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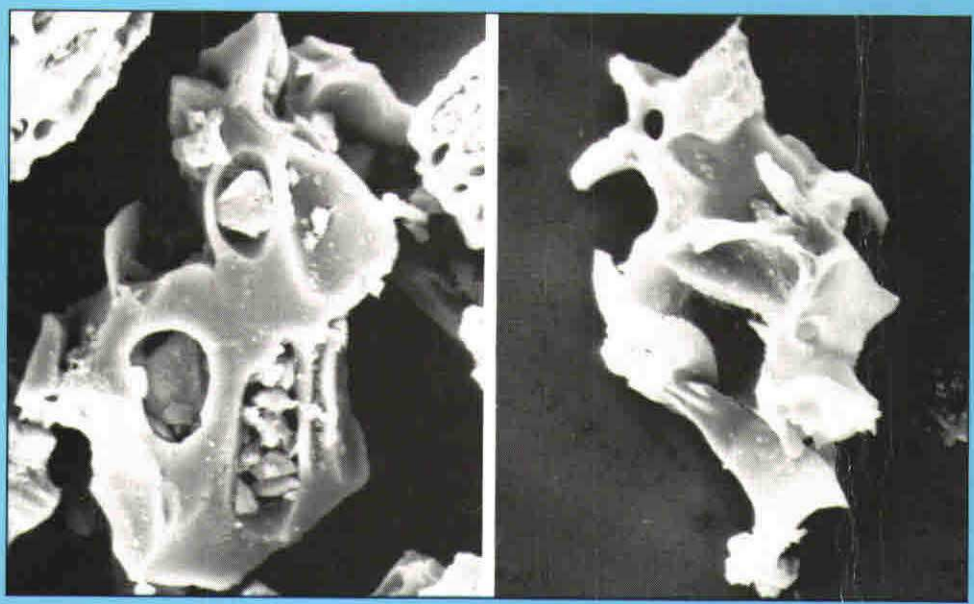

TEPHRA OR PHYTOLITH?

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QUATERNARY NEWSLETTER

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COVER PHOTOGRAPH:
Scanning electron micrographs of (left) Icelandic tephra (Kal-Y ash) and (right) a *Molinia* phytolith. Both approximately 40 microns in the long axis. See article by Bruce Lascelles and report on 2nd UK Tephra Workshop by John Hunt in this issue.

ARTICLES

PRELIMINARY OBSERVATIONS AT THE KIMBRIDGE FARM QUARRY, DUNBRIDGE, HAMPSHIRE: EARLY RESULTS OF A WATCHING BRIEF

D.R. Bridgland and P.A. Harding

Introduction

The earliest gravel pit at Dunbridge, which was worked during the first quarter of this century, lies to the south of the River Dun, close to its confluence with the river Test. This pit, now a Site of Special Scientific Interest (SSSI) known as Dunbridge Pines, was worked simultaneously with others in a lower terrace at Kimbridge and produced large numbers of Palaeolithic handaxes (Dale, 1912, 1918; White, 1912). Two divisions of the gravel at Dunbridge were recognised: an upper 'white' gravel, in which implements were found in mint condition, and a lower, heavily stained gravel with rolled handaxes.

Very little recent extraction of the gravel has occurred, making it impossible to confirm these observations. A new opportunity arose in 1991, when Hall Aggregates (South Coast Limited) obtained permission to extract gravel from Kimbridge Farm, adjacent to the old Dunbridge pit (Figure 1). Permission was granted subject to an archaeological watching brief, to take place throughout topsoil stripping and gravel extraction. In addition to the watching brief, Hall Aggregates commissioned Wessex Archaeology to record detailed sections through the gravel thus far exposed. The area of extraction, which comprises *c.* 19 ha, slopes gently north-west to south east from *c.* 148m OD to *c.* 120m OD. The first phase of work has removed material from the northern end of the site, adjacent to the old workings, exposing an east-west section across the pit, which is the subject of this report.

