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LATE PLIOCENE AND EARLY PLEISTOCENE STAGES OF EAST ANGLIA AND THE ADJACENT NORTH SEA

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Abstract

Seven stages, based on pollen assemblage biozones, have been recognised in the marine deposits of the Red and Norwich Crag Formations.

The **Pre-Ludhamian** and **early Ludhamian** sediments contain marine faunas (foraminifera) similar to those found in the Walton through Newbourn and Butley Red Crags, and the FA2 foraminiferal biozone (Reuverian C and earliest Praetiglian sub-stages) of the Netherlands. The **Pre-Ludhamian** is normally magnetised, and contains the planktonic foraminifera Neogloboquadrina atlantica, indicating an age not later than the late Pliocene N. atlantica partial range zone (3.2 to 2.3 Ma).

The **late Ludhamian** and **Thurnian** sediments contain progressively less diverse marine foraminiferal faunas comparable to those in the Norwich and Chillesford Crags, and the FA1 foraminiferal biozone (most of the Praetiglian and Tiglian A through C4c sub-stages) of the Netherlands.

The **Antian** and **Baventian** stages contain temperate and cold-water marine foraminiferal faunas. The **Bramertonian** and **Pre-Pastonian a** (sub-) stages contain very similar foraminiferal faunas. Although they are currently considered to represent two successive temperate to "glacial" cycles, nowhere is the Bramertonian found overlying the Antian, or the Baventian, and a single Antian + Bramertonian to Baventian + Pre-Pastonian a cycle, exhibiting considerable intra-stage variability, is still considered a possibility. The Baventian is normally magnetised and is likely to correspond to the Olduvai palaeomagnetic event (1.91 to 1.76 Ma). Since the base of the Pleistocene is taken internationally to correspond with the top of the Olduvai event, all of the U.K. succession up to and including the Baventian should probably be considered late Pliocene. (N.B. Zagwijn (e.g. 1975) has consistently drawn the base of the Pleistocene at the Praetiglian of the Netherlands succession; his level would post-date the Pre-Ludhamian and be no later than the Thurnian of the East Anglian succession.)

Comparison of the dating of the East Anglian succession with the global record of sea-level changes suggests that only the **high (sea-level) stands** are recorded **onshore**:

3.2 Ma to 2.4 Ma Pre-Ludhamian - Ludhamian - Thurnian

Red Crag Formation

2.0 Ma to 1.6 Ma Antian (?Bramertonian) - Baventian (?Pre-Pastonian a)

Smith's Knoll Formation

1.3 Ma to 0.8 Ma Pastonian - Beestonian

Yarmouth Roads Formation (pars)

0.5 Ma to 0.2 Ma Cromerian

Yarmouth Roads Formation (pars)

The **lowstands** at 2.4 to 2.0 Ma, 1.6 to 1.3 Ma and 0.8 to 0.5 Ma are probably only represented **off-shore**, by the **Westkapelle Ground, Winterton Shoal Formations** and **Yarmouth Roads Formation (pars)** respectively.

Introduction

Seven stages, (all based on pollen assemblage biozones), have been recognised in the marine deposits of the Red and Norwich Crag Formations (Funnell & West 1977, Funnell et al. 1979) of East Anglia. They are, in actual or assumed stratigraphical order: Pre-Ludhamian, Ludhamian, Thurnian, Antian, Baventian, Bramertonian, and Pre-Pastonian a. Three of these stages, the Thurnian, Antian and Baventian, have been provisionally identified on the basis of pollen and palynomorphs in deposits of the offshore Westkapelle Ground, Smith's Knoll and Winterton Shoal Formations of the southern North Sea (Cameron *et al.* 1984).

Consistent recognition of these stages in on- and off-shore sequences is made difficult because of: (a) the sporadic occurrence of pollen-bearing sediments in these often arenaceous and oxic marine deposits, (b) the influence of transportation and environment of deposition on the composition of pollen spectra from marine sediments. In the following paragraphs each of the stages is considered in turn in relation to, (a) its definition and stratotype, (b) magnetic signature, (c) foraminiferal content, (d) identification in co- or hypo-stratotypes, (e) correlation with European and global stratigraphies.

PRE-LUDHAMIAN

Defined by Beck *et al.* (1972) on the basis of a polleniferous sequence in the Stradbroke borehole (UEA 3, see Lord 1969). In Beck (1971, p. 59) the Pre-Ludhamian is defined as ranging from 233 to 309 feet below surface (= - 16.41 to -39.39 m O.D.). The *Pinus-Picea-Alnus* + *Betula* biozone exhibits NAP values of 15-25%, and low values of *Tsuga* and *Pterocarya* occur throughout. The spectra have been compared by West (1977, 1980b) with those of the Reuverian C sub-stage of the Netherlands.

Between 220 and 284 feet below surface (= -12.27 to -32.08 m O.D.) the Pre-Ludhamian sediments are normally magnetised (van Montfrans 1971).

Foraminifera from the Pre-Ludhamian sequence have been compared with assemblages from the Walton Crag of the Red Crag Formation (Beck et al. 1972, Funnell & West 1977). Carbon tetrachloride-floated assemblages have been listed by Funnell & Booth (1983). The planktonic foraminifera from Stradbroke have been re-examined recently, in the light of up-to-date research on the taxonomy and biostratigraphy of planktonic foraminifera of similar age from the North Atlantic (Weaver & Clement 1986). Neogloboquadrina atlantica occurs consistently in Pre-Ludhamian samples from 276'6" b.s. (= -29.5 m O.D.) to 234'5" b.s. (= -16.7 m O.D.), and sporadically in early Ludhamian samples including at 222' (= -12.88 m O.D.). These occurrences indicate an age pre-dating 2.3 Ma, the palaeomagnetically controlled last appearance datum for N. atlantica in the North Atlantic. Since the Pre-Ludhamian foraminiferal assemblages compare closely with those of the FA2 foraminiferal biozone of Doppert (1975), which occurs in the Netherlands Oosterhout Formation, which contains Reuverian C pollen, **all stratigraphical criteria agree suggesting that the Pre-Ludhamian is late Pliocene in age, corresponding to the latter part of the normally magnetised Gauss palaeomagnetic epoch, i.e. just prior to 2.47 Ma.**

Pre-Ludhamian pollen has also been reported from Red Crag at -36 to -37 m O.D. at Sizewell (West & Norton 1974). 'Float' populations of foraminifera at a similar depth (-35.1 to - 47.9 m O.D.), in another borehole at Sizewell (Funnell 1983) are similar to those in the pollen-defined Pre-Ludhamian sediments at Stradbroke. These are the only published accounts of Pre-Ludhamian deposits in East Anglia. Recent examination of material from BGS offshore boreholes 81/1A and 81/51 (Cameron et al. 1984) has confirmed the sediments of the offshore Red Crag Formation as Pre-Ludhamian on the basis of the foraminifera. (In addition to the species recorded by Cameron et al., the 'unfloated' assemblages contain abundant Pararotalia serrata, and Neogloboquadrina atlantica at 90.20, 80.90 and 75.61 m in 81/51 and at 34.20, 27.25 and 24.26 m in 81/1A).

A correlation with the on-shore Pre-Ludhamian Red Crag Formation can therefore be confirmed.

LUDHAMIAN

Defined by West (1961) on the basis of a polleniferous sequence in the Ludham (Royal Society) borehole. The Ludhamian is defined as ranging from 105 to 177 feet below surface (=-25.5 to -47.1 m O.D.). The Pinus-Picea-Alnus + Quercus-Tsuga-Betula biozone was divided into two sub-zones 'a' and 'b' at 132 feet b.s. (=-40.2 m O.D.). The earlier sub-zone is characterised by lesser amounts of Tsuga; small percentages of Pterocarya occur throughout.

West (1961) provisionally suggested correlation with the Tiglian stage of the Netherlands succession; Zagwijn (1975) preferred to equate it with the Tiglian C3 sub-stage. Foraminifera from the earlier Ludhamian (Lpla of Funnell & West 1977) assemblages contain numerous Red Crag species, but these are accompanied throughout by Elphidium frigidum (Funnell 1961). In this respect the assemblages resemble both 'unfloated' and 'floated' assemblages from the early Ludhamian of the Stradbroke borehole (Beck et al. 1972, Funnell & Booth 1983), and 'unfloated' assemblages from the Newbourn and Butley

Red Crags (West & Funnell 1977). N. atlantica has been sporadically identified amongst the sparse planktonic foraminifera from Ludham, (e.g. at 175'6" and 182' below surface =-53.5 and -55.5 m O.D.), and also occurs in the lowest pollen-analytically defined Ludhamian of Stradbroke (see above) within the normally magnetised sediment sequence.

(N.B. Beck (1971, p. 59) places the Stradbroke Ludhamian/Pre-Ludhamian boundary at 233' b.s. (=-16.41 m O.D.), cf. c. -15 m O.D. in Beck et al. (1972). The main foraminiferal change takes place between 215' and 222' b.s. (=-10.7 to -12.88 m O.D.) Elphidium frigidum is present in 'unfloated' assemblages to a depth of 248' b.s. (=-19.02 m O.D.). Therefore there is a transition from c.-19.02 m O.D. (E. frigidum lower limit), through -16.41 m O.D. (base of pollen stage) to c.-12.88 m O.D. (upper limit of abundant Red Crag foraminifera).)

Foraminifera from the later Ludhamian (Lp1b of Funnell & West 1977) contain some Red Crag species near the base, but towards the top of the Ludhamian of the Royal Society borehole they are often absent. Typical of these latter assemblages is the presence of Textularia suttonensis (cf. Funnell 1961, p. 349). (LIII Funnell 1961 = Lf3 Funnel & West 1977 of the Ludham Pilot borehole is more representative of the late Ludhamian assemblages in the Royal Society borehole than LII = Lf2.) The later Ludhamian sediments of the Stradbroke borehole (Beck 1971) do not contain foraminifera.

No magnetic record is available from the Ludhamian sediments of either the Ludham or Stradbroke boreholes, except for the basal 4.14 m of the Stradbroke Ludhamian as defined by Beck (1971, p. 59) which is normal. (N.B. the foraminifera at the level of the highest magnetic determination, but no higher, are still of Pre-Ludhamian aspect.)

The transition from foraminiferal assemblages of Red Crag aspect to those of Norwich Crag aspect, which occurs at, or slightly above the base of the later Ludhamian (Lp1b) is similar to that occurring between the FA2 and FA1 foraminiferal biozones in the Netherlands. In the Netherlands it approximates to the short-lived occurrence of Elphidium oregonense (not known from the U.K. either on- or off-shore); this (Van Voorthuysen et al. 1972) occurs at De Meern (Zagwijn 1975), approximately 10 to 20% of the way into the Praetiglian stage, up to or just before the rapid rise in NAP from early Praetiglian values of 20-35% to 30-65% (cf. Reuverian C values of 10-20%).

THURNIAN

Defined by West (1961) on the basis of the polleniferous sequence in the Ludham (Royal Society) borehole. The Thurnian is defined as ranging from 82 to 105 feet below surface (=-18.6 to -25.5 m O.D.). It is characterised by a high NAP of 45-65%, and a consistently low occurrence of Tsuga, in a Pinus-Alnus + Picea-Betula-Tsuga assemblage. West (1961), provisionally suggested correlation with the Eburonian of the Netherlands succession; Zagwijn (1975) preferred correlation with Tiglian C4c.

Foraminifera in the Thurnian deposits of the Ludham (Royal Society) borehole (see LIV Funnell 1961 = Lf4 Funnell & West 1977 of the Ludham Pilot borehole), are of Norwich Crag species only, small in size, of low diversity and stained brown in colour. This latter feature was taken (in conjunction with the unstained character of the foraminifera in the overlying Antian), as indicating a hiatus in deposition following the end of the Thurnian (Funnell 1961, p. 350).

