reference to physical properties of till (e.g. Mulholland, 1976) may sometimes lead to erroneous conclusions, as this approach ignores the influence of depositional process on sediment properties. Stratigraphic interpretation should be undertaken in parallel with sedimentological study.

Conclusions

Increasing awareness of the complexity of modern glacial processes provides a stimulus for further work to ascertain the origin of ancient diamict sediments. A facies classification might provide an alternative to the use of less informative mapping units including 'boulder clay', and 'till'.

The facies scheme presented here has been formulated during the investigation of a limited area, with a specific purpose. A wide range of diamict and matrix-rich sediment is identified. Observational evidence is used as the first step in interpretation, and gives support to the need for a process-related classification (Boulton, 1980). Some ambiguities result; these may be resolved in part by more research concerning the geometry, lateral and vertical relationships and preservation potential of modern glacial sediments in areas of known glaciological history.

Acknowledgements

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AN OVERLOOKED RECORD OF INTERGLACIAL OR INTERSTADIAL SITES IN NORTH-EAST SCOTLAND

By J.D. Peacock

Interglacial and interstadial sites are scarce in Scotland and the recent 'restitution' of that in the Burn of Benholm near Inverbervie (Donner, 1979) is significant in that it suggests that pre-late Devensian till might occur in this part of the country. The purpose of this note is to draw attention to an important paper published in an obscure book by A. Bremner (1943) which has apparently been overlooked in more recent work. In this he describes two further sites of interglacial or interstadial status in North-East Scotland. The following is a quotation:

'At Tippetty Brickwork the mashed-up remains of a peat-bed yield pollen grains of oak, pine, birch, etc. - a temperate flora. Part of the trunk of an oak tree . . . was found in finely laminated ("varve") clays resting on the Red Strathmore boulder clay in which the fragments of peat occur. A hundred yards or so away the same red boulder clay rests on a dark grey boulder clay with several erratics from sources to the north-west Near Balmedie Village, Belhelvie, a peat, consisting mainly of remains of reeds (*Phragmites*), is sandwiched between drift from the north-west below and red Strathmore boulder clay above'.

These statements suggest that the conclusion of Murdoch (1975) and Clapperton and Sugden (1977, p. 6) that the till units in Aberdeenshire can all be referred to one glaciation is incorrect and that at some localities the till below the distinctive red coastal (Strathmore) drift and its inland correlative of late-Devensian age belongs to an earlier glacial episode. It also suggests that the hypothesis that some parts of North-East Scotland escaped glaciation during the late-Devensian (cf. Synge, 1956) merits reconsideration, notwithstanding the apparent continuity of the meltwater channels across the area (Clapperton and Sugden 1977, p. 10).

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A REAPPRAISAL OF PLEISTOCENE STRATIGRAPHY
IN NORTH KENT AND EASTERN ESSEX, AND NEW
EVIDENCE CONCERNING FORMER COURSES OF THE
THAMES AND MEDWAY

By D. Bridgland

Introduction

The gravel deposits of north Kent and eastern Essex provide evidence of the Pleistocene history of the major rivers of south-east England. The earliest reference to these deposits in eastern Essex was by Wood (1866), who considered them to be of marine origin, deposited in an inlet opening out to the south. Whitaker (1889), who recognised that the gravels contained Lower Greensand chert from the Weald, later suggested that they were of fluvial origin, deposited when the Thames and Medway flowed in confluence north eastwards across the region. Subsequently the origin and composition of the gravels has been discussed by others, including Gregory (1922), Wooldridge (1923) and Gruhn, Bryan and Moss (1974), the last suggesting that the exotic rocks in the lower beds were derived from the Hastings Beds Pebblebeds of the Weald. Recently Lake *et al* (1977), reporting on a programme of boreholes in eastern Essex, discovered, beneath the terrace gravels, a series of buried channels which they attributed to a glacial origin.

To determine the origin of the gravels of eastern Essex the deposits were mapped, sedimentary structures described and clast lithologies determined. In addition clast lithologies were determined from the gravel deposits of the Tilbury area, the Hoo Peninsula and the Ugley region of north-west Essex, in order to establish pebble assemblages typical of Lower Thames, Medway and glacial origins respectively (Table 1 a, b, f). To assist the identification of the stone types, a reference collection of likely source rocks was built up from specimens collected from the Weald, the Midlands, and northern England.

The Southend and Dengie Peninsulas

The high gravels of the Southend and Dengie peninsulas, located at Rayleigh Hills, Belfair Park, Chalkwell, Canewdon, and small outcrops between the Crouch and Blackwater (Figure 1), are described in Table 1b and found to be indistinguishable from those of Medway origin from north Kent and to lack the exotic component of the Thames gravels. This relationship suggests that these gravels were deposited by an extension of the Medway across eastern Essex before the Thames occupied its present valley through London. At least three terraces of this ancient river can be recognised in the area (Figure 2).

The lower gravels of eastern Essex are summarized in Table 1c, and found to include the Thames exotic suite recognised in the Tilbury area, in association with stone types from the Medway. This is taken to indicate the first appearance of the Thames in the area, in the form of a combined 'Thames-Medway' (Table 1d). It is known from the work of Wooldridge (1938, 1960) and more recently Gibbard (1977, 1979) that the Thames was diverted by ice during the Anglian glaciation from an earlier course through the Vale of St. Albans and across central Essex (Rose, *et al.*, 1976; Green and McGregor, 1978) into its modern valley. The presence of till in the south-draining valleys of the Ingrebourne (Holmes, 1892) and Roding (Dines and Edmunds, 1925) shows that these valleys were in existence when the ice reached southern Essex. In turn this implies a drainage system extending at least from the London area to eastern Essex, tributary to the extended Medway. It is envisaged that it was into this system that the Thames was diverted by the Anglian ice. Certainly the combined Thames/Medway seems to have flowed across eastern Essex in a valley formerly occupied solely by the Medway.

Several problems arise when considering the details of the Thames Medway gravels. In eastern Essex the highest gravels with Thames exotics occur at altitudes (24 to 28 m O.D.) and have a surface gradient that suggest a correlation with the Boyn Hill Terrace. (Zeuner, 1959; Lake *et al.*, 1977) and the Black Park Terrace (Hare, 1974; Gibbard 1979) appears to be absent. This apparent discrepancy can be explained by the fact that the Black Park Terrace has a steeper downstream gradient than the Boyn Hill Terrace, and Evans (1971) shows that the Black Park Terrace should fall below the surface level of the Boyn Hill Terrace east of London (Figures 2 and 3). In eastern Essex the gravels correlated with the Boyn Hill Terrace overlie part of the buried channel system described by Lake *et al.* (1977). The channel contains a basal gravel, at 10 to 15 m O.D., which it is considered may represent the Black Park Terrace. This is overlain by finer deposits followed by the upper, Boyn Hill Terrace gravel (Figure 3).

This sequence can be compared with the important succession at Barnfield Pit, Swanscombe (Shephard - Thorn and Wymer, 1977), which contains evidence for a major non-sequence,