It is hoped that recording of detailed sections will take place at intervals during the life of the quarry, thus providing essential background information. This will allow artifacts found during the watching brief, and the earlier collections from Dunbridge, to be placed in context.

Four representative sections were cleaned at intervals along the exposed face (Figure 1). General observations were made of the weathered faces before they were cleaned, and detailed geological records were made once each section had been excavated by hand. Sections were also photographed and representative gravel samples collected for future lithological analysis to define gravel composition.

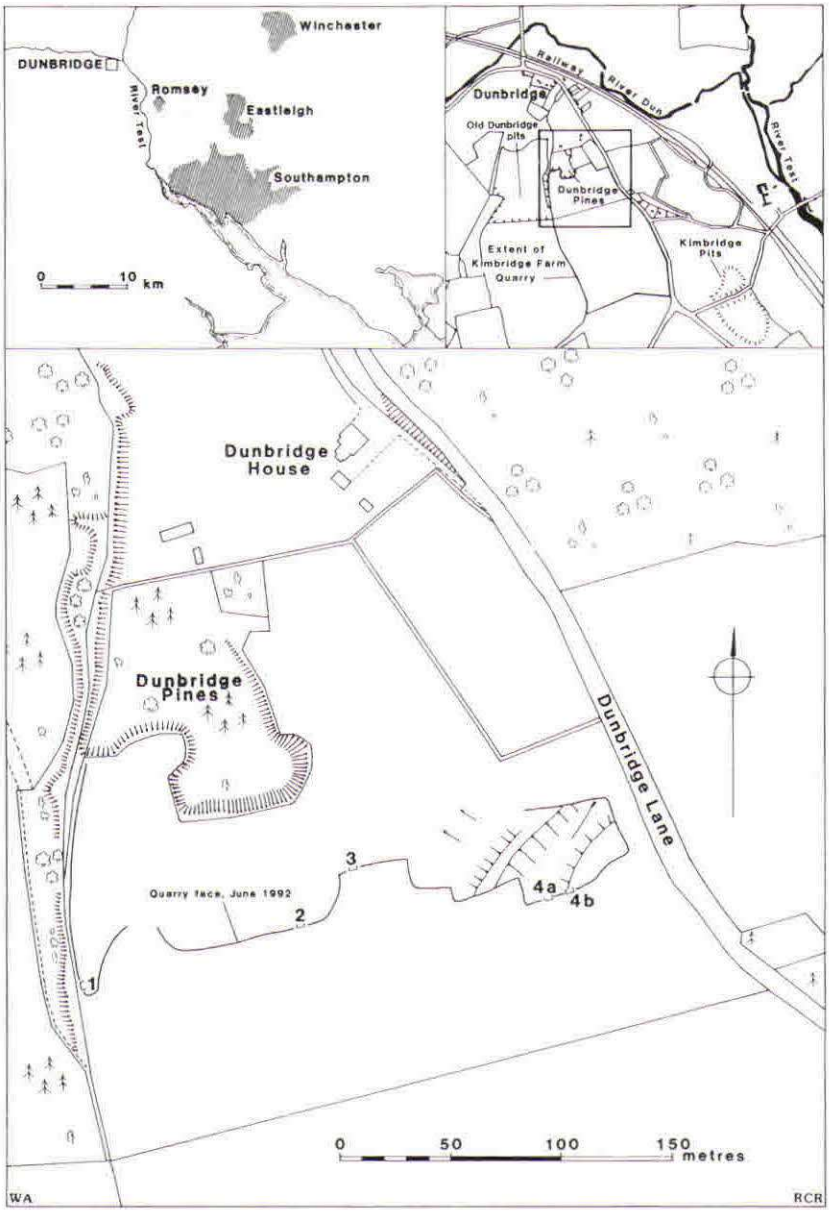

Figure 1. Location of sections 1-4b

Geological observations

Highly variable Reading Beds form the bedrock throughout the area of the Kimbridge Farm Quarry, consisting of well-bedded (usually cross-bedded) medium-fine sand and beds of well-rounded flint pebbles and, less frequently, large lenses of clay.