PRE-LUDHAMIAN - THURNIAN summary

The **Pre-Ludhamian,** which seems to be equivalent to the Walton Crag of the Red Crag Formation, is clearly late Gauss and Late Pliocene in age.

The **early Ludhamian** appears to be equivalent to the Newbourn and Butley Crags of the Red Crag Formation, and is probably also Late Pliocene in age. On the basis of the foraminifera it compares most closely with the latest Reuverian C and earliest Praetiglian. This would place it at the Pliocene-Pleistocene (Reuverian C-Praetiglian) boundary as defined by Zagwijn (1975, etc.). However, (a) the "Pliocene" aspect foraminifera in the early Ludhamian could be re-worked, or (b) the transition from "Pliocene" aspect (=Red Crag, =FA2) foraminifera to "Boreal" aspect (=Norwich Crag, =FA1) foraminifera could be diachronous between the Netherlands and East Anglia. In this latter case the early Ludhamian could equate with the Tiglian of the Netherlands succession, but a gap, corresponding to the whole of the Praetiglian and the cool, early Tiglian (A to C2) sub-stages would be implied in the East Anglian succession between the Pre-Ludhamian and the early Ludhamian. This clearly needs further investigation.

The **late Ludhamian** seems to represent the onset of Norwich Crag type marine conditions and assemblages in East Anglia. The foraminiferal assemblages are similar to those in the FA1 foraminiferal biozone of the Netherlands, the base of which occurs within the Praetiglian. This would place it in the Early Pleistocene as defined by Zagwijn (see above). The distinctive species Elphidium oregonense, which marks the FA2-FA1 boundary in the Netherlands, has not been found at the early-late Ludhamian boundary in East Anglia. However, if this foraminiferal biofacies transition is diachronous across the North Sea, (again see arguments above), the late Ludhamian could correspond to the Tiglian C3 sub-stage, as suggested by Zagwijn (1975).

The **Thurnian** contains impoverished "Boreal" aspect (=Norwich Crag, =FA1) foraminifera. It could correspond with the cold episode represented by the Praetiglian in the Netherlands. If not, following the alternative arguments developed above, it has to correspond with a cool Tiglian sub-stage such as C4c, as suggested by Zagwijn (1975).

Overall, therefore, **either** the East Anglian succession Pre-Ludhamian through Thurnian corresponds to the Netherlands succession Reuverian C through Praetiglian, and represents almost in its entirety the first major cooling in the North Atlantic area, (with its associated marine regression), culminating at 2.4 Ma (Shackleton et al. 1984), **or** it represents the Reuverian C (Pre-Ludhamian) and, after a so far unrecognised gap, part (?C3 through C4c) of the Tiglian (Ludhamian-Thurnian) of the Netherlands.

ANTIAN

Defined by West (1961, L3 = Lp3 Funnell & West 1977) on the basis of the polleniferous sequence in the Ludham (Royal Society) borehole. The Antian is defined as ranging from c. 72 to 82 feet below surface (=-c. 15.8 to -18.6 m O.D.). It is characterised by 35 to 45% NAP and the presence of Tsuga and Pteryocarya in a Pinus-Alnus-Tsuga + Picea-Betula assemblage. West also identified Antian pollen assemblages in the pre-Baventian sediments of Easton Bavents (Funnell & West 1962).

West (1961) provisionally suggested correlation with the Waalian of the Netherlands succession; Zagwijn (1975) preferred a correlation with the Tiglian C5. Foraminifera in the Antian deposits of the Ludham (Royal Society) borehole (LV Funnell 1961 = Lf5 Funnell & West 1977 of the Ludham Pilot borehole), are of Norwich Crag species only, of average size, moderate diversity, and white in colour. Ammonia beccarii (=batavus) is abundant.

BAVENTIAN

Defined by West (1961, L4b & c = Lp4B & C Funnell & West 1977) on the basis of the polleniferous sequence in the Ludham (Royal Society) borehole and the cliff exposures at Easton Bavents, Suffolk (Funnell & West 1962). At Ludham the Baventian was originally defined as ranging from 47 to c.72 feet below surface (=-8.1 to c. -15.8 m O.D.). It is characterised by 52 to 78% NAP with Betula-Pinus-Alnus in approximately equal percentages + Picea below c. 55' b.s. (c. -10.7 m O.D., i.e. Lp4B, and Pinus (dominant)-Betula-Alnus + Picea, i.e. Lp4c, above that level. Traces of Tsuga occur throughout.

West (1961) provisionally suggested correlation with the Menapian of the Netherlands succession; Zagwijn (1975) preferred a correlation with the Eburonian.

Foraminifera in the Baventian deposits of the Ludham (Royal Society) borehole (LVI & LVII Funnell 1961 = Lf6 & Lf7 Funnell & West 1977 of the Ludham Pilot borehole) are of Norwich Crag aspect. At and below 65'6" to 68'6" b.s. (=-13.9 to -14.8 m O.D.), in the lower part of Lp4b, they include Ammonia beccarii (=batavus) (as in Lf6). From 62' b.s. (=12.8 m O.D.) upwards, in the upper part of Lp4b, A. beccarii is absent and cold-water species of Elphidium such as E. frigidum, E. orbiculare and E. cf. bartletti become the most important species after the increasingly dominant Elphidiella hannai (as in Lf7). Similar assemblages of foraminifera, both with A. beccarii, in Lp4a and the lower part of Lp4b, and without A. beccarii, in the upper part of Lp4b, have been described from the Baventian of Easton Bavents (Funnell & West 1962) and Covehithe (West et al. 1980).

There are no foraminifera above 57' b.s. (=-11.3 m O.D.), i.e. in the pollen sub-zone Lp4c at Ludham. This sub-zone has subsequently been considered by West (1980a, p. 13) as equivalent to his Pre-Pastonian a sub-stage.

(N.B. there are erroneous statements in both Funnell et al. (1979, p. 501) and West et al. (1980, p. 7). There are no foraminifera in Lp4c at Ludham; the Lf7 level corresponds with the upper part of Lp4b in the Royal Society borehole).

BRAMERTONIAN

Defined by Funnell et al. (1979) on the basis of a short polleniferous sequence in Blake's Pit, Bramerton. The Alnus-Quercus-Carpinus + Pinus-Picea assemblage contains a trace of Tsuga and 14 to 24% NAP. It therefore has a lower NAP and negligible Tsuga compared with the stratotype Antian. Foraminifera from the stratotype Bramertonian are indistinguishable from those of the stratotype Antian, except for the sporadic presence of some (possibly re-worked) Red Crag species, which are not seen higher than the early part of the late Ludhamian in the Ludham boreholes.

PRE-PASTONIAN (Sub-stage a)

Defined by West (1980a, p.13) and correlated with Lu4c (=Lp4c Funnell & West 1977 of the Ludham (Royal Society) borehole and subsequently (Funnell et al. 1979) with the upper part of the sequence at Blake's pit, Bramerton. (N.B. it may help readers to know that the paper by Funnell et al. published in 1979, was completed after the completion of West's book, ultimately published in 1980, i.e. the publication dates are in reverse order to the sequence of research and interpretation.)

The Pinus-dominated 50% or more NAP pollen spectra are unlike any post-Pastonian cold pollen assemblage biozone in the U.K. succession (Funnell et al. 1979, p. 497).

Foraminifera from sediments at Bramerton and Sidestrand, identified by pollen as Pre-Pastonian a, are dominated by Elphidiella hannai and species of Elphidium, including cold-water species referred to under the Baventian (see above).

ANTIAN - PRE-PASTONIAN A summary

Nowhere in the U.K. on- or off-shore deposits can these four stages be found superimposed. In particular Bramertonian deposits can nowhere be identified overlying Antian deposits, even when the Baventian is present. In view of the fact that there is (a) no pollen in the Ludham (Royal Society) sequence between 70 and 75 feet below surface (=-15.2 to -16.8 m O.D.), and (b) sedimentological evidence at Easton Bavents suggests a possible non-sequence between the Antian and Baventian pollen spectra, an alternative solution to the succession of stages can be proposed. This is that the Antian is followed by a high Pinus, low NAP, low Tsuga Bramertonian episode (unrepresented by pollen at Ludham and by sediments at Easton Bavents), and that the Baventian terminates in a high Pinus Pre-Pastonian a episode (as envisaged by West 1980a, p. 13). Alternatively the Bramertonian is, partially at least, a facies variant of the Antian, and the Pre-Pastonian a of the Baventian. Such a reversion to an essentially earlier viewpoint would not contradict the evidence of the pollen and foraminifera. Indeed it might help to resolve possible problems over the correlation of the Chillesford and Easton Bavents clays and the interpretation of microtine mammal data (Mayhew & Stuart 1986).

OFF-SHORE FORMATIONS

Apart from the confirmation of the Pre-Ludhamian age and the recording of Neogloboquadrina atlantica in the off-shore Red Crag Formation, based on the examination of samples from BGS boreholes 81/1A and 81/51, the stage allocations in Table 1 are based on data contained in Cameron et al. (1984).

Table 1. Stage allocation of U.K. off-shore formations (cf. Cameron et al. 1984).

Red Crag Formation
Pre-Ludhamian foraminifera, including the late Pliocene (33.2-2.4 Ma) Neogloboquadrina atlantica present (N. atlantica partial range zone)
Westkapelle Ground Formation
Thurnian-like pollen spectra, but reversed magnetic polarity, with two normal events. Possibility 1: if Thurnian = late Praetiglian cold episode; early Matuyama and normal polarities = excursions only. Possibility 2: if Thurnian = early Tiglian cool episode; normal polarities = 'X' and Reunion events in the Matuyama reversed epoch at 2.23 and 2.07 Ma (thought to be equivalent to Tiglian A and Tiglian C3) (N.B. duration of normal events only 1,500 and 3,000 years respectively on assumption of 1 m ka^{-1} sedimentation rate.)

Smith's Knoll Formation
Antian-like pollen spectra, with abundant Spiniferites dinoflagellates as in Antian on-shore. Could equate with Tiglian C5.

Winterton Shoal Formation
Baventian-like pollen spectra. Onshore Baventian normal polarity. Could be Olduvai event (1.91-1.76 Ma). (N.B. up to 150 m of sediment accumulation possible in 0.15 Ma at 1 m Ka^{-1}).
Tiglian C6/Eburonian boundary thought to correspond with Olduvai event.

COMPARISON WITH GLOBAL SEA-LEVEL CHANGES

This comparison is based on a recent global compilation by Haq *et al.* (1987).

TABLE 2. Possible relation of North Sea stages with global sea-level changes*

Post-0.5 Ma (downlap surface age) highstand:	**Cromerian**
post-0.8 Ma (sequence boundary age) lowstand:	Menapian-Bavelian
post-1.3 Ma (dsa) highstand: Yarmouth Roads Fmn.=	**Pastonian-Beestonian** Waalian-Menapian
post-1.6 Ma (sba) lowstand: Winterton Shoal Fmn.=	Eburonian
post-2.0 Ma highstand: Smith's Knoll Fmn= **Antian (?Bramertonian)-Baventian (?Pre-Pastonian a)**	= Tiglian C-early Eburonian
post-2.4 Ma (sba) lowstand: Westkapelle Ground Fmn.=	Tiglian A-B
post-3.2 Ma (dsa) highstand: Red Crag Fmn.= **Pre-Ludhamian-Ludhmian-Thurnian**	= Reuverian C-Praetiglian

(* this table does not attempt to represent the more frequent, lower amplitude, shorter wave length sea-level changes that certainly occurred during the Late Pliocene and Early Pleitocene in the North Sea basin.)