<p>(a) POST-ANGLIAN THAMES</p> <p>Lower Thames Valley</p> <p>FLINT 90 - 97%</p> <p>L. GREENSAND CHERT 1 - 5%</p> <p>EXOTICS 1 - 5%</p> <p>RHAXELLA CHERT present.</p>	<p>(b) MEDWAY</p> <p>North Kent and high gravels of E. Essex</p> <p>FLINT 60 - 85%</p> <p>L. GREENSAND CHERT 15 - 40%</p> <p>HASTINGS BEDS sst., siltst., and ironstone - up to 1%</p> <p>EXOTICS usually absent, occasionally present, derived from pebble-beds of Cretaceous age in Weald.</p> <p>L. GREENSAND SANDSTONES - characteristic ssts. from L.Gsd. occas. present.</p>	<p>(c) PRE-ANGLIAN THAMES</p> <p>Chelmsford, Colchester and Brightlingsea area.</p> <p>FLINT 70 - 85%</p> <p>L. GREENSAND CHERT 0.5 - 2%</p> <p>EXOTICS 15 - 28%</p> <p>RHAXELLA CHERT absent.</p>
<p>(d) POST-ANGLIAN THAMES/MEDWAY</p> <p>Lower gravels of Eastern Essex.</p> <p>FLINT 75 - 94%</p> <p>L. GREENSAND CHERT 5 - 25%</p> <p>EXOTICS 0.5 - 3%</p> <p>HASTINGS BEDS present, but rarely more than 0.2%</p> <p>RHAXELLA CHERT present</p>	<p>(e) PRE-ANGLIAN THAMES/MEDWAY</p> <p>Clacton area (including Holland Gravel).</p> <p>FLINT 75 - 85%</p> <p>L. GREENSAND CHERT 2 - 5%</p> <p>EXOTICS 10 - 30%</p> <p>RHAXELLA CHERT absent or extremely rare.</p>	
<p>(f) PROXIMAL OUTWASH (Anglian)</p> <p>Ugley (Essex)</p> <p>FLINT 50 - 70% (mainly non-Tertiary)</p> <p>EXOTICS 8 - 10%</p> <p>NON-DURABLES (Chalk + exotics) 20-40%</p> <p>RHAXELLA CHERT rel. abundant.</p>	<p>(g) DISTAL OUTWASH (Anglian)</p> <p>St. Osyth area</p> <p>FLINT 87 - 95% (mainly non-Tertiary)</p> <p>L. GREENSAND CHERT 0 - 3%*</p> <p>EXOTICS 5 - 10%</p> <p>RHAXELLA CHERT rel. abundant.</p> <p>* - indicates proximity to Medway confluence.</p>	<p>(h) MEDWAY/DISTAL OUTWASH (Anglian)</p> <p>Clacton area.</p> <p>FLINT 60 - 80% (mainly non-Tertiary)</p> <p>L. GREENSAND CHERT 14 - 32%</p> <p>EXOTICS 1.5 - 8%</p> <p>RHAXELLA CHERT rel. abundant.</p> <p>(Other Anglian erratics present.)</p>

Table 1. Summary of the lithological composition of various gravels in north Kent and eastern Essex.

between the Lower Gravel and Loam and the Lower and Upper Middle Gravels. Below the non-sequence from 23 to 27 m O.D. the deposits contain only Clactonian artifacts, while above, from 27 to 32.5 m O.D., Acheulian artifacts occur. The break in sequence, at 27 m O.D., closely coincides with the bench level of Boyn Hill deposits at New Graylands Lane Pit, Swanscombe, and at Dartford Heath (Chandler and Leach, 1912), and with the level at which Boyn Hill gravels overlie Anglian Till at Hornchurch (Holmes 1892). It is suggested that this level represents the true Boyn Hill bench, while the lower part of the succession, containing the Clactonian artifacts, belongs to the Black Park aggradation.

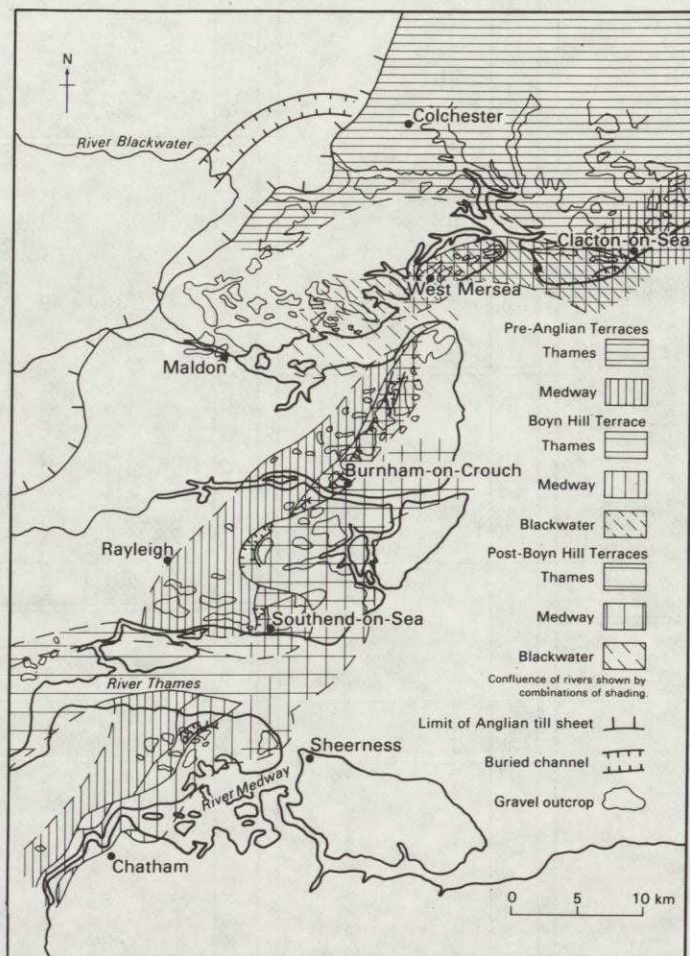


Figure 1. Distribution of gravel terraces in eastern Essex and north Kent.

The inclusion of the Type site of the Clactonian Industry in the Black Park aggradation (see below), suggests an association between the Late Anglian - early Hoxnian Black Park Terrace and the Clactonian Industry, and the Late Hoxnian - Early Wolstonian Boyn Hill Terrace with Acheulian artifacts.

Below the Boyn Hill Terrace there occurs a series of three terraces associated with a second buried channel. The channel occupies a large meander loop to the south-west of Rochford (Figure 1), where it cuts out the earlier terraces. The floor of this channel reaches below O.D., but it is overlain in the Rochford area by a poorly developed terrace at 18 - 20 m O.D. and a rather more extensive feature at 11 to 12 m O.D. (Figure 2), which has been correlated from their height and surface gradient with the Upper Taplow and Lower Taplow Terraces respectively (Evans, 1971). The basal gravel of this channel may represent the Lynch Hill Terrace of the Middle Thames (Hare, 1947), which, like the Black Park Terrace has a steep gradient, and has fallen below the level of the later Taplow aggradations (Figure 2). The lowest terrace of the sequence in eastern Essex forms an extensive sheet of gravel to the north-east of Southend, with a surface elevation of some 7 m O.D., and is correlated with the Upper Floodplain terrace of the Lower Thames (Evans, 1971). Gravel at a height indicative of the Taplow and Upper Floodplain Terraces of the Dengie Peninsula is mainly limited to small patches of sandy gravel occurring along the edge of the coastal marshes, and the little evidence that is available suggests that these deposits represent one or more small local 'misfit' streams, rather than the main Thames-Medway. This implies that the main river turned eastwards along the approximate line of the Crouch Estuary during the period represented by these terraces. The Lower Floodplain Terrace of the Lower Thames falls to about 0 m O.D. east of Tilbury, and is presumably submerged in the Southend area. It is likely that this is the terrace recognised from echo-soundings off the Essex coast by D'Olier (1975), indicating a further shift southwards of the river, to form the modern estuary.

The Clacton Area

On the basis of gravel composition and elevation, the Boyn Hill Terrace of the Thames-Medway can be traced from the Dengie Peninsula, across Mersea Island, to Clacton, where it is represented by the lowest terrace of the area, at about 10 m O.D. At a lower level, basal gravels in the Clacton Channels, which fall to below 4 m O.D., and contain a Clactonian Industry (Warren, 1955) may represent the Black Park Terrace. These are overlain by a partially estuarine sequence yielding Hoxnian pollen (Pike and Godwin, 1953).

The higher gravels of the Clacton area show a lateral change from west to east. To the west of St. Osyth the gravels are identical in composition to the pre-Anglian Thames gravels of central

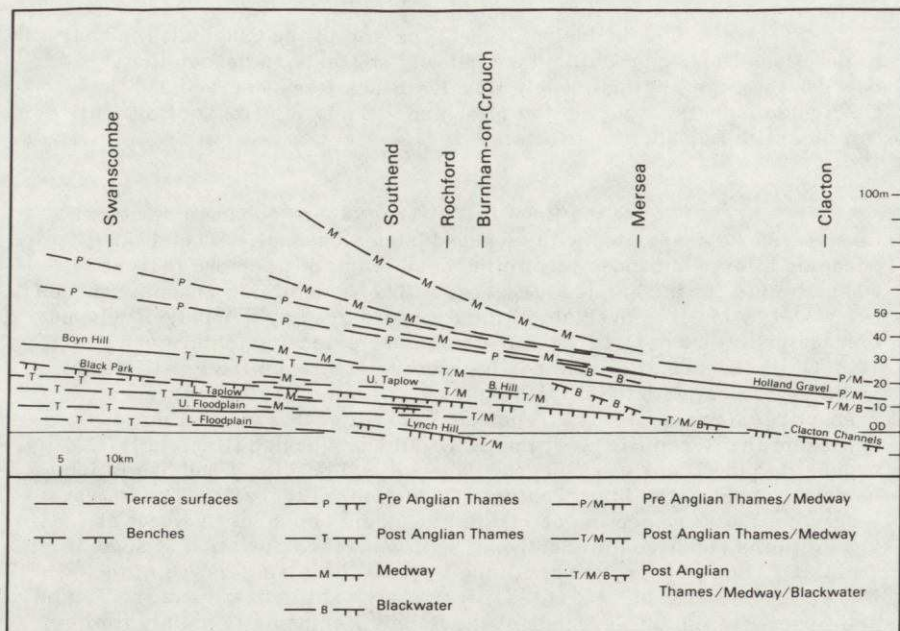


Figure 2. Long profiles of the river terraces of north Kent and eastern Essex.