The erosion surface at the base of the Pleistocene deposits had been exhumed by quarrying in the most recently worked area in the eastern part of the existing quarry, where it could be mapped in some detail (Figure 1). A system of elongated scoured 'deeps' trending north-east to south-west was apparent. Two large features of this type, with widths of 20m - 25m, dominated the floor of the quarry in the north-eastern part of the workings. The easternmost of these features was the deeper by some 1.5m. The sediments filling it are recorded in Section 4a (Figure 3). The detailed form of the bedrock surface could not be observed in this western part of the workings, as the Palaeogene beds have been extracted in this area.

On a smaller scale, minor scour features were observed in the bedrock surface beneath the Pleistocene gravel at the base of Section 3. These features are similar to those recorded at Wood Green, in the Avon valley, by Bridgland and Harding (1987).

Lower, well-bedded deposits

In all four logged sections, well-bedded gravel and sand deposits were observed in the lower part of the Pleistocene sequence. In the western part of the current workings such deposits are restricted to around 1m in thickness, increasing to *c.* 2m at the extreme western edge of the pit in Section 1 (Figure 2). In the north-eastern corner of the pit the Pleistocene sequence as a whole thickens considerably and up to 5m of well-bedded sand and gravel has been observed. The bedding in these deposits is manifested in the general horizontal disposition of elongated clasts and in variations of matrix type, also disposed horizontally. Cross-bedding has been observed only rarely; cross-bedded pebbly sands were encountered in Section 1, where the orientation of the foreset planes suggest palaeocurrent flow towards the south-south-west. The range of the bedding structures observed is consistent with the interpretation of the gravel and sand as the product of fluvial deposition. The predominance of widespread horizontal beds of gravel and the general paucity of fine-grained sediments suggests deposition in a gravel-bed river, probably one with multiple braided channels. Such conditions are thought to have occurred mainly during the colder periods of the Pleistocene, when vegetation cover was limited and there was a rich supply of course-grade sediment from the valley sides. The very limited