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I am grateful to Richard West for critically reading the original draft of this article. I have omitted some of my more speculative comments as a result of his criticisms, but some remain in the hope of provoking further discussion and investigation.

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AN INEXPENSIVE PEBBLE-SPLITTER FOR CLAST LITHOLOGICAL ANALYSIS

P.F. Jones, S.A. Taylor and P.R. Joy

Clast lithological analysis increasingly forms a significant part of many Quaternary research investigations and there are now recommended procedures to help achieve a uniformity of approach (Bridgland 1986). Although certain clasts are readily identifiable from their abraded surfaces, many need to be broken open to provide a fresh face. This is particularly important where the lithological characteristics are obscured by surface coatings, strong patinas or other weathering effects. In the case of weak lithologies, one or more sharp blows with a hammer may be all that is required to achieve breakage. However, obdurate clasts such as well-rounded quartzites are often difficult to split in this manner and there is also the danger that they may be propelled sideways at high speed. These problems can be overcome by the use of a home-made pebble splitter constructed from a simple hydraulic car jack (Fig. 1).

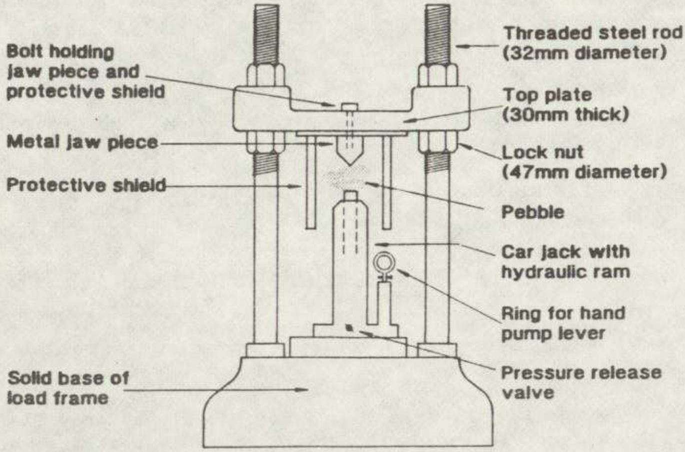


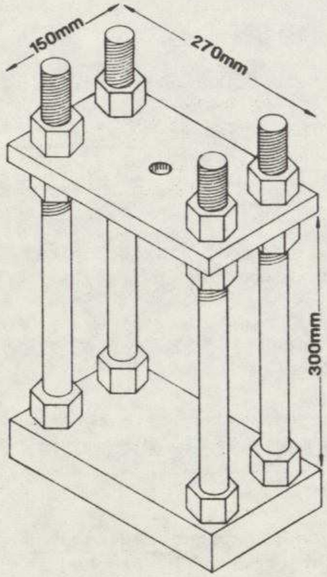
Fig. 1.

The pebble-splitter described here works on the principle of a compression loading machine. It comprises a rigid load frame within which pressure can be exerted on a given pebble by means of a hydraulic ram. A safety shield is provided to contain the specimen and protect the operator. The apparatus was made at relatively low cost. Most of the component parts were produced from items discarded by the Engineering department at Derbyshire College. The only essential purchase was that of the hydraulic jack obtained from a local motor spares shop for approximately £10.

The rigid load frame required for the apparatus was readily made by adapting an old four-column engineering press (30 ton capacity). A serviceable alternative could be constructed from two strong metalplates and four threaded connecting rods (Fig. 2). The top plate of the load frame can be moved by adjusting the four sets of locking nuts. Its position can then be fixed so as to restrict the size of clast that is accepted by the apparatus. In this example, the crushing jaw was adjusted to accept clasts with a-axis of up to 28 mm (i.e. to within the medium-coarse gravel range). For larger clasts, including cobbles, it is more appropriate to use a commercial heavy duty rock-splitting machine. One machine employed for this purpose at Derby was constructed by Cut Rock Engineering (Engineering Laboratory Equipment Ltd) and will accept rock samples of up to 178 x 178 mm.

The Beva hydraulic car jack incorporated in the pebble splitter has a maximum capacity of 3 tons (30 kN). This compares with the 8 ton (80 kN) capacity of the Cut Rock Engineering machine. For stability, the jack was welded to the bottom plate of the load frame. The top plate of the load frame holds a wedge-shaped static jaw piece made of mild steel. This is bolted on from the upper side of the plate and can be replaced when worn. When in position, the jaw piece also holds in place a thin metal sheet from which a protective shield is suspended. The shield was made from 12 mm gauge aluminium tubing of 120 mm external diameter. This was cut longitudinally into two pieces which were then hinged together along one length (Fig. 3). One piece of tubing was attached at its semi-circular end to the thin metal sheet and the other was left free to open and close as an access door to the crushing jaw. When closed, the door can be firmly fastened by means of a metal catch.

To split pebbles a sample is placed between the jack-ram and the steel jaw piece. The pressure release valve on the jack is closed down and the hydraulic hand pump is operated until the pebble is gripped. The access door should then be firmly closed and further pressure exerted by means of the hand pump to break the sample. The release valve must then be opened so that the jack ram can be returned to its former position.



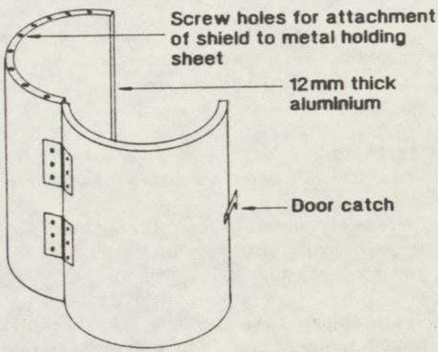


Fig. 3.

Fig. 2.

Acknowledgements

We would like to thank D. Evans and S. Chambers for help with the assembly of the apparatus and A.J. Skinner for assistance with the diagrams.

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MEGACEROS OR *MEGALOCEROS*? THE NOMENCLATURE OF THE GIANT DEER

Adrian M. Lister

The "giant deer", or "Irish elk", is one of the best-known of European Pleistocene mammals. However, there is confusion over the correct generic name for this taxon, with authors divided between *Megaloceros* Brookes, 1828 and *Megaceros* Owen, 1844. It seems worthwhile trying to provide a definitive answer to this problem, the history of which is as follows.

In 1827, Sir Joshua Brookes published a listing of his zoological collection (Brookes 1827a), which included the following (p. 14):

"*Fossil Bones*. ... likewise two uncommonly fine Crania of the Megalocerus antiquorum *Mihi*. (Irish), with unusually fine horns, (in part restored.) ..."

This appears to be the first published usage of either of the names here in question. In two subsequent editions (Brookes 1827b & 1828a), the same passage occurs, virtually identical to Brookes (1827a) except that "Megalocerus" is replaced by "Megaloceros".

However, on the basis of these publications, neither *Megalocerus* nor *Megaloceros* is valid, since the description provided by Brookes is insufficient under the Code of Zoological Nomenclature (ICZN 1985). Citation of a type locality (in this case, Ireland) is an invalid part of a definition (Article 13c), without which Brookes's description could refer to almost any horned animal.

Later in 1828, Brookes published a new and enlarged listing of his collection, in the form of a catalogue for a forthcoming auction (Brookes 1828b). This contained the following (p. 61):

"Fam.3. Cervidae
Subfam. MEGALOCERIDAE
Megalocerus
Cornibus deciduis palmatis
. . . .
Species
Antiquorum"

Because it was a sale catalogue, the validity of Brookes (1828b) as a basis for zoological nomenclature has been questioned. Recently, however, the ICZN have approved it as an available publication (ICZN 1977). Moreover, the phrase "Cornibus deciduis palmatis" constitutes a definition sufficient under the Code (Article 12) to validate Megalocerus.

In 1844, Sir Richard Owen, ignoring Brookes's publications, named the Irish giant deer Cervus (Megaceros) hibernicus. The name Megaceros was borrowed from Hart (1825), who had used it at specific level to describe the same species (as Cervus megaceros). Under the Code, this previous usage at the specific level does not affect the priority of first usage at the generic or subgeneric level, so that Owen (1844) is the source for Megaceros.

Following Owen (1844), the use of Megaceros became widespread, to the apparent total exclusion of Megalocerus. It soon became used as a full genus rather than subgenus; again, this does not alter Owen's priority for the name at generic level (Article 43). Brookes's name for the giant deer was forgotten for over a hundred years, until in 1945 G.G. Simpson, in his influential classification of the mammals, revived it, with the spelling Megaloceros. Since that date, both Megaceros and Megaloceros have been in common use to describe the same cervid taxon.

On the basis of the Code of Zoological Nomenclature, it is clear that Brookes's name for the giant deer, as published in Brookes (1828b), has priority over Owen's. Before 1945, there would have been a strong argument for validating Megaceros on the basis of usage. This is not the case today, however, and Megaceros should be dropped.

The only outstanding question is the valid spelling of the name proposed by Brookes. Strictly, Megalocerus is correct. However, it has barely been used since 1828, whereas Megaloceros has been widely in use since 1945. On the basis of this, and at the suggestion of Dr. P.K. Tubbs, the ICZN has been requested formally to suppress Megalocerus, and to place Megaloceros Brookes, 1828 (gender masculine) on the Official List of Generic Names in Zoology, with type species M. antiquorum Brookes, 1828 (= Alce gigantea Blumenbach, 1799). The "Irish giant deer" should therefore be known as Megaloceros giganteus (Blumenbach), and the correct name for a Tribe or Subfamily based on it would be, respectively, Megalocerini Brookes, 1828 or Megalocerinae Brookes, 1828.

I thank Dr. P.K. Tubbs, Executive Secretary of ICZN, and Mr. N. Monaghan, National Museum of Ireland, for valuable discussion.

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INVESTIGATION OF A PROBABLE UPTON WARREN INTERSTADIAL SITE NEAR BENGEWORTH, WORCESTERSHIRE

D. Maddy, D.H. Keen and D.R. Bridgland

During the summer of 1986, excavations for the construction of the Evesham bypass at Bengeworth, Worcestershire, exposed a section of fossiliferous Pleistocene sediments (G.R. SP058433).

The section exposed (Fig. 1) lay within a depression situated between two patches of Terrace no. 4 deposits of the River Avon (Tomlinson 1925). The surface of the exposed sediments lay at approximately 43 m O.D., the surface of Terrace No. 4 at this point lying some 4 m above at approximately 47.0 m O.D.

The sediments revealed (Fig. 1) consisted of a thin basal gravel (0.27 m) overlain by 0.6 m of faintly laminated sands and silts containing fossiliferous lenses. Capping the sequence in the centre of the depression was a series of fining upwards, matrix supported, fine gravel beds, interbedded with sands and occasional clay bands.

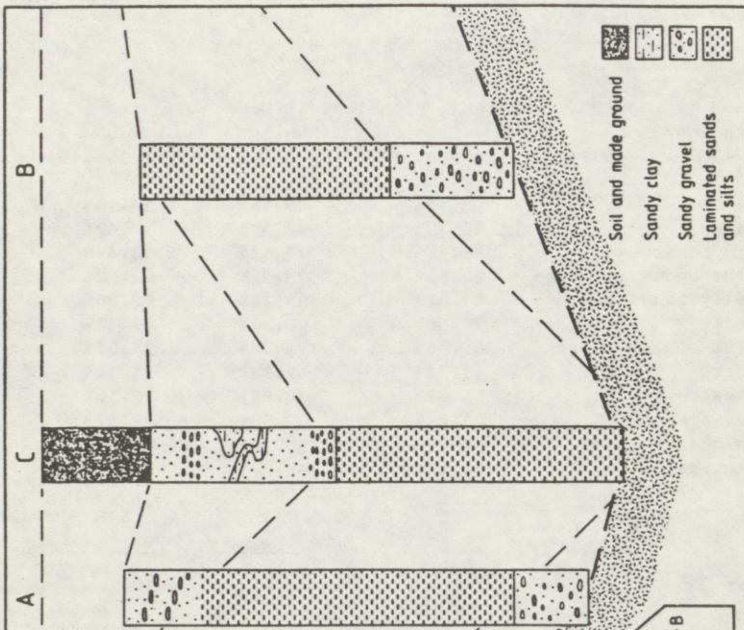

Fig. 1.