Essex, which have been traced to St. Osyth by Rose, et al. (1976) (Table 1 c), while to the east the gravels show an increased Lower Greensand Chert content and a decrease in exotics (Table 1 e). It is suggested that this change in composition represents the confluence of the pre-Anglian Thames and the extended Medway (Figure 1). These gravels occupy a series of terraces covering the Tendring Plateau, the lowest of which runs from Brightlingsea through St. Osyth to Clacton and Holland-on-sea, where the pre-Anglian Thames-Medway deposits have been referred to as the Holland Gravel (Warren 1955). The upper two metres of the deposits of this terrace (Figure 2) comprises sand or very fine gravel of very different character from the underlying pre-Anglian Thames and Thames-Medway deposits. At St. Osyth the upper gravel, compared with the underlying deposits, contains a significantly lower proportion of quartz and quartzites, a higher proportion of Carboniferous chert and Jurassic silicified limestones, a greater variety of igneous rocks and, for the first time, Rhaxella Chert.

This gravel also has a very low proportion of Tertiary flint pebbles, which usually comprise about half the flint in Thames gravels of all types. The analysis of ice-proximal outwash deposits at Ugley (Table 1 f) has shown that the composition of the upper gravel at

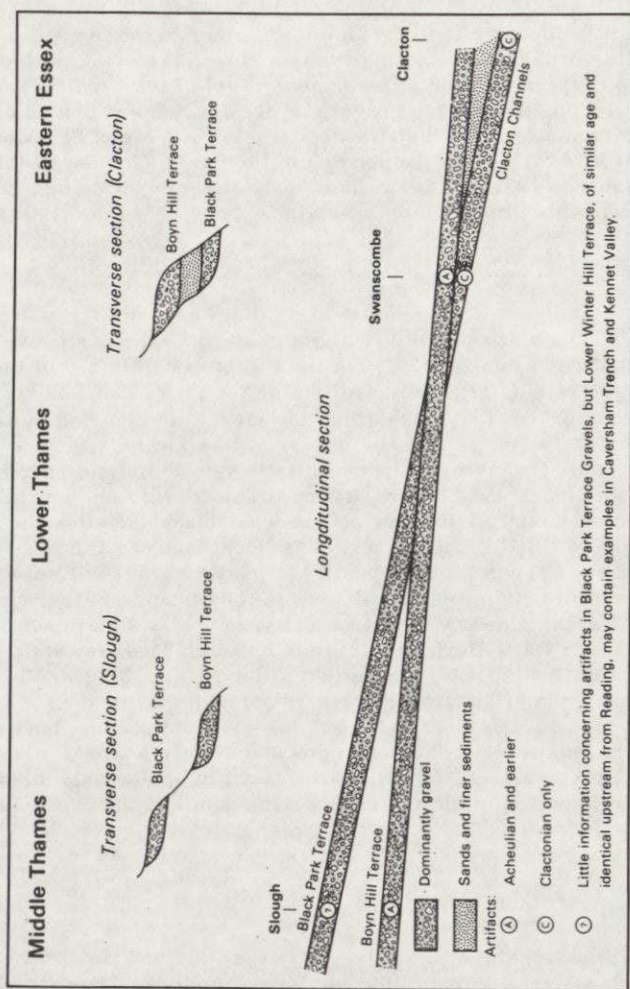


Figure 3. Diagrammatic representation of the relationship between the Black Park and Boyn Hill terraces in the middle and lower Thames region.

St. Osyth resembles the durable portion of Anglian outwash gravels, and it is suggested that this gravel represents a sheet of distal outwash overlying the pre-Anglian Thames gravel, reflecting the arrival of Anglian ice, blocking the Thames upstream of St. Osyth (Table 1 g). Further east, overlying the pre-Anglian Thames-Medway gravels, the upper gravel is marked by an extremely high Lower Greensand Chert content, up to 30%, while the exotic component is correspondingly reduced (Table 1 h). This clearly reflects the confluence of the extended Medway with the outwash stream occupying the lower reaches of the ice-blocked Thames valley, and it is apparent that, whereas the Thames had very

much dominated the Medway at their confluence prior to the arrival of the ice, the latter provided five or six times as much material as the outwash stream in the formation of the upper gravel of the Clacton area (Table 1). The deposition of this gravel may well have been contemporaneous with the formation of lacustrine deposits in the Vale of St. Albans, in a pro-glacial lake formed by the ponding of the River Thames by the Anglian ice (Gibbard, 1977), with the main body of sediment being abstracted by deposition in this temporary lake.

Conclusion

The study of the gravels of eastern Essex has provided a significant addition to our knowledge of the Pleistocene history of the Thames drainage system, generally confirming the views of Wooldridge (1938, 1960) and Gibbard (1977, 1979) that the river was diverted by ice from a more northerly course into its modern valley. The sequence in eastern Essex shows that this diversion initially served only to re-route the river between Slough and Clacton, where it rejoined its original alignment. The northern part of this new course was abandoned after the formation of the Boyn Hill Terrace, and subsequent courses ran eastwards along the line of the Crouch Estuary until the modern Thames Estuary, of comparatively recent origin, was established. The tracing of terraces across eastern Essex, aided by the lithostratigraphically significant deposits of the Black Park-Boyn Hill terrace in which Thames exotics and Rhazella Chert first appear, shows that differential subsidence in the area, suggested by numerous authors (e.g. Wooldridge & Henderson, 1955; Gruhn et al., 1974; Greensmith & Tucker, 1980), cannot have been particularly important over a long period. Figure 2 shows a steepening of terrace surfaces as these are traced in an easterly direction in the coastal area, which might reflect the subsidence of the North Sea Basin during the Holocene (Devoy, 1979; Greensmith & Tucker, 1980).

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THE FORMATION OF GROUND - ICE DEPRESSIONS - A RECORD OF AN ALTERNATIVE EXPLANATION.

By A. J. Sutcliffe

We commonly read that kettle holes and pingo basins are formed by the melting of bodies of buried glacier ice or ground ice, but these are not the only explanations that have been put forward to account for depressions in permafrost areas.

Isbrants Ides, writing in 1706 of an expedition to Siberia, which took place about 1693 (Sloane, 1728) reported that:

"Amongst the Hills, which are situated to the North-East of Makofskoi, not far from thence, the Mammut's Tongues and Legs are found; as they are also particularly on the Shores of the Rivers Jenize, Trugan, Mongamesa and Lena... Concerning this Animal there are very different reports. "The Heathens of Jakuti, Tungusi, and Ostiacki say, That they continually, or at least by reason of the very hard Frosts, mostly live under Ground, where they go backwards and forwards; to

confirm which, they tell us, That they have often seen the Earth heaved up, when one of these Beasts was on the March, and after he was past the Place, sink in, and thereby make a deep Pit. They further believe, that if this Animal comes so near the Surface of the Frozen Earth, as to smell, or discern the Air, he immediately dies, which they say is the Reason that several of them are found dead on the high Banks of the River, where they unawares come out of the Ground."

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'YARMOUTH REVISITED'

Report on:

27th FIELD CONFERENCE - MIDWEST FRIENDS OF THE PLEISTOCENE

By C.A. Whiteman

During the course of a month's visit to the U.S.A. this year to study palaeosols, I was privileged to join over 130 members of the Midwest Friends of the Pleistocene (F.O.P.) and to be generously entertained by them during their 27th Field Conference to S.E. Iowa. This meeting was sponsored by the Iowa Geological Survey and the Iowa State University, and its leaders were: George R. Hallberg, Thomas E. Fenton, Timothy J. Kemmis, and Gerald A. Miller.

F.O.P. is a regionally organised body in the U.S.A., akin to the Q.R.A. in Britain, although it runs its affairs less formally; funds are simply handed on each year to the organiser of the next field conference. On the other hand, their guide books are excellently produced and a valuable source of data on sections and their analyses.