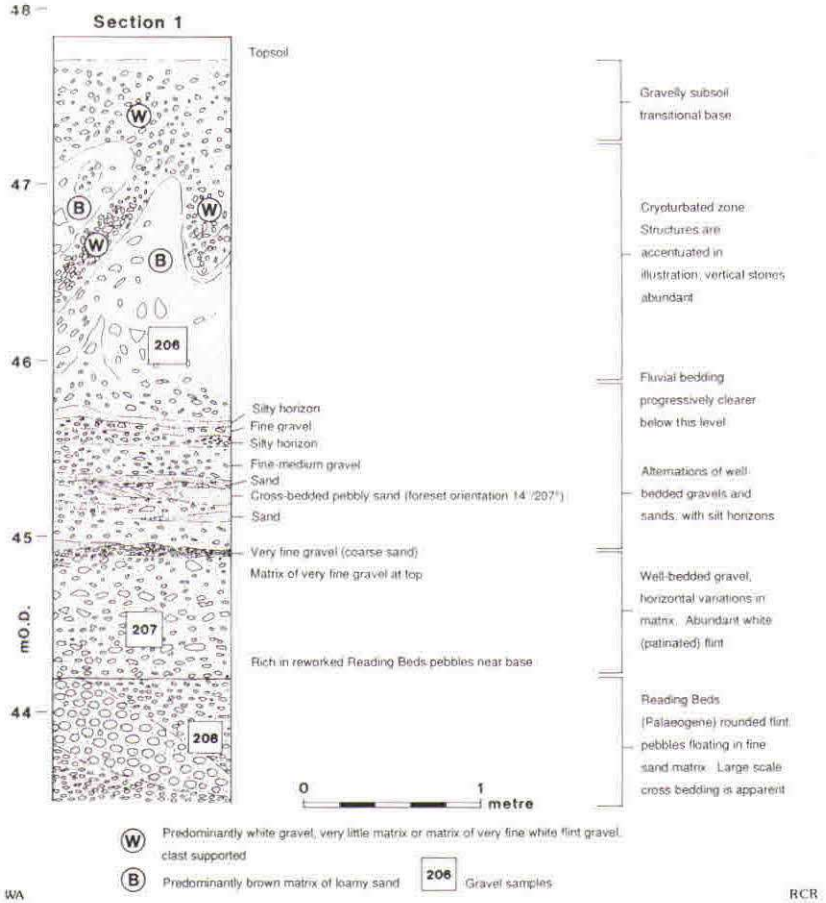

Figure 2.

palaeocurrent evidence (one reading of flow to the south-south-west) is consistent with deposition by the main River Test.

As far as can be determined in advance of laboratory analyses, the bedded gravels comprise fine to course gravel clasts set in a variable matrix of silt, fine to course sand or even very fine gravel (granules). The deposits are mainly matrix-supported, but occasionally no matrix is present (open framework clast-supported gravel). A thin veneer of clay sometimes coats the gravel clasts, probably introduced by percolating ground water.

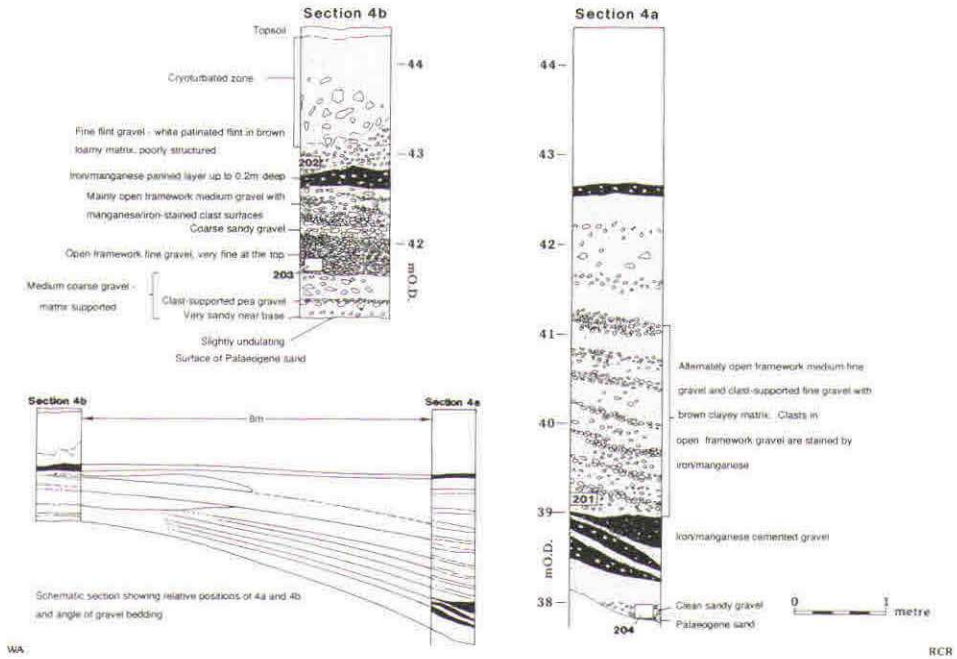

Figure 3.

The gravel clasts are almost entirely formed from flint, either in the form of angular fresh material, sub-angular whitened (patinated) material or rounded pebbles reworked from the underlying Palaeogene bedrock. Rounded flint pebbles are only abundant in basal parts of the gravel in areas close to occurrences of pebble beds within the bedrock. Fragile iron-encrusted clay clasts ('boxstones') were occasionally encountered in the lowest gravel. These have presumably been reworked from the Reading Beds as they cannot have withstood prolonged fluvial transport. Future analyses of the clast content of the various gravels, to determine the proportions of different types of flint and, in addition, the shapes of flint clasts, may allow the distinction of different

gravel types, comparable with the divisions recognised by Dale (1912; see above). The restricted range of rocks present in the Dunbridge gravels is entirely expected, given the bedrock types available within the Test catchment.