Gravel Analysis

A sample from the basal gravel was collected and the 11.2-16.0 mm size fraction identified and counted. The results of this count, (No. 1) along with two others from the gravels underlying Terrace no 4. near to this site at G.R. SP 054446 and SP 056445, are shown in Table 1.

Table 1. Lithological Data

Lithology	No.1 (SP 058433)	No.2 (SP 054446)	No.3 (SP 056445)
Quartz	05.12%	09.56%	18.55%
Quartzite	18.18%	42.42%	28.62%
Hard Sandstone	04.79%	10.53%	04.40%
Calcareous Sandstone	00.50%	02.25%	02.52%
Shelly Sandstone	01.82%	00.14%	00.00%
Shell	20.66%	00.56%	03.46%
Flint	37.36%	14.04%	11.01%
Chert	03.31%	02.39%	03.14%
Limestone	05.62%	16.85%	25.16%
Ironstone	01.32%	00.98%	02.52%
Igneous	00.00%	00.28%	00.31%
Misc. Hard	01.32%	00.00%	00.31%
Total Count	432	712	318

The lithological composition of sample no. 1 suggests that the gravel is derived, at least in part, from the gravels underlying terrace no. 4, but also that there is a major component of local or sub-local material. The high percentage of shell fragments is made up primarily of Liassic Gryphaea and other Jurassic debris such as echinoid and ammonite fragments and also belemnites. These fragments could not have survived substantial transport and are believed to have been derived, in the main, from the underlying Lias Clay. Percentages of shell fragments in Terrace no. 4 gravels are considerably lower, hence such a direct derivation from Terrace no. 4 gravels is unlikely. Other material of local origin includes hard Lias limestone, calcareous sandstone, shelly sandstone and some ironstone.

The origin of the flint, chert, quartz and quartzite is however, more likely to be the reworking of Terrace no. 4 gravels, as none of these have any immediate bedrock source. The percentages of quartzite and quartz in sample no. 1 are considerably lower than the percentages present in the gravels underlying Terrace no. 4 (samples no. 2 and no. 3). This gives a further indication that this gravel is relatively flooded with local material and is therefore unlikely to have been deposited by the river responsible for the gravels underlying Terrace no. 4.

The high percentage of flint in sample no. 1 is somewhat problematical. One possible explanation is that the flint is derived from frost shattered surface debris, originally from the surface of Terrace no. 4, washed downslope and incorporated into the Bengeworth gravel. Frost shattering would lead to an increase in the numerical availability of flint debris relative to other less susceptible lithologies.

Faunal Evidence

The faunal remains recovered included Mollusca and several bone fragments (from section b, Fig. 1).

Mammalian Remains:

Mammalian fossils from section b were identified by Mr. A.P. Currant (B.M.N.H.). The remains were an astragalus of Bisonpriscus Bojanus (extinct bison) and several fragments of antler of Rangifer tarandus Linné (Reindeer). The form of bison present is the small, slender limbed variety found only at Upton Warren Interstadial sites (Currant, pers comm.). The association of bison and reindeer is typical of Upton Warren mammalian faunas and is recorded from such sites as Upton Warren in the valley of the Salwarpe, also in Worcestershire, but to the north of the Avon valley (Coope, Shotton & Strachan 1961). The reindeer/bison assemblage at Tattershall, Lincolnshire was considered by Rackham (1978) to represent only the warmest part of the Interstadial between c.43 and 42 ka, its occurrence being rare after this time. Therefore, although the fauna recovered from the Bengeworth cutting is small, the form of the bison present may be a useful indicator of age.

Mollusca:

Three samples each of approximately 5 kg wet weight were taken for molluscan analysis. The samples were oven dried, sieved to 0.5 mm and sorted under a 10-40x stereo-microscope. The Mollusca recovered are listed in Table 2. A total of 554 individuals separable into fourteen taxa was recorded. The species are primarily those of marshland, the species Lymnaea truncatula, Anisus leucostoma and Oxyloma pfeifferi together making up 64.5 % of the snails present in the sample. These are accompanied by Lymnaea peregra, Gyraulus laevis and Pisidium casertanum which together make up 2.3 % of the sample, these species prefer slightly more aquatic conditions, although it is likely that these were no more than small pools.

The terrestrial fauna is entirely one of grassland. Vallonia pulchella is most likely to have inhabited damp areas. Pupilla muscorum, Vallonia costata and Vertigo pygmaea however, prefer a greater degree of dryness whilst Trichia hispida is associated with vegetated ground. Slugs (Deroceras sp.) may be found in any of these land habitats. The local environment was therefore primarily a marsh with grassland of varying degrees of dampness on the banks.

The regional environment is more difficult to determine. Where as in this case, the faunal assemblage has a restricted number of species it is generally regarded as being of cold climate type (Holyoak 1982, Keen in press), but the occurrence of V. pygmaea, T. hispida and V. costata suggests warmer, interstadial conditions, rather than anything colder. Holyoak (1982) considers that the latter two species are found in the Upton Warren Interstadial, but only records the former from the Brimpton Interstadial. Thus the Mollusca provide no exact indication of age, but clearly point to an interstadial rather than stadial conditions.

Discussion

The Bengeworth deposits therefore appear to represent the sediments of a small stream or marshy hollow. The altitude of the deposits and their close proximity to the terrace flat of No. 4 Terrace, which extends for some 200 m WNW. from the Bengeworth cutting, would perhaps lead to the correlation of the two deposits, especially as those exposed in the road cutting are well within the height range of Terrace No. 4 (42-47 m O.D. at Bengeworth). The fauna from Terrace No. 4 recorded from the base of gravels underlying Terrace No. 4 at Ailstone in the Stour valley, is of probable interglacial type (Tomlinson 1925), but the Mollusca and Mammalia from the Bengeworth cutting are clearly of colder aspect.

The only interstadial deposit so far described in the Lower Avon is that at Fladbury (Coope 1962), but this site is beneath Avon Terrace No. 2 low down on the valley floor at 20 m O.D., some 10 km downstream of Evesham.

Table 2. Mollusca

Bengeworth, Evesham 1986

Lymnaea truncatula (Müller)	1	240	71	311
Lymnaea peregra (Müller)		8	1	9
Anisus leucostoma (Müller)		31	13	44
Gyraulus laevis (Müller)			1	1
Pisidium casertanum (Poli)		2	1	3
Psidium sp.		1		1
Oxyloma pfeifferi (Rossmässler)		2	1	3
Vertigo pygmaea (Draparnaud)		24	4	28
Pupilla muscorum (Linné)	1	21	11	33
Vallonia costata (Müller)		2		2
Vallonia pulchella (Müller)		3	2	5
Vallonia sp.		2		2
Deroceras sp.	7	19	41	67
Trichia hispida (Linné)	1	34	9	44
	10	389	155	554

Whilst the main river was depositing the sands and gravels that now underlie Terrace No. 2, contemporary stream activity from small tributaries dissected the earlier, higher terraces. It is probable that the basal gravel at Bengeworth represents the lag deposit of the river responsible for this incision; this probably occurred under relatively cold conditions prior to the warming of the interstadial. With the onset of the interstadial there was a change to more stable conditions; stream incision and gravel movement ceased, to be replaced by lower energy flows and finally marshy conditions.

A similar sequence also of Upton Warren Interstadial age is recorded by Kerney, Gibbard, Hall & Robinson (1982) from the sediments of the Thames at Isleworth, W. London. At this site, as at the much smaller scale site of Bengeworth, an initial cold climate gravel is succeeded by silts as the climate ameliorated. Kerney et al. believe this sequence to represent the change from markedly seasonal, cold climate flow conditions at the base, to more equable conditions in the centre of the sequence.

It follows from the evaluation of this site that care must be taken in the interpetation of river terrace sediments and their included floras and faunas, developed in areas of limited topographic dissection such as the Midlands. Old accounts of fossils or material in museum collections must be considered of only limited use unless their position can clearly be related to well defined stratigraphic marker horizons in the field.

Conclusions

Evidence is presented for the occurrence of deposits datable to the Upton Warren Interstadial which lie within the height range of gravels underlying Terrace no. 4 of the Avon, which are assumed to pre-date the Upton Warren Interstadial. The site therefore demonstrates the danger of relying primarily on the altitude of deposits as a surrogate for their age.

Acknowledgements

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QN: field meeting report

REPORT ON THE ANNUAL FIELD MEETING OF THE ASSOCIATION: WESSEX AND THE ISLE OF WIGHT, 21-25 APRIL 1987

Fine weather is not essential for a successful field meeting but it certainly helps. Immediately after Easter 57 members gathered at Glen Eyre Hall, Southampton University, and in sunny, interglacial conditions saw a great variety of Quaternary sites and deposits. These are detailed in the 180 page Field Guide, so this report concentrates on the points which generated discussion on site. Everyone learned a lot on this meeting, not least the organiser, regarding just how many colleagues had active research interests in the area. The Field Guide is the first published account of a number of projects now reaching fruition or recently completed.

The first day in the New Forest included a stimulating diversity of sites. In Long Slade Bottom, near Brockenhurst, two soil sections, demonstrated by John Catt and Paul Reynolds, brought home the contribution which loess had made to the soils of the area and provoked a lively discussion on the vegetational conditions under which colluviation would occur. At the second stop, at Holbury gravel pit, Paul Reynolds outlined the complex sequence of pedogenesis and erosion which had led to an older brickearth lying above a younger one, provoking a discussion on the rate at which soil micromorphological changes occurred. The next visit was to a locus classicus, the Ipswichian interglacial deposits at Stone, known locally as Lepe Country Park. These coastal deposits were first systematically investigated by West and Sparks in 1960, and reinvestigated in 1975 by a team including Chris Green and David Keen, who discussed the deposits on site. They demonstrated estuarine clays with an abundant but restricted mollusc fauna of only four species. Looking across to the Isle of Wight from there, it was easy to appreciate the size and power of the Solent River system which had probably then flowed to the sea at about this position. Paul Reynolds then demonstrated, in the low cliff above the Ipswichian deposits, the pedogenic evidence for a cool and then a warm period, before the Late Devensian upper brickearth was deposited. In view of the now overwhelming evidence of a series of warm and cold episodes during the time period 125-70 ka BP - evidence from oxygen isotope studies of ice and ocean cores, from sea-level studies, from faunal assemblages and from the commonly seen breaks in organic deposition between pollen zones IpIIb and IpIII - it was generally agreed that the idea of a unitary interglacial stage covering some 55,000 years was overdue for revision.

After a lunch with Marston's real ale in the garden of the Mailman's Arms, Lyndhurst, the afternoon was spent at two New Forest valley mires, Church Moor and Cranes Moor. At the first site the basal peat contains a number of typical Devensian Lateglacial species including Betula nana and Homalothecium nitens, with a peak of 76% birch pollen higher up the profile dated to 12,440 a B.P. Mike Clarke and Keith Barber discussed the remarkable continuity of mire and woodland habitats in this area before everyone moved on to the west of the Forest and the unique mire complex at Cranes Moor, pictured on the front cover of the Field Guide. Here there is an extraordinary depth (2.5 m) of Boreal peats, rich in Sphagnum in the part of the mire shielded from base-rich flushes, which were demonstrated by Keith Barber and Mike Clarke. At the base of the peats, on top of the underlying Barton Sand, there is a creamy-white 'mud', in fact a saturated alumino-silicate identified as proto-imoglite allophane, the origin and depositional environment of which led to much discussion.