The meetings of the Midwest F.O.P. date from 1950 when S. Judson led a party to E. Wisconsin. Subsequent leaders have included H.E. Wright, R.V. Luke, W.D. Thornbury, R.P. Goldthwait, J.C. Frye, H.B. Willman and R.F. Black and venues span the states from the Dakotas to Michigan and Minnesota to Kansas. Two meetings have penetrated beyond the Canadian border. Meetings have been held almost annually; the informality is such that no-one is completely sure of the accuracy of a list recently compiled by Leon Follmer, leader of the 1979 meeting in Central Illinois! This meeting was also concerned

with palaeopedology, examining ".....details of the development of the Sangamon Soil under varying environmental conditions in its type region " (Follmer, 1979).

It is significant that consecutive meetings (1979 and 1980) should attempt to unravel the intricacies of perhaps the two best known palaeosols, the Sangamon and the Yarmouth, which have lent their names to interglacial stages separating the Wisconsinan and Illinoian glacial stages and the Illinoian and Kansan glacial stages respectively, in the U.S.A.

Therefore it was especially interesting to be in Iowa for a meeting that proposed "a review of the Yarmouth type area including Leverett's original definition and our present re-evaluation (Hallberg and Baker 1980)", a consideration of "the relationships of the Yarmouth and Sangamon Palaeosols" and the demonstration of "a depositional model for the deposits of the early Illinoian Kellerville Till Member, of the Glasford Formation in southeast Iowa." (Fig. 1).

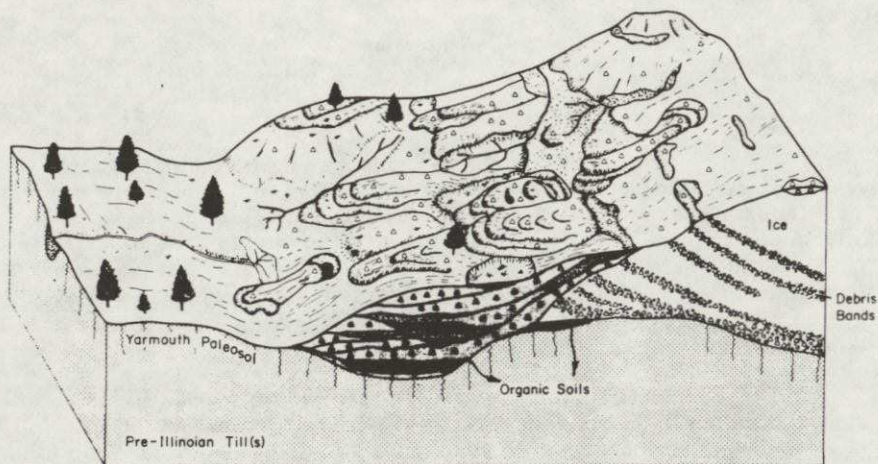


Figure 1. Cover illustration and Figure 8 in the F.O.P. Guidebook, p. 37 (Hallberg *et. al.*, 1980).

The conference was convened in Burlington, Iowa, a right bank junction whose wealth derived from the surrounding rich agricultural community and its focal communications. The nearby Canaan Township, little more than a hamlet, proclaims itself the richest in the

world! Around 2 million dollars is the value of a section of land hereabouts which, as the guidebook comments, says something about the applied value of 6-8 feet (1.8-2.4 m) of Wisconsinan loess!

A short meeting on Friday evening welcomed visitors and set the scene. George Hallberg, the senior leader, pointed out that much Quaternary work in the U.S.A. is carried out by State Geological Surveys and Departments of Agronomy in relation to hydrogeological and soils programmes. Quaternary formations were often defined, at least partly, with an applied value in mind; for instance, clay mineralogy and geotechnic properties such as bearing capacity could often be related to geomorphic surfaces and their associated sediments.

Transport for the main field excursion on Saturday was provided by distinctive American yellow and black school buses, robust vehicles as well suited to Quaternary field studies as their normal week-day function.

Palaeopedologists will appreciate the interest shown in the first stop (Hallberg *et al.*, 1980, p.23) within sight of F. Smith's farm. This is the location of one of the two well sections reported by Frank Leverett in 1898 and 1899, and it was from these sections that he concluded that a significant interglacial interval separated the Illinoian from the Kansan glacial stage. The name of the nearby township of Yarmouth, proclaimed today in 2 M high letters from the grain silos, entered Quaternary literature as the formal name of a soil and an interglacial stage.

In those days (1890's), soils were less well understood. They were recognised only by the organic rich part of the profile, "the peats and mucks within what he (Leverett) interpreted as alluvial deposits" (Hallberg *et al.*, 1980, p. 25). In addition, Leverett described the generally weathered nature of the underlying Kansan Till but did not recognise this as part of the palaeosol even though it did contribute to his conclusion regarding the existence of an interglacial stage. In fact it has generally been the weathering of the till surface that has led to the recognition of an interglacial stage at this level in the stratigraphy where it has been seen outside the type area. Leverett himself, on the basis of coniferous wood fragments from the organic deposits, was obliged to recognise that the organic soil was deposited during a cooler climate. He nevertheless considered this to be the latter part of the Yarmouth stage.

On the four inch cores, kept on ice since the previous October and available for inspection much discussion revolved (heat was generated!) around the precise upper boundary of the Yarmouth Palaeosol. The generally fine texture (silty, silty clay loam with occasional fine sand lenses) and the similar darkish colours (10YR2/1-3/1, 5GY-5G4/1 Munsell Colours) of both till and till derived sediments contributed to the difficulty

of field recognition. Soil structure becomes an important diagnostic characteristic but a wide range of laboratory techniques including bulk density, moisture content, porosity, saturation, clay mineralogy, particle size, carbonate content and sand fraction mineralogy contribute to the stratigraphic boundary decisions. Figure 2 (Hallberg *et al.*, 1980, Figure 9) p. 41) illustrates that the boundary has been located at the junction of the Mucky stratified early Illinoian organic sediments (part of the Leverett's soil) and the underlying well-developed till-derived mineral horizons.

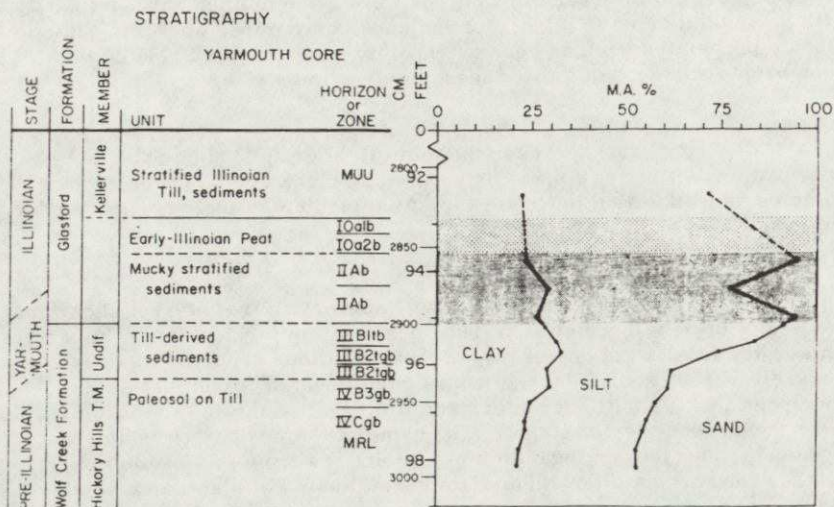


Figure 2. Stratigraphy and particle size properties for a portion of the Yarmouth core (Hallberg *et al.*, Figure 9, p. 41).

Subsequent stops (2, Old Brun Farm Section, Hallberg *et al.*, 1980, p. 45 and 3 The Mediapolis Section, p. 53) elaborated the variability of the sediments in relation to the palaeo-landscape and the Illinoian ice margin. Stop 3, additionally, provided an exposed reference section for the Yarmouth Stage to supplement the reference cores of the Yarmouth Transect (Stop 1, Yarmouth, Iowa. Hallberg *et al.*, 1980, p. 23).

The lunch break was taken in the pleasant surroundings of a small country park. Participants were invited to help themselves to a packed lunch, the most prominent feature of which was a nine inch long, six (6!) sliced beef roll, hardly conducive to erudite discussion afterwards.