Unbedded cryoturbated deposits

The uppermost 3m (approximately) of the Pleistocene deposits in each section show little clear evidence for sedimentary bedding. There is, however, no sharp break between well-bedded and unbedded deposits; instead the bedding becomes progressively less clear in the upper 2m, usually disappearing completely 1.5m from the surface. Two reasons for this lack of bedding in the uppermost deposits can be suggested, both implying that the gravels were once fluvially bedded throughout and have been modified, rather than suggesting that a separate, unbedded upper deposit is present. These are (1) cryoturbation (frost-heaving) of the upper part of the sequence during one or more cold episodes since deposition, and (2) pedogenesis, the combination of various soil-forming processes, which would have progressively modified the upper parts of the sequence since deposition.

Cryoturbation, which can itself be regarded as a pedogenic process, has clearly affected the Dunbridge sediments. This is apparent from the abundance of vertically orientated clasts in the upper part of the sequence, although involutions are not readily visible in the Dunbridge sections. Careful examination, however, suggests that involutions are present, in the form of pockets of coarser gravel that have been let down into finer gravel within the cryoturbated layer at the top of the Dunbridge Gravel.

Other post-depositional modifications

The occurrence of upper bleached and lower unbleached gravels at Dunbridge, separated by a major iron pan horizon, was noted by Dale, (1912, 1918). He recognised that these phenomena might result from post-depositional modification of the deposits, brought about by percolating ground water (a theory advocated by Whitaker, in Dale 1912), but also suggested that gravels of different ages might be represented. Bridgland and Harding (1987) noted that iron/manganese cemented layers were relatively common in the Dunbridge gravel within the SSSI at Dunbridge Pines, but could not distinguish upper bleached and lower unbleached gravels; instead they found that bleached flint commonly occurs throughout the sequence. Similar findings to these can now be reported in the western part of the area investigated in June 1992, which is close to the SSSI. However, recently excavated exposures in the north-eastern corner of the quarry have revealed the type of stratigraphy reported by Dale. In particular, a persistent iron/manganese pan, 1.5m - 2m below the top of the

sequence, can be traced throughout this area. It extends westwards to between Sections 2 and 3 and is thus recorded in Sections 4a and 4b (Figure 3). The majority of the gravel above this layer is whitened; it contains abundant white patinated flint in a loamy matrix that is brown when freshly cut, but dries to a very pale buff/white colour. The majority of the gravel below the pan is of brown colouration, although white patinated flints are still commonly included. The occurrence of the pan suggests that translocation of mineral salts in ground water may be responsible for the bleaching of the upper gravel. Future analyses of the gravel samples may provide further evidence for differentiating the upper and lower gravels and for determining the origin of these distinctions.

Terrace stratigraphy

Despite the significant decline in the level of the bedrock surface from west to east within the existing exposures, the continuity of bedded gravel throughout the area indicates that a single terrace formation of the River Test is represented. This is the same deposit that was exploited in the early part of the century in the Dunbridge pits, from which large collections of palaeoliths were obtained. This gravel was termed the 'Belbins Stage' by White (1912), after Belbin's Pit, Romsey (SU 364 228). This gravel unit was a source of palaeoliths wherever it was worked, although nowhere was it more prolific than at Dunbridge. It is thus clear that a careful examination of these deposits, in search of artifacts, is called for during the working life of the Kimbridge Farm Quarry.

Comparison with an earlier transect of trial excavations across the site (Colcutt *et al.* 1988), sited further south than the current exposures, confirms that a lower terrace formation occurs in the south-eastern part of the site. This may prove to be the upper edge of the terrace remnant exploited by the erstwhile Kimbridge pits (Figure 1), which were also a source of palaeoliths, although less prolific than the Dunbridge pits. This lower terrace gravel was given the name 'Mottisfont Stage' by White (1912). It is also possible that the lower gravel recognised in the 1988 transect represents a previously unrecognised formation intermediate between the Belbins and Mottisfont units.