The second day was spent in the Avon Valley and Dorset, the morning involving two sites of that favoured habitat of many Quaternarists, the gravel pit. After a drive across the striking northern plateau of the New Forest, the party descended upon Wood Green gravel pit where David Bridgland and Phil Harding had redug their impressive 1986 section and laid out a large collection of hand-axes previously found at the site. One did not need to be an expert in Palaeolithic archaeology to appreciate the richness of this site, where over 400 hand axes have been found. It was then a short drive down the Avon Valley to Ibsley gravel pit where Martin Clarke, Chris Green, Keith Barber and Tony Brown expounded upon the Avon terrace sequence and the odd interglacial deposit found beneath the Avon floodplain. It is clear that the sequence of 10 lower and 5 higher terraces here, with the interglacial deposits underlying terrace 3 of the lower group, must represent a sequence which extends back through most of Quaternary time.

Lunch in Wareham was followed by the minibus convoy driving down to the Isle of Portland, through a Weymouth whose crowded beaches resembled August rather than April. At the viewpoint car part at the north end of Portland, Alan Carr gave the scientific background to the magnificent, 18 km long Chesil Beach. Then it was down to Portland Bill, site of David Keen's recent reinvestigation of the famous raised beaches. In the rather surreal surroundings of a tourist spot overshadowed by the domes and blockhouses of the Admiralty Underwater Weapons Establishment, David demonstrated that the East and West Beaches were of different ages, being respectively of oceanic isotope stages 5e and 7, about 120 and 200 k years old. The final stop of the day was at Rimsmoor, a doline or conical solution hollow near Bere Regis. Unlike many other dolines in the area, Rimsmoor must have some kind of plug of Reading Beds clay at its base and a series of radiocarbon dates through the peat infill - rather than a limnic infill which would have resulted had the doline been a collapse feature - allowed Paul Waton and Keith Barber to give a peat accumulation and doline subsidence rate of 4 years/cm, and to describe briefly the high-resolution pollen diagram covering the last 7,000 years. Cameras clicked in unison as several members sank above their wellington boot tops in extracting a core!

Days three and four were spent on the Isle of Wight, the last day, for which about half the party stayed, being optional. During the ferry crossing from Lymington to Yarmouth, Rob Nicholls expounded from the bridge companion-way on his recent researches into the course and deposits of the Solent River, and on the manner and timing of the breaching of the Wight-Purbeck chalk ridge, and this theme of sea-level change was pursued in Yarmouth harbour by Bob Devoy. It was clear that despite the problems of finding and sampling suitable deposits there is a rich vein of research to be mined in the Solent area.

After a scenic drive along the SW. coast of the Isle of Wight, the party visited the hair-raising cliff-falls and landslides of the St. Catherine's Point area which are John Hutchinson's speciality. Radiocarbon dates, of buried trees and charcoal, of 4500-4000 a B.P. give an indication of the chronology of landsliding, as does the presence of a Romano-British brooch at the base of a colluvial deposit on top of Gore Cliff Here, on the optional day, the party filed onto a narrow ledge above a 200 foot sheer drop while Richard Preece enthused over the molluscan fauna - which includes the appropriately-named *Vertigo pygmaea*! On the same morning John Hutchinson stood over the developing fracture-line of the next cliff fall and told us that in the absence of close monitoring there was no way of knowing when the next fall would occur. Several of us quickly developed an inordinate interest in the mollusc fauna of the fields to the rear.

Lunch at the Star Inn, Wroxall, on day three was taken once more in a sunny garden before heading for Bembridge and the interglacial deposits recently worked upon by Richard Preece and James Scourse. At Bembridge School the Steyne Wood Clay, an estuarine deposit at 38-40 m O.D. is possibly Cromerian *sensu lato* and a correlative of the deposits at Boxgrove, whilst on Bembridge Foreland and at Lane End deposits of Ipswichian IIb-III and Ip IV age respectively are found related to the well-known raised beach. These exciting deposits were the climax of the meeting of those not staying overnight on the island and soon they were off to Fishbourne for the crossing to Portsmouth. The remaining members crossed Arreton Down, from where Rob Scaife pointed out various sites, and then repaired to the National Sailing Centre at Cowes, with its comfortable bar overlooking the river.

The Saturday morning was devoted to Holocene palaeoecology, including the colluvial molluscan site at Gore Cliff mentioned earlier. Rob Scaife led the party deep into the Wight interior, to his site at Gatcombe Withy Bed. This extraordinarily rich fen wood, one of many peat deposits investigated by Rob on an island which many thought to be devoid of such deposits, has a complete Flandrian record in a depth of barely 3 m. Detailed pollen counts of 2 mm contiguous samples across the Elm Decline horizon showed the very beginnings of agriculture in the area, and this was nicely complemented by the ease with which Neolithic flint flakes could be found in the adjoining field. The final stop at Brook Bay on the south-west coast was also notable, as the party scrambled up cliffs of alluvium and gravel to find the infamous 'Noah's nuts' (hazelnuts) and tree remains. Rob's just-completed pollen diagram from an organic lens in the cliff shows an apparently late-Flandrian assemblage, emphasising the rapid rate of valley infill and coastal erosion in the area. The final lunch was a leisurely affair in the garden of the New Inn at Shalfleet, in sunshine with temperatures in the seventies it was as if the climate was mirroring the lack of glacigenic sediments - a lack which was, I am assured, certainly not felt by the participants in a meeting which was varied, interesting and enjoyable. As organiser I would like to sincerely thank everyone for their contributions, and for bearing with my insistence on keeping to schedule, for the sake of those who performed late in the day, or had to catch a ferry.

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I wish to open for discussion by the membership a cause for the concern of all. Talking with my female colleagues at Discussion and Field meetings over the last few years has revealed an increasing dissatisfaction with what we see as our marginality to the life of the Q.R.A. Frequently there are <u>no</u> women speakers at the January meeting. Only five women have ever served as officers of the Association, yet a rapid analysis of the membership reveals at least 120 women members out of a total of 800. That is nearly 15% yet our public visibility is closer to 1%.

Before our present vague feelings of dissatisfaction crystallise into active disaffection something needs to be done to make female members of the Q.R.A. feel more integrated with their male colleagues. I am not arguing for pro-rata 'token' female representation, this would create a negative masculine response. However, the men who run the Q.R.A. need to consider that, due to the demands of husbands and children, more of the women members probably only work part-time or even pursue their Quaternary interests as amateurs. The fact that, perhaps, they do not work for Universities, Polytechnics or Research Institutes does not make their work of less worth, but at the moment it is difficult for such women to be actively involved in Q.R.A. life. Yet they are probably the people most in need of the encouragement and support the Q.R.A. could offer if it chose to. I have so frequently been told at Discussion meetings by women with small children working from home how much stimulus they get from such professional contact.

It is counterproductive to criticise without offering constructive suggestions to remedy the problem discussed. Therefore I suggest:

(1) that a questionnaire should be drafted and sent to all members on which we can list our research interests and the geographical areas in which we work. This information could then be published in the membership list in résumé.

(2) that committee members should represent certain sub-disciplines of Quaternary research, as in AMQUA. I suspect that apart from the 'famous names' many Q.R.A. members don't know what other Q.R.A. members do, so that when officers are up for election the same limited range of (mainly male) names appears repeatedly. If three representatives of each discipline were put up for election, possibly nominated by departing committee members in the same subject who should at least know their own colleagues, the membership could then vote more informedly, especially if a five-line biography was submitted by the candidates. The Q.R.A. has become too big for the present ad hoc arrangements to continue. Elections need to be put on a more formal footing.

When I have raised these criticisms with officers in private conversation it has been pointed out that people not in full-time employment find it hard to cope with the costs of travel to committee meetings. Never having been an officer I do not know how often committees meet but if such meetings are timed to coincide with Field or Discussion meetings then I imagine that most people would be able to attend. On a similar topic I think the A.G.M. should be held at the January Discussion meeting because more of the membership attends that than the Easter Field meeting. (Some of us do our own field work then). Alternatively, all members should be balloted on all important decisions taken at the A.G.M. I sometimes feel that decisions are being taken without adequate consultation.

I close with a plea to my female colleagues. Part of our marginality is our own fault. Unless we participate actively we will continue to be ignored. I have done my bit. Details of the Palaeolithic Conference I am organising in early 1988 will be found elsewhere in QN. Someone with a real job should organise the Discussion meeting. How many of you have run a Field meeting? All of you out there doing research should submit abstracts or create posters for the Discussion meeting and make our voice heard. If we don't do something quickly, once the Q.R.A. joins with the Geological Society we will be completely swamped by all those male geologists! At least join:

Women in Geoscience, 61a Broughton St., Edinburgh, H1 3RJ.

Finally, before you ask, no I can't become a committee member. The 1988 conference is my swan song. I am emigrating in search of a full-time tenured post having given up hope of attaining such in the U.K., but I will continue my membership of the Q.R.A.

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QN: thesis abstract

QUATERNARY GEOMORPHOLOGY OF PART OF THE ELWY VALLEY AND VALE OF CLWYD, NORTH EAST WALES

Helen J. Livingston
Ph.D. Thesis, University of London, King's College, 1986

The area of North East Wales presented in this thesis in terms of its glacial geomorphology and Quaternary history consists of the Elwy Valley downstream from Llanfair Talhaiarn, the north-east edge of the Denbigh Moors and the central part of the Vale of Clwyd. The study area centres on Pontnewydd Cave, the deposits of which are being excavated by the National Museum of Wales and consist of a serious of debris flows which have entered the cave through the present cave mouth. The debris flows have been dated to between 10 - 15 and 350 ka by Uranium Series and Thermoluminescence dating.

The main aims of the study were (1) to determine the Quaternary sequence in the study area by examination of the landforms and deposits and (2) to find out if a correlation could be established between the sediments of Pontnewydd Cave and those of the study area. Existing work has shown that the area suffered repeated glaciation during the Quaternary and marks the zone of junction between Welsh deposits of relatively local provenance and "Northern" deposits laid down by Irish Sea ice which penetrated the Vale of Clwyd from the north. A geomorphological map of the study area has been compiled and laboratory studies have provided the basis for four possible sedimentary classifications. It is shown that the variability of glacial sediments favours a facies classification and the Landform-Sediment approach. "Welsh" and "Northern" glacigenic suites

are discussed in terms of Landform-Sediment Associations. The Welsh suite is shown to pre-date the Northern. Active ice features studied include "Welsh" drumlins and the "Northern" lodgement till plain. The Vale of Clwyd moraine, kames and delta-kames, as well as the glaciofluvial terrace of the Elwy Valley are indicative of deglacial phases, while the solifluction deposits suggest widespread periglaciation.

Despite certain similarities between the cave sediments and those of the valley in terms of particle size, shape and lithology, it has not been possible to make any firm correlations. Thermoluminescence dates were obtained for silty sediments but the results are unacceptably old. Comparison of the study area sequence with that of Cheshire-Shropshire suggests that both the Welsh and Northern ice advances are of Upper Devensian age.

QN: reviews

The Scientific Study of Flint and Chert. Edited by G. de G. Sieveking and M.B. Hart (1986) Cambridge University Press (ISBN 0 521 26252 6) 290 pp. price £60.00 ($79.50).