The afternoon session began with a demonstration at the Pleasant Grove Section (Hallberg *et al.*, 1980, p. 66) of the nature of the till/till contact where the Yarmouth Palaeosol is absent. An

abrupt contact separates the more yellow (10YR Munsell colour), siltier and more illite rich, coal bearing Kellerville Till Member (Illinoian) from the browner (7.5 YR Munsell colour), sandier, more expandable clay rich Hickory Hills Till Member (pre-Illinoian) below. In places the lower till is leached. A grey, reduced patch, about 10 cm in diameter, of finer texture and enriched in secondary carbonate may have been an animal burrow (Krotovina) indicative of previous sub-aerial exposure of the lower till.

The rest of the afternoon was devoted to two sites where the Sangamon and Late-Sangamon Palaeosols were demonstrated. At the Bjork Farm Transect (Hallberg *et al.*, 1980, Stop 5, p. 68) the purpose was "to look at the relationships between the superglacial and sub-glacial facies of the Kellerville Till Member to examine the landscape relationships of the Sangamon or Late Sangamon Palaeosol and to observe a local late-Wisconsinan or Iowan erosion surface developed on the Illinoian deposits".

The final stop (Hallberg *et al.*, 1980, Stop 6, p. 85) was on Mediapolis Flats where several cores were displayed demonstrating "a paleo-drainage sequence of Sangamon Paleosols on a modified but undissected remnant of the original surface developed on the superglacial facies of the Kellerville Till Member". This provided an excellent demonstration of the need to consider a palaeo-catena rather than a single profile when describing soil stratigraphic units (Valentine and Dalrymple, 1975). Distinctive variations in colour, intensity of structural development, thickness and the nature of the soil forming materials were apparent. A reddish, well-developed B horizon within till occurred in a core from a high point of the palaeo-landscape. In other cores the soil was developed in a varying amount of hillslope sediments derived from and deposited upon the till. Several feet of gleyed, leached swale-fill sediments underlay the palaeosolum in depressions in the till surface. Here colours were greyer and structure often less well developed.

The interest shown in this last site, reached during the considerable heat and humidity of the afternoon, was undoubtedly enhanced by the provision of cans of beer and Pepsi nestling between the ice cubes in two large plastic dustbins. A note in my field book states "this is a very civilised field trip!"

The day was concluded by an excellent meal followed by a short F.O.P. business meeting during coffee. This was climaxed by the singing of the F.O.P. song. It was revealed, to the writer's surprise, that a very distinguished member of the Q.R.A. had a hand in the composition of the song while accompanying three other members of F.O.P. in a car returning from one of the early (1950's?) meetings.

On account of Burlington's proximity to a tornado track three inches of rain fell overnight rendering the sites scheduled for Sunday impossible. Gumbotil (and/or accretion gley (Frey et al., 1960)) takes some negotiating at the best of times!

The party had to be content with the demonstration of the thickest Pleistocene palaeosolum known in Iowa, obtained from the Mt. Union Cemetary site. Including the overlying Wisconsinan deposits and the underlying Hickory Hills (pre-Illinoian) Till Member the core extended for over 10.5 m alongside the car park of the Holiday Inn Motel. The site from which the core was obtained lies beyond the Illinoian till margin where the Yarmouth and Sangamon Palaeosols merge to produce a very thick, strongly developed palaeosol on relatively stable upland divides. In this type of location, buried by the Wisconsinan deposits the palaeosol becomes known as the Yarmouth-Sangamon Palaeosol. Such "giant" palaeosols represent pedogenic development keeping pace with the slow accumulation of fine textured sediments (accretion gley) in swales on the pre-Illinoian palaeolandscape (Hallberg et al., 1980, pp 97-104).

This meeting represented the culmination of six years of cooperative work by geologists and soil scientists in Iowa and Illinois (Hallberg et al., 1980, p. 1). The work has redefined type sections for the Yarmouth. It becomes the well developed palaeosol in the undifferentiated sediments and the underlying Hickory Hills Till Member of the Wolf Creek Formation (Table 1). It excludes Leverett's sediments and organic deposits, now considered part of the superglacial facies of the Kellerville Till Member of the Glasford Formation of Illinoian age. Hallberg and Baker (1980, p. 129-130) propose that "the type-section for the Yarmouth Palaeosol and Yarmouth Stage be designated the Yarmouth Core Site as given in Descriptions 1 and 3; and that "the upper boundary of the Yarmouth Paleosol and Stage are considered to be the contact between the Early (or pro-) Illinoian peat and murky stratified sediments and the underlying paleosol in till-derived sediments and the Hickory Hills Till Member of the Wolf Creek Formation" (Figure 2). The type area for the Yarmouth Palaeosol remains the same, that is "the region around the Yarmouth drilling transect" (Hallberg and Baker, 1980, p. 130).

Members dispersed during mid-morning, having sated their appetites for giant palaeosolums. Mine had been whetted for the wide range of palaeosols subsequently seen across the continent during the following month. My gratitude is due to those new American friends who first drew my attention to the F.O.P. meeting and to the organisers and members for their generous hospitality during the meeting. The visit, of which this report records part, was made possible by a NERC Overseas Travel Grant and was undertaken during the tenure of a NERC Research Studentship.

Time Stratigraphy	Rock Stratigraphy	Soil Stratigraphy
WISCONSINAN STAGE	Wisconsinan loess *	Basal loess paleosol. *
SANGAMON STAGE	Unnamed sediments; * includes Sangamon and Late Sangamon Pediment and Alluvium; and undifferentiated sediments.	Sangamon and Late-Sangamon Paleosols
ILLINOIAN STAGE	GLASFORD FORMATION Kellerville Till Member superficial and subglacial-basal till facies.	
YARMOUTH STAGE	WOLF CREEK FORMATION (including unnamed, undifferentiated sediments)	YARMOUTH Paleosol
PRE-ILLINOIAN STAGES undifferentiated	Hickory Hills Till Member Aurora Till Member Winthrop Till Member ALBURNETT FORMATION unnamed sediments, unnamed till members.	Dysart Paleosol Franklin Paleosol Westburg Paleosol

* informal names.

Table 1. Present Pleistocene stratigraphic nomenclature for eastern Iowa. (Hallberg et al., 1980, Table 1, p. 4).

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REPORT ON A SHORT FIELD MEETING
IN WEST CORNWALL
18-21 SEPTEMBER 1980

By P.C. Sims

Twenty-three members of the Q.R.A. attended this meeting which was led by Professor N. Stephens and P. Sims. Guest speakers in the field were Dr. K. Atkinson, Dr. C. Caseldine, Rev. B. Clarke and Dr. P. O'Sullivan. The meeting focused on a number of 'classic' sites in West Cornwall but opportunity was also taken to see some lesser known localities. The meeting included something of interest for everyone ranging from giant erratics, rock platforms and raised beaches, through head, and possible glacial deposits to soils and palaeosols, peats and lake deposits. The sites and existing opinions are outlined in a Field Guide produced for the meeting (Sims, 1980).

Day 1

The meeting began in Plymouth and the first stop was on the Southern flanks of Bodmin Moor at Colliford in the St. Neot Valley (SX 181 709). Members braved atrocious conditions for about 30 minutes whilst Chris Caseldine explained the work which he and Ed Maltby were undertaking.

Here a number of Bronze Age barrows have been excavated exposing underlying masses of granite boulders and stones apparently imbricated and of congelifRACTATE origins - possibly stone stripes. Buried soil profiles exist in the excavations and a model of pedogenesis is suggested in which increasing acidification and podzolisation occurred.

We were soon all wet through and more than ready to sample the delights of the Crossroads Motel at Redruth.

Day 2

Our first stop was at Godrevy Point on the eastern side of St. Ives Bay, where a number of small sections of head, raised beach and sandrock are present above a somewhat undulating and shattered wave-cut rock platform. It was a fine morning and in the bright sunshine the discussion ranged around the problems of a) the exact number of head deposits and their lateral variation b) the changing level of the platform/raised beach interface and c) the existence or otherwise of periglacial cryoturbation features and fossil ice-cracks. Nick Stephens made the point that many so-called periglacial features could now be attributed to modern processes particularly the effects generated by rapid downslope movements of saturated material which had later partly dried out producing tension cracks which would subsequently be infilled by a later downslope sediment supply.

The group then moved on to the south coast of the peninsula by way of the Hayle-Marazion depression to a long section of the western end of the beach at Prah Sands (SW 575 280). Our movements were a little constricted here due to the narrowness of the beach present at high tide. The sea was fairly rough and at one stage the party narrowly missed being submerged by a breaker which suddenly surged up the beach to give many of us wet boots again, having only just managed to dry them out from the night before.

As we moved laterally along the beach, black peat was seen below blown sand and overlying a light grey stoneless clay. Below this, a brown silty clay with angular stones derived from a nearby quartz porphyry dyke passed below modern beach level. Further west along the beach the party had to navigate through and around various groups of sun-bathers in order to examine further exposures. The cliff sections thicken along the beach and in places well developed dessication cracks with iron indurated margins are present at the base. At one point a dark coloured horizon occurs a metre or so above the modern beach containing small fragments of charcoal. This was thought to indicate the existence of an exposed land surface before the massive thicknesses of head were deposited - an interpretation supported perhaps by the presence of the dessication cracks.

Our next stop after a convivial lunch at the Coach and Horses Inn, Rosudgeon was Porthleven. A fresh southerly wind and surging surf conditions unfortunately prevented us from examining the famous giant 50 tonne (?) erratic in close detail. However the party viewed the well-marked notches at the base of the cliff noting the cemented raised beach material.

At Loe Bar, our next stop, the meeting was addressed by Paddy O'Sullivan who briefly introduced us to the history of this bay-bar feature. He indicated that the modern bar had only become established in

historical times. Derek Mottershead suggested perhaps a two-stage development of the bar with material being rolled in from offshore during the Flandrian transgression to be ultimately established in its present position by later storm surge or storm wave activity.

Paddy O'Sullivan further reviewed the results of some palaeolimnological studies currently being undertaken in Loe Pool and demonstrated a modified 'icy finger' sediment sampler to the group.

At this stage the directors of the meeting encouraged the participants to retrace their steps back to the giant erratic in the hope that the tide had dropped sufficiently for us all to approach the rock. Jim Rose and Colin Whiteman succeeded in mounting the beast amid much spray and further managed to leap off before becoming totally immersed in a sea which continued to prove rather photogenic.

Neil Page noted that the cliff notches were similar to fluvio-glacial features he had seen in Scandinavia and thus proposed that we should consider the notches with their cemented material as ice marginal channels. In support he commented on the smoothing in the notches. The origin and stratigraphical position of the giant rock itself remained enigmatic.

We left Porthleven with the sun beginning to set and headed for our final stop of the day at Crousa Common (SW 776 201). Here the directors had previously tracked down small exposures of rounded gravels now largely masked by modern field and soil improvement. As the sun finally set over the Lizard the group was still engaged in a discussion of the origin of the Crousa Common gravels. A number seemed to favour warm (Tertiary?) processes, the gravels being a residue from the weathering of the granitic/gabbro/serpentine bedrocks, later rounded by fluvial or marine action. Others favoured a cold origin, but with the time at 7 pm and a one hour's drive back to our hotel, the matter was left unresolved.

Day 3

We began at Dobles sand pits on the northern flank of St. Agnes Beacon (SW 7065 5110). Here Keith Atkinson introduced us to the work that he had undertaken with others on the extent and origin of this intriguing sand deposit. He pointed out that firstly no basal pebble beds or conglomerate layer (as reported in the literature) had been found during his investigations in the area and, that secondly there was considerable lateral variation and facies change in the deposit. The meeting was shown upper sands which are unfossiliferous, extremely well sorted containing only a few sporadic pebbles or angular fragments. The group then worked down through the succession to the basal sands. Keith Atkinson indicated some channel fill features and showed us that the con-

tact between the sand and the deeply weathered and stained bedrock surface was marked by an extensive cemented sand layer forming a 0.5 metre thick iron pan. Within the pan, large tubular structures have been found whose origin remains uncertain.

Some discussion occurred regarding the origin of these sands. Opinions varied between tropical lagoon coastal sand dunes, late Oligocene fluvial deposits - based in part on the existence of dated lignitic clay, to possible cold fluvial, glacial outwash sediments.

Our next stop was at the northern end of Fistril Bay, Newquay. Here, the solution weathering features present in the aeolianite above the raised beach proved an interesting focus for discussion as did the nature of a gully with its cemented beach material and irregular floor.

After an excellent picnic lunch, the party viewed a number of small sections at the southern end of the beach. Extensive discussion took place on the age and position of the raised beach in relation to the tills deposited at Fremington in North Devon and in the Isles of Scilly. Many of the group joined in the general argument which perhaps predictably reached no firm conclusions apart from the need to have a reliable absolute dating technique. At this point Ann Wintle's work on thermoluminescence was mentioned as a possible key technique for the future.

The meeting then embarked on a magical mystery tour as we travelled cross-country from Newquay to the coast. One group favoured the direct route whilst another, led by a certain Professor of Geography as navigator, tried the scenic or 'around the houses' approach. At one stage the respective groups in their minibuses passed each other, going in opposite directions. Participants were truly amazed when both minibuses managed to get together again as we arrived at our next stop, Pendower (SW 898 382).

A fine 1 km long raised beach section is displayed here, with head above and limestone and quartzite erratics on the wave-cut platform(s) below. There seemed general agreement on a one beach, one head model but again the dating of these features remained elusive. Considerable interest was shown by many of the party over a modern erratic of several hundred large goose barnacles clinging to a large timber plank left stranded on the out-going tide.

Our final stop of the day was at an unscheduled SSSI located in the New Inn, Veryan. Here, exposures of modern dry-stone walling were admired while excellent St. Austell ale from the wood was sampled. After this short stop, the group returned to Redruth where

much sampling of other diverse beverages was to take place before the night was out.

Day 4

Began wet again, after torrential overnight rain. Undaunted, although a little delayed by a slow breakfast, the group travelled to our first stop of the day at Daymer Bay and Trebetherick.

We were met on site by the Rev. Ben Clarke, who gave a spirited performance in a temporary lecture theatre which was established in one of the minibuses. After his excellent introduction, we were led into the field to see various parts of this well known section. Most discussion in the field centred around the origin and stratigraphic position of the so called boulder bed. Chris Green strongly supported the view expressed by Arkell in 1943 that this deposit represents a possible interglacial river terrace gravel. In support he pointed to the fact that this was an estuarine site at the mouth of the River Camel. John Boardman, however, proposed a preglacial origin and suggested that the deposit was a gelifluctate incorporating locally derived bedrock and the residue of ancient river gravels which had been mixed together during movement down the valley side slope. In support of this he referred to the results of recent macrofabric analysis which possibly suggested the products of mass movement. Ben Clarke stated that he felt the boulder bed might represent a possible last interglacial beach associated with marine erosion of a Bristol Channel moraine. However, he did not rule out the possibility that the deposit was a glacial till. Despite the unsuccessful search for striations on quartzite blocks and the discovery of a flint pebble in the deposit the possibility of a glacial origin was considered unproven. However, the party left the exposure fully appreciating the significance of the deposit and the reasons for the controversy that has surrounded its interpretation.

After an excellent lunch at the Pityme Inn, the party moved to the famous section at Hawks Tor on Bodmin Moor where Andrew led us through the Allerød interstadial. John Boardman opened a discussion on the climatic conditions which prevailed during the late Devensian and Andrew Brown reluctantly drew analogies with the oceanic yet cold climate of western Norway.

Further exposures were explored at the northern end of the site. Previously recorded cryoturbation features were interpreted as being of modern fluvial origin where fine gravels had been loaded on top of wet peat bands with some associated mixing in a relatively high energy environment.

After an expression of sincere thanks to Peter Sims

and Nick Stephens for organising the field meeting, the party dispersed from Bodmin Moor, some direct to their homes and others via Plymouth.

Reference

Sims, P. C., 1980, Quaternary Research Association Field Meeting Guide to West Cornwall, 18-21 September 1980. Plymouth, 53 pp.

QUATERNARY STUDIES AT ABERDEEN

By J.S. Smith

Quaternary studies in Aberdeen greatly benefited from the sound foundations laid by T.F. Jamieson, pioneer Quaternary geologist in N.E. Scotland. Although an agriculturalist by training, through his careful recording of the many exposures opened up during railway construction during the mid-19th century, Jamieson established the reality of several regional glaciations, and drew attention to the likely presence of Scandinavian erratics in the lower tills. In the inter-war years of the present century, the work of the Geological Survey officers and of the Aberdeen schoolteacher Alexander Bremner further increased our knowledge of ice movement in Deeside and Speyside, with the latter researcher producing the first published maps of glacial land-forms. Bremner was the first to present evidence in N.E. Scotland for ice readvances, a topic which has since become a contentious issue in Scotland.