This volume is a product of the International Flint Symposium which met from 10th-15th April 1983 at Brighton Polytechnic. This meeting, the fourth in a series begun at Maastricht, the Netherlands, in 1969, was according to the editor's preface to foster multidisciplinary studies between geology and archaeology. The connections between Pleistocene geology and archaeology are easily seen, but the organisers of the symposium have chosen a much wider focus, so that there are papers in this volume in which the geology/archaeology link is definitely more implicit than explicit. In some cases indeed, the supposed link is very tenuous indeed, perhaps needing the magnification accorded by an S.E.M. to be clear!

The volume contains thirty two papers. The opening eleven concentrate on aspects of Cretaceous deposition and the location of flint and chert within the Upper Greensand and Chalk. Of particular interest to this reviewer were the papers by Clayton and those by Schmid and Curry. The first of these provides a clear review of the geochemistry of flint formation in the chalk which must go a very long way towards solving the old question of how these large silica masses became emplaced in an otherwise soft limestone. The papers by Schmid and Curry are of more direct interest to Quaternary Scientists. Schmid describes the use of colour, fossil content and texture of flint as a means of lithostratigraphic correlation in the chalk of the Netherlands and West Germany. The successful correlation of stratigraphies on this basis can, this author believes, be used to provenance the flints of isolated archaeological finds. One might also see an application here in the study of erratic assemblages, although the author does not comment on this. Curry's paper uses the silicified Foraminifera in rotted flints from the Reading Beds to reconstruct Eocene palaeogeography, and concludes that movements of flint pebbles from S. Hampshire to Berkshire (up to 200 km) occurred during the deposition of this formation. Curry's plea for more studies of flint movement based on the content of micro-fossils might allow much extra detail to be gained of sediment sources in the Palaeogene. If such a body of data could be accumulated it might also be usable in Pleistocene sediment provenance work.

After this initial section, there are three papers very directly on the theme of the symposium. All of these are concerned with attempting to link flints in archaeological assemblages with source areas. The papers by Larick and Takács-Biró take the obvious differences in flints from areas of the Perigord and of N. Hungary, as a starting point for determining the movements of pre-historic peoples. Bush and Sieveking use more sophisticated geochemical techniques to characterise the flint mine products of the English Neolithic as an assistance to tracing archaeological finds to their source. It is clear from their paper that the well known trading of Graig Llwyd and Langdale axes from W. Britain was only a tiny fraction of the Neolithic axe trade. Grime's Graves and Cissbury in particular were vast sources of polished flint axes c. 5000 BP, almost prehistoric Birminghams alongside which the western sites were primitive.

The next two papers are concerned with the distribution of flint in Quaternary deposits (Gibbard) and in the clay-with-flints (Catt). Both these papers contain distribution maps of the flint bearing deposits under consideration and a review of the origins of these sediments. Catt ends with the valuable conclusion that further work is required on the clay-with-flints as a potential source of data on Plio-Pleistocene events which are in urgent need of revision.

The second half of the papers in the volume are not so closely grouped as those of the first half. Several are reasonably closely connected to the general theme in that their topic is some aspect of flint, but others are included in the volume because they are concerned with the Chalk, while others have no discernible association with the theme at all.

In the first group Briggs shows that not all flint in Irish drift deposits is from Antrim, while Lautridou et al. and Sieveking and Clayton outline their experiments on the freezing of flint. The former very extensive study, is on the basis of flint and chalk weathering, the latter uses a few experiments as an aid to the evaluation of flint artefacts. The dating of burned flint by TL methods is addressed by Göksu-Ögelman who shows the usefulness of this method over a wide range of ages, and stresses the virtue for the archaeologist that the material dated, burned flint, is a directly cultural material not an associated product.

The second group contains three papers about the English chalklands and one which contains a comparison between areas of Cretaceous outliers in Sweden and SW. England.

Two of these papers, by Waton and Ellis, are sections from recent Ph.D. theses and use pollen and Mollusca respectively to examine palaeoenvironments in Sussex and Hampshire. Waton provides data on pollen successions from Winchester which suggest that the Chalk Downs were originally forested similar to the surrounding non-chalk tracts, but once cleared in the early Neolithic showed no regeneration of woods. Ellis shows that the Flandrian molluscan biozones of Kerney (1977) are applicable in Sussex as well as Kent. Williams casts an ever perceptive eye over the periglacial landforms of the South Downs and concludes that the widespread, but largely undescribed shattered chalk which occurs along the cliffs of the Sussex coast is evidence for former permafrost despite the lack of ice wedge polygons or other generally agreed indicative features. Lidmar-Bergström's attempts to correlate the long term landscape development of S. Sweden and SW. England via the flint-bearing remanié deposits occurring in both areas does not really convince. While the work in Scandinavia shows a coherent scheme of landscape development, the comparison with S.W. England is based on the literature, much of which is decidely old, and therefore not really comparable.

The last group of papers is a series using analytical techniques, principally SEM, to analyse sediments. Although a volume such as this will have some papers closer to the general theme than others, some of this last group could equally well fit into any compilation on sedimentology. Lindé at least uses flint as one of the materials subjected to experimental transport to develop particular surface textures, but Bull, Whalley and Marshell and Krinsley and Trasty make no mention of the theme of the symposium at all! While these review papers are useful, their distance from the central theme is so great that their inclusion here must be questioned.

The volume is well produced, with few typographical errors, although such errors that there are are magnified by giving one of the editors an incorrect initial on the front cover. While many of the individual chapters are of considerable interest, there are too few on any one topic to attract any but the rich to buy this book. However eclectic one's tastes it is unlikely that more than eight or nine of these papers will be in any one person's direct research interests, and £60.00 is a large price to pay for a small number of moderate length papers however interesting. The objectives of the symposium in attempting to assist links between geology and archaeology are laudable and this volume shows that it has succeeded to some extent, but the scientific worth of the publication would be greater if it had been produced at one third of the price and so have been more generally available.

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Recent earth movements - an introduction to neotectonics. By C. Vita-Finzi, University College, London. Published March 1986 by Academic Press, price US$ 50 (cloth).

This book was written predominantly for undergraduate students in geology and geomorphology and as such it provides a well-balanced bridge between the two subjects. The lively style and well-chosen illustrations, together with an admirable lack of unnecessary technical jargon, also make it of interest to anyone with an involvement in the earth sciences.

Recent is used in its informal sense to denote the immediate rather than the distant past. The author does, however, take refuge in the technical definition of the geological term Recent (viz. the last 10,000 years) when a time limit becomes desirable. The term neotectonics refers to the structures and structural history of the Earth's crust since the Miocene (approximately the last 10 million years). The limited time scale of the past 10,000 years is in many cases too short for geologically significant changes to have occurred. A result of this is that in places the author has been forced to stray farther back in time, although throughout the book the emphasis remains on the present and the immediate past.

The book describes and illustrates the main sources of evidence for recent earth movements. In doing this the author introduces many new and imaginative approaches. Emphasis is placed on the importance of measurement and chronology rather than the ragbag of anecdotes and curiosities which might have been used to illustrate this subject. Inevitably, however, the text relies heavily on accounts which are in places anecdotal. This is in part a result of the nature of the study and in part a measure of the state of development of the subject. Many of these descriptive accounts strengthen rather than weaken the text in that they bring the subject to life. The author suggests that in some areas the subject is still undergoing a transition from the descriptive historical field to the status of an experimental science.

One of the great strengths of this book, and one which makes it such enjoyable reading, is that it challenges many half-formed or half-remembered ideas and prejudices. An example of this is the eustatic hypothesis and its corollary the concept of continental stability. The author questions the validity of the eustatic concept yet he reminds us that it still apparently works for long timescale, long range correlations such as those used in oil exploration seismic stratigraphy. The hypothesis begins to creak yet refuses to croak when coastal sea level changes are compared with measurements of the geoid (displaying sea level differences of almost 180 m). A recurrent theme is the importance of horizontal as against vertical movements. The author provides a reminder of the relative importance of vertical movements which have suffered over the past 20 years at the expense of horizontal movements. The fact that the rate of vertical uplift of the Baltic area is comparable with the rate of horizontal plate movements is easily overlooked. The book provides a well-balanced mixture of fact, example, interpretation and critical discussion. It introduces some well-known and other less well-known controversies and doctrinal disputes and presents these in a modern context.

The subject of earthquakes and their relationship to faulting is central to the subject of neotectonics. The topics are discussed at a level appropriate to a reader who is not a specialist in structural geology. There are, however, some minor flaws which could be misleading. For example a diagram illustrating the classification of faults juxtaposes different types of fault in a geologically impossible situation. A more important criticism concerns the section on fault plane solution diagrams. These diagrams, derived from a study of the first motion of earthquake waves emanating from a specific earthquake and received at a net-work of seismic stations, are of fundamental importance in the study of neotectonics. They provide illustrations of the direction and sense of movement on individual fault planes. The text and diagrams fail to adequately describe to the non-specialist the concepts and techniques involved in the production of these diagrams.

The book is generally well illustrated with an excellent range of good quality diagrams and photographs. There are a few cases of figures which are not well linked with or used to good effect in the text, similarly there are a few figures which do not clearly illustrate the features mentioned in the caption.

The examples in the book show an inevitable bias towards the author's areas of research and expertise in the Mediterranean area and the Middle East. The book would have been strengthened by further examples of neotectonic deformation from the western U.S.A. and also possibly from other tectonically active areas such as the western Pacific, the Andes and the Himalayas. This point illustrates the conflict between the geologically brief time scale of 10,000 years and very slow crustal deformation processes. Inevitably, in such a short time span as the Recent, some important topics in neotectonics have been neglected. A few brief digressions back in geological time would have been appropriate to illustrate how techniques such as multi-channel seismic surveys, side-scan sonar, deep-sea drilling and piston coring have, over the past few years, revolutionized our understanding of tectonic processes, in particular those involved in sedimentary basin development and the subduction of oceanic sediments.

This book discusses a wide range of techniques and approaches. It emphasises the importance of astute field observations despite the technological progess which has transformed our understanding of geology over the past 20 years. The author does, however, emphasise the ambiguity of much evidence and he illustrates how field evidence has often been selectively used to support a particular case.

The point is well made that the hypothesis of the collapse of Minoan Crete as a result of the eruption of Thera has been substantiated more by the pressure of repetition than by scientific investigation.

The chapters entitled "Maps and memories" and "Monitoring change" emphasise the use of instrumental methods for tracing crustal movements. Good accounts are given of the monitoring of movements on volcanoes and active fault zones by the use of surveying, strain and tilt meters. These chapters are wide ranging and comprehensive. They introduce many topics and give detailed descriptions of individual examples.

The final chapter on "Future earth movements" is used to restate the recurrent theme of the need for caution with traditionally accepted explanations, and the necessity for an open mind and a multi-method approach. The book emphasises how the innate caution of the geologist dealing with an unknowable past must be balanced against the certainties required by engineers and planners.

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Anthropogenic Indicators in Pollen Diagrams by Behre, K.E. (editor)
Rotterdam: A.A. Balkema. 232 pages. ISBN 90 6191673 9.

This volume is based on the results of a symposium held at Wilhelmshaven in 1985. Geographically limited to the area north of the European Alps, the book contains 17 papers which focus upon the interpretation of human activity from palynological data. Twelve of the papers are in English and the remaining contributions are in German with long English summaries. It is produced in a camera-ready format, a number of the diagrams are fold-outs contained in an envelope bound into the hard-back cover and there is no index.

A strength of the book lies in the methodological and interpretational emphases of most of the contributions. Within palynology, these involve especially a consideration of the spatial interplay between pollen sampling sites. A number of papers present the results of multiple-profile research at various scales of enquiry. Thus, Vorren (Norway), Vasari and Väänänen (Finland) look at evidence from cores separated by about 70 m, while Kaland (Norway) and Behre and Kucan (West Germany) provide interesting contrasts from the examination of many sites separated by about 0.1-2.0 km. The spatial variation of species in modern samples is discussed by Janssen and Groenman-van Waateringe (The Netherlands), while the latter author together with Berglund et al. (Sweden) are concerned particularly with different land-use activities as reflected in pollen counts.