In the fifties, Francis Synge, then cartographer in the Department of Geography at Aberdeen, and working on the Quaternary largely in his spare time, produced the first working synthesis on the glaciation of N.E. Scotland. It is rumoured that he had a moraine-indicator mounted on the handlebars of his cycle! Although the pattern he described in his 1956 article in the Scottish Geographical Magazine is no longer entirely accepted, the maps which appeared have found their way into a surprising number of textbooks and articles, and remain a great stimulus to contemporary work in the area. At the same time, Kenneth Walton was making companion investigations into the sequence of shoreline displacement at the Loch of Strathbeg, and drawing attention to the drift-plugged sea stacks of North-East Scotland's cliff coast.

Under the late Professor Walton's active encouragement, a growing number of staff and research students with interests in physical geography continued the task of investigating the Quaternary in North-East Scotland and the Moray Firth coastlands. In those days great stress was

placed on the detailed mapping of the landforms. Colleagues at the Macaulay Institute, notably Sid Durno, provided the vital palynological evidence, while Ewart "Fitz" Fitzpatrick of the University Soil Science department worked on periglacial problems, and was, as he is now, a source of lively argument and stimulation. By the mid-sixties, the arrival in Aberdeen of Chalmers Clapperton and David Sugden, then working for their doctorates on glacial topics in the Cheviots and Cairngorms respectively, brought in new ideas on deglaciation. David's work in the Cairngorms, in particular, was later to provide a source of healthy controversy with work being carried out by Brian Sissons and his research students from Edinburgh, in particular on the behaviour of the Scottish ice between Older and Younger Dryas times. Readers of a recent issue of the Scottish Geographical Magazine will be aware that the discussion continues. Although now working for the Geological Survey of Ireland, Francis Syngé characteristically found time during holidays and week-ends to continue his Quaternary interests in Scotland, notably in the Loch Ness area with John Smith, and in Skye and Lewis with Jost von Weymarn. In the Loch Ness area, the mapping of the raised shore marks revealed a Late-glacial marine incursion, the subject of a week-end Q.R.A. meeting in Easter this year. With the arrival of palynologist Rod Gunson and glacial geomorphologist Alastair Gemmell, Quaternary interests broadened to include pollen and sediment analysis. In partnership with R. H. Kesel of the University of Louisiana, Alastair Gemmell has investigated the origins of the controversial so-called Pliocene gravels of lowland Buchan, and the results of their work, shortly to be published, is likely yet again to call into mind the truth or otherwise of J. K. Charlesworth's ideas on 'Moraineless Buchan'.

Over the years, Aberdeen has developed very close links with the British Antarctic Survey, with David Sugden and Chalmers Clapperton spending several seasons in the deep south supervising their post-graduates as well as conducting their own research. Several post-graduate research students have successfully completed doctorate theses based on glacial topics in the Antarctic or sub-Antarctic and members of the teaching staff with Quaternary interests have spent significant leave of absence periods in Colorado, Peru and Sweden. At least four successful student expeditions have studied glacial phenomena in Greenland and Iceland in the last ten years, reflecting the strong staff interest and commitment to Quaternary studies in Aberdeen. Most recently we have been joined by Judith Maizels, our first lady member of the teaching staff, who brings us expertise on fluvial and glacial sedimentation. Topics currently under investigation by post-graduate students include surging Icelandic glaciers, the Quaternary of the Falkland Islands and the Quaternary significance of the superficial deposits of N.E. Scotland.

Quaternary research has also become allied to the field of applied physical geography. The Department of Geography first produced a terrain map dealing largely with Quaternary drift forms and deposits for the Invergordon Public Inquiry in 1967. As a result of the mapping programmes associated with contract research topics, many

new Quaternary sections have been discovered and logged, and there has been some academic spinoff in the form of research publications. An inventory of the soft parts of the Scottish coastline carried out by Professor Bill Ritchie, John Smith and Sandy Mather has provided data on sea level changes in the Western Isles. More recently the team has been joined by Ian Ralston, who has added an archaeological dimension to Quaternary research.

There are now nine members of the teaching staff of the Department of Geography at Aberdeen who have interests and carry out research in the Quaternary. The department is supported in its teaching and research work by ten technicians, a newly opened suite of physical laboratories for pollen analysis, photogrammetry, sediment analysis and archaeological study, and by a Department Field Centre at Tarradale near Muir of Ord in the Scottish Highlands. Several Quaternary options are taught at both Junior and Senior Honours level. Although the exuberance of the 1960's has mellowed (with a few exceptions) into the maturity of the eighties, Quaternary studies have considerable activity and potential in and around Aberdeen as well as in the Highlands and Islands of Scotland, where many opportunities for original research remain untouched.

BOOK REVIEW

Air Photo-Interpretation for Soil Mapping. By D. M. Carroll, R. Evans and V. C. Bendelow, 1977. Harpenden: Soil Survey (Technical Monograph No. 8). 85 pp, 20 figures, 18 plates. Price: £2.00 paperback.

Air-photography is a tool which is well established in Quaternary research in Britain for the study of glacial geomorphology and river terraces, and for recording the position of significant exposures in active gravel pits or eroding cliffs; but it has been comparatively neglected in published work on periglacial features. One would wrongly suppose from some current textbooks that 'chalkland patterns' were limited to the Breckland, while there is no hint at all that apparently analogous patterns can also be detected on sandstone, limestone and river gravels. Similarly, thermokarst depressions are more widely distributed in southern Britain than the published maps imply.

Hitherto geologists and ecologists have been well provided with manuals of photo-interpretation designed for their use, but there has been little on soils outside specialist journals, and few of the relevant papers are concerned primarily with Britain. This monograph from the Soil Survey of England and Wales is thus to be welcomed, especially in view

of its modest price. The title of the book is accurate: the main chapters will principally be of value to those actually or potentially engaged in mapping soils. But there is much more of general application about soils and their appearance on air-photographs in the introductory chapters while the descriptions of air-photographs, photogrammetry and stereoscopy are the best plain intelligible accounts of these topics in a brief space that I know. The diagrams are very clear, and it is unfortunate that the commentary on Figure 8, through being over-condensed, fails to make sense, though the diagram itself is first-class. Topics of special interest to Quaternary scientists, such as patterned ground, are briefly mentioned and relevant literature cited; the best review of soil patterns as seen on air-photographs in Britain is still Evans (1972).

The monograph is obtainable from the Soil Survey, Rothamsted Experimental Station, Harpenden, Herts, AL5 2JQ.

Reference.

- Evans, R., 1972. Air photographs for soil survey in lowland England: soil patterns. Photogrammetric Record, 7, 302-322.

FORTHCOMING PUBLICATION

QUATERNARY SCIENCE REVIEWS: AN INTERNATIONAL MULTIDISCIPLINARY REVIEW JOURNAL

Quaternary Science Reviews is an international multidisciplinary and interdisciplinary journal which meets the need arising from an explosion of data and ideas within the many diverse fields of Quaternary Research.

Articles of up to 12,000 words length are required to review the 'state of the art' not only for specialists in the same field but also for the Quaternary community at large. Also required are shorter items of news, views, comment and discussion.

Part I of Volume I (4 parts) will appear in the second half of 1981. Instructions to authors may be obtained from the editor:

Dr. D. Q. Bowen
Quaternary Science Reviews
Llandinam Building
The University College of Wales
Aberystwyth SY23 3DB.

Further details about Quaternary Science Reviews are obtainable from:

Pergamon Press
Headington Hill Hall
Oxford OX3 0BW.

NATURE CONSERVANCY COUNCIL ANNOUNCEMENTS

PROPOSED MODIFICATIONS TO THE SOUTH-EASTERN LENGTH OF CHESIL BEACH

The Nature Conservancy Council have recently received a report which proposes substantial modifications to the south-eastern part of Chesil Beach, extending over a length of approximately one mile from the north-western termination of the present sea wall at Chiswell. The report has been prepared for Wessex Water Authority and Weymouth & Portland Borough Council and recommends that:

- (a) The crest of the beach for a length of 1600 metres be modified by the installation of three courses of gabion mattresses extending 7 metres to seaward and 10 metres to landward of the present crest. The beach landward of the mattresses would be regraded so as to pile shingle against, and over, the margins of the mattresses, raising the beach height by over 2 metres. To fill the mattresses and regrade the beach, substantial quantities of "foreign" material would be imported.
- (b) A new intercepting drain 3.5 metres in overall width and 5.5 metres in overall depth be constructed landward of the beach crest for a distance of 500 metres to the north-west of the existing sea-wall.

- (c) Unspecified modifications be made to the recently excavated drainage channel west of the road and running the length of the tank farm, whose construction has already constituted major disturbance to the back beach area. The new proposals appear to involve further importation of "foreign" rock fill.
- (d) The Weymouth to Portland road be raised. No details of how this is to be done are given.