The difficulties of working in areas were cultural indicators are sparse, uncertain or likely to be filtered by the forest trees encircling clearings, is forcibly brought out by Vuorela's paper on slash-and-burn cultivation in Finland. Turner's utilisation of principal components analysis on data sets from seven European sites indicates how multivariate statistics can reveal human impacts which might not be apparent where they involve small amounts of pollen. The place of fire in eological history is a feature of Vuorela's paper and is also found in the articles by Vorren, Pott (West Germany), Kaland and Moore et al. (U.K.). These last two papers, along with that of Vasari and Väänänen, make valuable comments concerning the relationships between site hydrology and palaeoecology.

Useful and sometimes intriguing points are to be found in most of the papers. Vorren notes the floristic variation of turf roofs related to their northerly or southerly aspects. Kaland demonstrates the use of lake sediments and pollen influx data to reveal peat cutting and soil erosion. Berglund *et al*. show how *Plantago lanceolata* can be strongly under-represented, while Behre and Kucan, Lange (East Germany) and Groenman-van Waateringe intimate that the species can be an indicator of arable rather than simply pastoral activity. Aaby (Denmark) finds that early Neolithic clearances lead to *increases* in arboreal pollen influx because the reduced woodland canopy promotes flowering - and woodland regeneration can *reduce* pollen influx values (presumably from filtration effects). Beug (West Germany) suggests that elm leaves were not fed to cattle in his study area since *Ulmus* pollen values increase in times of cultural impact. Both Willerding (West Germany) and Wasylikowa (Poland) compare pollen and plant macrofossil records, revealing the relative strengths and weaknesses of each.

Some aspects of the book may be criticised. In spite of the title, there is no discussion of possible hunter-gatherer impacts on vegetation - for 'anthropogenic' read also 'agricultural'. Where pastoral and burning activities are examined they are clearly related to agricultural period times, though the assiduous Mesolithicist may be able to discern something of use. In the absence of an index (the worst sin), an attempt by the editor to draw together the varied topics in the book would have been welcome. The English of several of the summaries translated from German leaves something to be desired while the variability of print type in the camera-ready format (save for the miniscule) print of Turner's paper) is worth tolerating if it has kept the price down. This is primarily a book for palynologists but that should not deter other users for whom a perusal of the abstracts at least may reveal material of value. The reviewer would certainly urge all British palynologists with interests in the Holocene to read the volume - it provides those of us reared on Scandinavian, North American and home-grown literature with an excellent idea of current Continental research and may encourage us to look afresh at the interpretation of pollen-analytical data.

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ECONOMIC ASPECTS OF QUATERNARY SCIENCE

by the QRA External Affairs Subcommittee

As part of its work to bring the importance of Quaternary studies to the attention of the public, parliament and other scientists, the Association's External Affairs Subcommittee is preparing a series of pamphlets which attempt to explain certain aspects of this in simple terms. The first of these concentrates on the economic value of multidisciplinary Quaternary studies, and contains contributions from several members of the subcommittee. An early draft was available at the 1987 Annual General Meeting in Southampton, and amendments subsequently suggested by other QRA members are incorporated in the version given below. Any others who wish to comment on the pamphlet or suggest additions and improvements are invited to contact Dr. J.A. Catt, Soils and Plant Nutrition Department, Rothamsted Experimental Station, Harpenden, Herts. AL5 2JQ, who is the subcommittee member responsible.

The External Affairs Subcommittee anticipates that the pamphlet will be used in more or less modified form for various purposes. A comprehensive version will be considered by the Publications Subcommittee for printing and public distribution. Another purpose is to encourage QRA members to formulate economically useful as well as scientifically inspired research projects, which may attract financial support more readily and bring Quaternary Science more to the attention of the public.

Introduction to the Quaternary

During the Quaternary, which is the most recent major period of geological time (approximately the last 2.5 million years), the climate of mid-latitude regions such as Britain fluctuated between the intense cold of ice ages and temperate (interglacial) episodes similar to the present day. In some cold stages large ice caps spread over the northern parts of Europe and N. America, and around their margins there were zones of bare, deeply frozen ground subject to intense soil erosion and deposition of windblown sand and dust. The large amounts of water retained in the ice sheets resulted in a worldwide lowering of sea-level by 100 metres or more, so that shallow sea areas such as the eastern English Channel and southern North Sea became dry land during the cold stages.

We now know from the study of deep ocean sediments that there were about 17 major cold periods during the last 1.5 million years, and yet others between about 2.5 and 1.5 million years ago. We are also aware of smaller, short-term climatic changes, which were probably superimposed on the major changes throughout the Quaternary, but have not yet been completely resolved. For example, the main ice ages were not long periods of continuous intense cold, but the coldest episodes, known as stadials, were separated in time by milder spells (interstadials) lasting from a few centuries to several thousand years.

Quaternary Science is a multidisciplinary area of research aimed at recognising, dating and explaining past climatic fluctuations, and clarifying their effects on man, animals, plants, soil characeristics and geological processes of erosion and deposition by glaciers, rivers, the sea, the wind and downslope movements under the influence of gravity. This work is coordinated internationally by INQUA (International Union for Quaternary Research) and is supported within Britain by the QRA (Quaternary Research Association).

In Britain, certain aspects of Quaternary Science are taught in many university and polytechnic departments of geography, geology, botany, zoology, archaeology, soil science, civil engineering, physics, meteorology etc., but full courses in all aspects are taught only as an MSc at City of London and North London Polytechnics and an M. Phil. at Cambridge University. The British research capability in Quaternary Science is similarly dispersed among many such departments and various NERC, SERC and AFRC institutes. Quaternary research is also assuming increasing importance in several industries, such as oil and mineral exploration, civil engineering and water supply. The geological importance of Quaternary deposits was recognised in Britain over a century ago when the British Geological Survey decided to introduce special ('drift') editions of their maps. However, these portray few of the effects of Quaternary processes on the landscape, and most of them urgently need revising. The present lack of a focal institute for Quaternary Science places a heavy responsibility upon the QRA to stimulate and coordinate British research and improve British education in this broad multidisciplinary field, especially when sites of great importance are often available only for very short periods in temporary exposures, such as building sites.

Quaternary Science and Civil Engineering

Processes of erosion, deposition, weathering and rock disturbance under alternating cold and temperate conditions affected the entire land surface of Britain during the Quaternary. So it is hardly surprising that ground conditions influencing the building of roads, airfields, reservoirs, bridges, tunnels, houses and larger structures can only be understood or predicted from a detailed knowledge of the history of events during at least the more recent part of the Quaternary. Civil engineers have learned this lesson through numerous costly errors in many parts of the country, as the following examples show:

a) During construction of the M6 in 1962 an extensive landslide occurred at Walton's Wood, Staffordshire, where the motorway was routed along the side of a valley eroded by glacial meltwater and subsequently covered by unstable slope deposits. If road engineers had been aware of these features, the motorway could have been re-routed and the expensive reconstruction after the landslide avoided.

b) Similar landslides occurred in 1963 during construction of the Sevenoaks Bypass, Kent. These resulted from reactivation of solifluction sheets (layers of stony mud flowing over a permanently frozen subsoil) formed during the last main cold stage of the Quaternary. The road had to be re-routed downslope, and several partly completed bridges on the first route were demolished. It should have been possible to predict the presence of the solifluction sheets from the lobate shape of steps in the slope.

c) Similar landslides during construction of the M4 near Swindon resulted from the failure to recognize the danger of removing the toe of a solifluction sheet dating from the same period as the sheets at Sevenoaks.

d) The failure of the Carsington Dam during construction in 1984 has been attributed partly to the failure to recognize and remove another solifluction sheet.

e) Another failure to recognize solifluction deposits, which were interlaced by shear surfaces at residual strength, led to landslipping of the excavation for a reservoir below the Cotswold escarpment in 1985. This site had to be abandoned.

f) Yet another unrecognized solifluction sheet led to landslips during construction of a large housing estate in 1983-5 near Hastings, E. Sussex. About 200 of the houses and associated roads and services were affected.

g) During enlargement of the Penmanshiel railway tunnel in 1979 a disastrous collapse occurred on the site of a glacially eroded anticline, in the core of which the shale bedrock had been glacially disturbed and weakened by earlier interglacial weathering. The main railway line from London to Edinburgh was closed for five months until a new bypass line was opened.

Excluding the Penmanshiel Tunnel disaster, which led to the loss of two lives, the total cost of the construction failures quoted is estimated to have been about £50,000,000 (1986 prices). Failures of a similar nature throughout the country over the last 30 years have probably cost several times this amount in total.

Foundation failures are also common in limestone areas as a result of subsidence into solution cavities. The development of these cavities is closely related to the Quaternary history of erosion and weathering in the area, and the prediction of subsidence risk depends to a large extent on the correct interpretation of Quaternary events. Other problems can arise in areas covered by deposits of Quaternary windblown silt (loess) when foundations are not adequately drained.

Quaternary Science and Gravel Resources

In Britain sand and gravel production is the largest non-fuel mineral industry in terms of both volume and value. In 1983, 107,000,000 tons were produced at a value of approximately £378,000,000. In value terms, this was approximately 30% of non-fuel mineral production in Britain. Almost all of the country's sand and gravel comes from Quaternary deposits, including some offshore which contribute about 15% of the total. The occurrence and distribution of some Quaternary sands and gravels, such as those forming river terraces and raised beaches in south-east England, can be predicted if the Quaternary history of an area is understood. But other deposits, notably those of glacial origin, seem to occur more sporadically, and further research into processes of glacial deposition is required to help understand their distribution in northern England, Scotland and Wales.

The suitability of sands and gravels for different purposes (e.g. aggregate for concrete, granular fills and filter materials) depends upon their composition, which is determined by their source and mode of deposition. For example, glacial gravels often contain fragments of soft or weatherable rocks which are unsuitable for concrete because they are too weak or likely to react with and soften the concrete. In contrast gravels from older river terraces in south-east England are composed almost entirely of hard, inert flint, because they are mainly derived from local Chalk and Tertiary deposits, which are flint-rich, and most of the other constituents have been removed by abrasion during fluvial transportation or by several episodes of interglacial weathering since formation of the terraces.

Quaternary Science and Placer Deposits

Placer deposits are accumulations of valuable minerals (e.g. gold, diamonds, tin, titanium) in fluvial and shallow marine sediments. They account for more than half of the total world production of gold, tin and titanium and a smaller proportion of world diamond production. Some placer deposits are modern and related to current fluvial and marine processes, but the majority originated at various earlier times during the Quaternary.

Originally placer deposits were thought to occur almost randomly, but an increasing understanding of the effects of changing climate on sea levels and fluvial regimes has recently revolutionised exploration techniques for these mineral accumulations. For example, intense weathering of rocks during the very long period of stable climatic conditions before the Quaternary led to a relative concentration of many valuable minerals in the soil, because they were not weathered, dissolved and removed in solution so easily as other rock constituents. In many low-latitude regions, the numerous major climatic changes of the Quaternary led to alternating arid and humid conditions, which resulted in erosion of the enriched soils and episodes when the valuable minerals were further concentrated by fluvial action. The placer minerals are therefore sought in river deposits of certain ages, which are traced using conventional dating methods in Quaternary Science and knowledge of fluvial processes of erosion and deposition.

Palynology and petroleum exploration

The study of fossil pollen assemblages in sediments (palynology) was developed by Quaternary scientists to investigate the effects of climatic changes on vegetation, to help date the changes, and to correlate deposits of the same age but different composition from site to site. Similar methods have recently proved useful for dating and correlating the small samples of older sediments recovered from oil exploration boreholes. Along with geophysical information, this enables geological structures favourable to the formation, migration and accumulation of oil and gas to be identified.