The Nature Conservancy Council have been asked to comment on these proposals and it would be most helpful to us in this task if members could apprise us of their opinion on the effect that these modifications would have, both on the stretch of beach directly affected, and on the overall scientific value of Chesil Beach as an internationally well-known shingle feature. It would also be most useful for us to receive data on the usage made of Chesil Beach by members, students and/or colleagues for research and education. As matters are moving rapidly over the consideration of the proposed works, an early reply would be much appreciated. Please send your comments to Dr. G.P. Black, Head of Geology and Physiography Section, Nature Conservancy Council, Foxhold House, Thornford Road, Crookham Common, Newbury, Berkshire, RG15 8EL.

J. E. Gordon

GEOLOGICAL CONSERVATION REVIEW - MIDDLE AND LOWER THAMES REGION.

A review of Quaternary sites in the Middle and Lower Thames region has recently been initiated by the Nature Conservancy Council Geological Conservation Review Unit. The aim of this programme is to identify the most important sites representing the Quaternary history of the area. Initially a provisional list of sites will be made upon which a final selection will be based. In order to make a start to this project an interim list of sites has been compiled from information listed in the records of the Nature Conservancy Council with amendments based on personal experience. This list has been sent to Quaternary Scientists known to have research interests in the area in order that they can comment upon the information and, if possible provide further amendments or additional data. It is almost inevitable however, that the list of people to whom this information has been sent is incomplete and it would be gratefully appreciated

if any other members of the Quaternary Research Association who have information that may be of relevance could contact me at the following address: Geological Conservation Review Unit, Nature Conservancy Council, Pearl House, Bartholomew Street, Newbury, Berks., RG14 5LS.

D. R. Bridgland.

GRANT SOURCES

X INQUA CONGRESS FUND

Members are reminded that funds are available from the X INQUA Congress Fund for individuals to further their interests in Quaternary studies. This fund is supported by the interest derived from the financial surplus from the X INQUA Congress held at Birmingham in 1977. Further details and a Conspectus for the Fund is given in Quaternary Newsletter No. 29 November 1979. However, it should be noted that the closing date has been revised to 30th November 1980 and not the 31st October as previously stated. Application forms are available from the Executive Secretary, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG, telephone 01 839 5561 ext. 249/203.

ROYAL SOCIETY TRAVEL GRANT

The Royal Society invite applications for travel grants from members of the Quaternary Research Association who intend to attend the 13th International Botanical Congress in Sydney, Australia, between 21st-28th August 1981. Persons wishing to be considered for a grant should apply directly to: Miss B. M. de Vere, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG for an application form. This should be completed and returned to the Royal Society not later than Wednesday 10th December, 1980. Group travel arrangements have been negotiated with Meon Travel Ltd. and details will be circulated with the application forms.

QUATERNARY RESEARCH ASSOCIATION PUBLICATIONS FOR SALE

Quaternary Newsletter.

Numbers	Price to Members		Price to Non-members
1-3	10p each		40p each
4-8	out	of	print
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18-22	40p each		80p each
23-26	50p each		£1.00 each
27-28	out	of	print
29-32	50p each		£1.00 each

Quaternary Research Association Field Guides.

Title	Date	Editor/Compiler	Price to Members	Price to Non-members
Clacton	1973	J. Rose & C. Turner	£1.00	£2.00
Exeter	1974	A. Straw	£1.00	£2.00
Aberdeen + Quaternary Studies in North East Scotland	1975	A.M.D. Gemmell	£2.00	£4.00
Oxford	1976	D. Roe	£1.00	£2.00
Bristol	1977	K. Crabtree	£1.00	£2.00
Keele	1978	E. A. Francis	£2.00	£3.00
Vale of St. Albans	1978	J. Rose & P. L. Gibbard	£2.00	£3.00
Mallorca	1978	K. Crabtree, J. Cuerda, H. A. Osmaston, & J. Rose	£2.00	£3.00
East Central Ireland	1979	A. M. McCabe	£2.00	£3.00

Glasgow	1980	W. G. Jardine	£2. 00	£3. 00
Inverness	1980	F. M. Synge & J. S. Smith	£1. 00	£2. 00
West Cornwall	1980	P. C. Sims	£2. 00	£3. 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

- December 3rd - 4th 1980 Western Pacific Working Group (Australian Sector) of the International Quaternary Association's Loess Commission workshop and field meeting on Aeolian Dust Mantles of Australia, China and New Zealand. The meeting will be based on Canberra and will consider aeolian materials and landforms with particular reference to such deposits derived from both hot and cold arid regions. The workshop is divided into two parts to consider: i) regional perspectives, ii) specific problems including processes, soils, chronology and applied aspects. Further details can be obtained from Dr. J. M. Bowler, Department of Biogeography and Geomorphology, Australian National University, P.O. Box 4, Canberra, A. C. T. Australia, 2600.
- January 2nd -3rd 1981 Quaternary Research Association Discussion Meeting to consider the findings of the IGCP- 24: Quaternary Glaciations in the Northern Hemisphere. Further details and a Registration Form are included in the Circular issued with this News letter. Members should note that the dates have been changed from those given in previous Newsletters
- 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 16th 1981 A joint meeting of the Institution of Mining and Metallurgy, the Institution of Geologists, and the Geological Society to consider the geological aspects of the extractive industry in the United Kingdom. Further details can be obtained from: The Secretary, Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR.

- March 25th-26th 1981 Geological Society of London/British Geomorphological Research Group. Residual Sediments. To be held at the Geological Society. Further details can be obtained from Dr. C. Wilson, Geological Society, Burlington House, Picadilly, London, W1V 9HG.
- March 27th-30th 1981 British Geomorphological Research Group 21st Anniversary Conference on Problems of Large-scale Geomorphology. To be held at London School of Economics/King's College, London. Further details can be obtained from Dr. D. Brunnsden, Department of Geography, King's 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. This is being organised by Dr. R.J. Rice. Further details are given in the Circular issued with this Newsletter.
- 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, Dr. J.J. Lowe and S. Lowe. Further details will be given in the Circular issued with this Newsletter.
- May 15th-18th 1981 Quaternary Research Association Short Field Meeting to East Cumbria, under the leadership of J. Boardman, Dr. D. Huddart, J.M. Letzer and J. Rose. Further details are given in the Circular issued with this Newsletter.
- May 27th-29th 1981 South African Society for Quaternary Research. The annual conference will be held at the Transvaal Museum, Pretoria. The main themes will be palaeosol concretions, caves, geomorphology of arid environments. It will be followed by an excursion to the Kimberley district and then by a conference of the South African Association of Archeologists. Further details can be obtained from the Conference Secretary, Department of Archaeozoology, Transvaal Museum, P.O. Box 413, Pretoria 0001, South Africa.
- June 1st-6th 1981 Quaternary Research Association Short Field Meeting to Harris and Lewis, Outer Hebrides, under the leadership of Dr. J.D. Peacock and D. Balfour. Further details are given in the Circular issued with this Newsletter.
- June 3rd-4th 1981 The Royal Society - Discussion Meeting on the Evolution of Sedimentary Basins. Organized by Professor M. H. P. Bott, Sir Peter Kent, Dr. D.P. McKenzie and Dr. C. Williams. Further information can be obtained from The Executive Secretary, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG.

- 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 21st-28th 1981 13th International Botanical Congress, Sydney, Australia. Details of a source of funding for members to attend this Congress are given on page 43 of this Newsletter. Further details of the Congress can be obtained from Dr. H.J.B. Birks, Botany School, University of Cambridge, Downing St., Cambridge, CB2 3EA.
- September 1981 Quaternary Research Association Short Field Meeting to Central and South-eastern Gramplains 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.
- September 1981 Quaternary Research Association Study Course to examine: i) basic principles of Soil Mechanics, and ii) Geotechnical problems relevant to Quaternary Studies. Organizer: Dr. M. Paul.
- May 1982 Quaternary Research Association Short Field Meeting to Suffolk. Leaders: P. Allen and Dr. 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.
- August 1st-9th 1982 XI INQUA, Moscow. In addition to the Congress field meeting are being arranged from July 23rd-31st and August 10th-19th. The First Circular has been issued and further details can be obtained from Dr. Ismail P. Kartashov, Secretary - General of the XI INQUA Congress, Geological Institute, U.S.S.R. Academy of Sciences, Pyzhevsky 7, Moscow 109017, U.S.S.R.
- 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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