Together with studies of marine microplankton, pollen assemblages are also used to interpret the depositional environment of pre-Quaternary deposits. Palaeoenvironmental interpretation from these fossil assemblages depends upon a detailed knowledge of the ways in which pollen is transferred from living plants to modern sediments, and of the effects of transport and other processes in preferentially removing or concentrating certain pollen types. Techniques for investigating these problems developed originally for Quaternary deposits are becoming increasingly important in the search for oil, especially in aiding small-scale sedimentological modelling for field development projects. Almost all palynologists employed in the oil industry were originally trained as Quaternary palynologists.

A further branch of petroleum palynology is concerned with the identification of petroleum source rocks through investigation of their total organic composition and its maturity level (extent of change since burial). This work allows prediction of the likely hydrocarbon types (oil, gas, condensate) generated from the source rock at various times during its burial history. In favourable circumstances it gives confidence that adjacent geological structures contain hydrocarbon reservoirs.

Quaternary Science in agriculture and forestry

The distribution of soil types throughout Britain depends entirely on Quaternary processes of erosion and deposition under changing climatic conditions. Among the country's most productive soils (MAFF Grade 1 land) are those derived wholly or mainly from windblown silt (loess) deposited during the last extremely cold episode about 13,000 to 20,000 years ago. These soils are very easy to cultivate, have good natural reserves of plant nutrients, and are very drought-resistant. However, they are weakly structured through lack of clay, and in some circumstances are consequently very easily eroded, leading to permanent degradation of the good quality land, loss of crops, and pollution of waterways, roads and urban areas. Much of this could be avoided by more suitable farming practices if the distribution of loess was known in much greater detail.

Soil characteristics inherited from cold stages of the Quaternary when the land surface was deeply frozen for long periods are often important in forestry. Subsoil horizons compacted by formation of ice layers (fragipans) were subsequently hardened by deposition of chemical cementing agents, and are now impenetrable to tree roots. As a result tree growth is stunted and the shallow rooting leads to loss of mature trees by windblow, unless the fragipan is broken by very deep cultivation. More detailed information about the distribution of fragipans would therefore be useful for forest and woodland planning in upland areas.

Future climatic changes

The broad outlines of a complex history of climatic change during the Quaternary have been reconstructed from measurements of oxygen isotopes in foraminifera recovered from successive strata of deep-sea sediments, and also from pollen analyses of organic sediments preserved in bogs or on the floors of deep lakes. Exact dating of many of the climatic changes is difficult, but statistical analysis of the more precisely dated sequences strongly suggests that the climatic changes are mainly related to the amounts of solar energy reaching the earth, as determined by cyclical perturbations in the movement of the earth around the sun. These astronomical cycles are all harmonic, but they have different periods (23,000, 41,000 and 90,000 years), and when superimposed on one another produce disharmonic cycles of variable length and intensity, thus giving a complex pattern of change. However, the combined effects of the cycles on the amount of solar radiation can be calculated from astronomical constants, to give an extremely accurate method of dating past changes and also for predicting future changes.

At present the time scale on which major climatic changes can be predicted is too long to be of much immediate interest. But smaller changes are likely to occur in the shorter term, and could well (a) affect the capability of a mid-latitude country such as Britain to grow its own food, (b) greatly increase national fuel requirements, (c) affect the stability and safety of disposal sites for radioactive waste, or (d) by influencing sea-level, perhaps render low-lying such as central London uninhabitable. The study of fossil beetles, which in the distribution of their different types reflect temperature changes much more rapidly than most other animals and plants, has shown that some of the past climatic changes of this magnitude occurred within a few centuries at the most. Even within historic times we have experienced climatic changes which have greatly influenced human activities; for example, during the 'Little Ice Age' (1550-1850 A.D.) mean annual temperatures were often 2°C. below present levels for periods of several years, and this shortened the growing season by up to five weeks. A decrease of only 1°C. in average annual temperature would increase the cost of heating U.K. homes (i.e. the domestic sector only) by approximately £1,000,000,000 per year. Such climatic changes may be partly associated with the astronomical cycles, but other unknown factors are almost certainly involved. These are likely to be identified only by more detailed palaeontological and sedimentological investigation and more precise dating of past changes. The key to future climate therefore lies very much in our ability to reconstruct and explain past climates.

The case for Quaternary research in Britain

The examples of the economic value of Quaternary Science discussed above demonstrate the necessity for a continuing steady support for research into several aspects of the Quaternary period. Yet over the last 6-7 years government funding for Quaternary research in British universities, polytechnics and research institutes has declined even faster than that for other subjects. Many promising research proposals in Quaternary Science fail to attract grants or studentships because the appropriate research council has insufficient funds. As a result research talent is lost, sometimes even to unemployment, and the lead in Quaternary Science which Britain once had is slipping from our grasp. This contrasts with the situation in the U.S.A., Japan and other E.E.C. countries, where funding for all aspects of Quaternary Science research has been increased over the last decade.

The money lost on even the limited number of earthwork failures quoted earlier would pay the life salaries of 100 university lecturers in Quaternary Science or the cost of 2000 Ph.D. studentships. A small fraction of it invested by industry or government would ensure that proper provision is made for teaching of Quaternary Science throughout the higher education sector, and allow a satisfactory level of Quaternary research in universities, polytechnics and research institutes to be restored.

In conclusion, we suggest that increased resources and effort are required for the following:

1. To establish or strengthen, as appropriate, a Quaternary Science input to all undergraduate courses in geology, geography, civil engineering, mineral exploration, petroleum exploration, botany, zoology, archaeology and soil science.

2. To increase the number of M.Sc. courses in Quaternary Science.

3. To increase the level of research support for Quaternary Science in universities, polytechnics and research institutes.

4. To set up a Quaternary unit within British Geological Survey, with improved Quaternary mapping as its main task.

5. To establish an interdisciplinary institute or centre for Quaternary Science in Britain, similar to the Quaternary Research Center of University of Washington, U.S.A. or the Norwegian Geotechnical Institute, which would act as a focus for this widely dispersed subject and stimulate both pure and applied research in it.

John A. Catt
Acting Head of Soils Division
Rothamsted Experimental Station

CORRECTION: 'ERRATICS IN THE HISTORY OF GEOLOGY IN BRITAIN'

The abstract of Dr. C.S. Briggs' paper (Newsletter 51, pp. 11-13) contained various typographical errors and omissions that were made during preparations for printing. The paper was delivered at the Annual Discussion Meeting on the 150th Anniversary of Glacial Theory in 1986. The last part of the abstract should have read: 'The writer would very much appreciate information as to the whereabouts of manuscript accounts and early lists of boulders or actual collections of stones, photographs or slides. Any assistance would be most gratefully acknowledged in future published work'. The address printed was incomplete, it should read: Dr. C.S. Briggs, Pwlldrainllwyn, Trefenter, Llangwryryfon, nr. Aberystwyth, Dyfed, SY23 4SR.

RECENT RESEARCH ON THE EUROPEAN PALAEOLITHIC

An international conference is being organised by Esmée Webb on 6-7 January 1988 to be held at Connaught Hall of the University of London. Confirmed speakers include researchers from Belgium, Czechoslovakia, Denmark, France, Hungary, Italy, Poland, Portugal, USSR, Yugoslavia and Britain. Further details are obtainable from Esmée Webb who, because she is teaching a field school in the United States during the summer vacation, should be contacted before 31 JULY 1987 at the following address: Department of Anthropology, Appalachian State University, Boone, NC 28608, USA.

CENTENARY SYMPOSIUM OF SOCIÉTÉ BELGE DE GEOLOGIE /BELGISCHE VERENIGING VOOR GEOLOGIE

Will be held in Brussels on October 10th-15th, 1987. Details from Monsieur E. Groessens, Secretaire Général, Société belge de Geologie, r. Jenner str. 13, B-1040 Brussels, Begium.

MIDLANDS QUATERNARY SEMINAR

As an attempt to provide a focus for workers on the Quaternary in the Midlands it is proposed that a Midlands Quaternary Seminar be started. It is envisaged that the Seminar will meet once or twice a term in either Birmingham, Coventry, Leicester or Nottingham. The meeting will have one lecture at each session, but will also provide an informal meeting place for all interested in the Quaternary. Although the initial meetings will be on Midlands topics, it is hoped that future meetings will be broader in geographical scope and take in other items of current controversy. It has been arranged that the first meeting will centre around a lecture by Dr. G.R. Coope on the recent mammoth find at Condover, Shropshire. This meeting will be held at 5.30 p.m. on Wednesday 28th October in the Geography Department of Coventry Polytechnic. A second seminar at a time and place to be notified will be given by Mr. J. Rose on his recent work on the Wolstonian of the Midlands. For further details of this seminar series contact either Dr. A.G. Dawson or Dr. D.H. Keen at the Dept. of Geography, Coventry Polytechnic, Priory Street, Coventry CV1 5FB.

EISZEITFORSCHUNG OF SCHWEIZERISCHE NATURFORSCHENDE GESELLSCHAFT

This meeting, concerned entirely with the Quaternary, will be held in Luzern from 8th-11th October, 1987. It will be preceded and followed by field excursions (3rd -7th October, 11th-12th October). Details from: Naturforschende Gesellschaft Luzern und Landeskomitee für Quartarforschung SNG, Luzern, Switzerland.

CALENDAR OF MEETINGS

(NOTE Q.R.A. Meetings are listed in the accompanying Circular)

31st July-9th August 1987	XIIth INQUA Congress, Ottawa, Canada (see Newsletters 48, p. 44; 49, p. 48; 50, pp. 48-51).
7th-9th September 1987	North of England Soils Discussion Group Annual Field meeting, Manchester (see Newsletter 51, p. 22).
7th-11th September 1987	Second International Symposium on Radiocarbon dating and Archaeology at Groningen, The Netherlands (see Newsletter 51, p. 22).
18th-20th September 1987	IGCP 200 UK Working Group Final Field Meeting in the Lincolnshire Fenlands (see Newsletter 51, p. 22).
20th-25th September 1987	Spanish Association for the Study of the Quaternary (A.E.Q.U.A.) VIIth Meeting at Santander, Spain (see Newsletter 50, p. 52).
27th-29th September 1987	BGRG Meeting in Oxford (see Newsletter 49, p. 49).
27th Sept. -2nd Oct. 1987	5th International Flint Symposium at Bordeaux, France (see Newsletter 51, p. 22).
8th-11th October 1987	Eiszeitforschung of Schweizerische Naturforschende Gesellschaft, in Luzern, Switzerland (see notice above).
10th-15th October 1987	Centenary Symposium of Société Belge de Geologie/Belgische Vereniging voor Geologie, Brussels (see notice above).
28th October 1987	Midlands Quaternary Seminar, Coventry (see notice above).
6th-7th January 1988	International Conference on Recent Research on the European Palaeolithic, London (see notice above).
8th-11th April 1988	Symposium on the Geomorphology of Southern Africa, University of Transkei, Southern Africa (see Newsletter 50, p. 52).

22nd-25th May 1988	Geological Association of Canada, Mineralogical Association of Canada, Canadian Association of Petroleum Geologists, Joint Meeting at St. John's, Newfoundland (see Newsletter 49, p. 48).
10th-15th July 1988	International Working Meeting on Soil Micromorphology, at San Antonio, Texas, U.S.A. (see Newsletter 51, p. 23).
19th-23rd September 1988	International Symposium on Engineering Geology, at Athens, Greece (see Newsletter 51, p. 22).
9th-19th July 1989	28th International Geological Congress to be held at Washington, D.C., U.S.A. (see Newsletter 48, p. 44).

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