The flint artifacts

The watching brief has recovered seven flint flakes and a flint core during the first year of gravel extraction at the site. These pieces were all found at the quarry, with the exception of a flake that was identified at the washing plant. None of the material was found *in situ*, although one flake was found in disturbed gravel at the top of the section and may be associated with that part of the deposit.

The flakes are all large robust pieces, ranging from 115mm to 55mm in length and 74mm to 42mm in width. Three flakes have stained surfaces, while the remainder are patinated white. Condition ranges from slightly rolled to very rolled.

The core is an undiagnostic single platform flake core with a prepared striking platform. It is in a sharp condition and both unstained and unpatinated. The raw material is a nodule from the gravel with incipient thermal fractures and a large cherty inclusion in the centre. These imperfections would not allow unbroken flakes to be removed and resulted in the core being abandoned.

The flakes collected from the pit during the first year of the watching brief are technologically undiagnostic. They could have been removed during the manufacture of handaxes or flake cores. Their dimensions, robustness and condition are consistent with artifacts that have survived being dispersed and transported during the deposition of gravel in fast flowing streams. The flake found near the top of the section, which was in a slightly rolled condition, represents the only piece capable of being placed in a stratigraphic context. This piece confirms the observations of Dale (1912), who described unrolled white patinated material in the upper gravel at Dunbridge. Flakes from Dunbridge were not normally collected by the early gravel diggers. Roe (1968) listed 1,021 pieces from the old pits, of which only 43 (4.2%) were flakes. Controlled excavation of Palaeolithic sites invariably reveals that flakes are more numerous than implements. However, when the collections were being made at Dunbridge, only handaxes attracted the interest of the collectors.

The core is in a sharp condition, which suggests that it came from the upper part of the deposit. It is, however, undiagnostic and cannot therefore be dated with certainty to the Palaeolithic. Undiagnostic flake cores of this type have been made in all prehistoric periods. It is not unconceivable that it may be from an unidentified intrusive feature in the gravel.

Discussion

The Pleistocene sections at Dunbridge (Kimbridge Farm Quarry) allow a distinction to be made between a lower well-bedded, generally unbleached gravel and an upper poorly bedded or unbedded, generally bleached gravel. The bleached and unbleached gravels are separated in much of the most recently excavated area by a persistent iron/manganese pan, although this does not necessarily coincide with the top of the well-bedded gravel (there is a gradation between well-bedded and less well-bedded gravel). This distinction, which could not be made in the limited exposures excavated within and near the SSSI at Dunbridge Pines in 1986 (Bridgland and Harding, 1987), may be comparable with the more complex stratigraphy recorded by Dale (1912). This is of

potential importance, since Dale claimed that different Palaeolithic industries, distinguished on the basis of typology as well as condition, (the latter being related to the type of gravel in which they are preserved), occur within the different parts of the Dunbridge stratigraphy. Analyses of the units recognised in the modern quarry, together with a comparison of artifacts collected during the watching brief with those in earlier collections, should throw some light on the validity of Dale's claim.

Acknowledgements

Wessex Archaeology would like to thank Hall Aggregates (South Coast) Limited, particularly Rosemary Box, for its financial support and assistance. The watching brief is carried out by Phil Harding, and the survey work was undertaken by Phil Harding and David Bridgland. The project is managed by Carol Newman. The illustrations are by Robert Read.

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DIATOMS AS RECONSTITUTED QUATERNARY TEPHRA?

Bruce Lascelles

There is increasing research into the identification and correlation of tephra layers in W Europe, mainly from Icelandic eruptions during the Holocene. Quaternary tephra has been found across Scotland and Scandinavia (Dugmore, 1991), but not further south. This study, which set out to locate tephra in sediments from the North Wales area, found instead concentrations of opaline silica at points where tephra falls might be predicted. This has raised the questions about tephra stability and re-constitution addressed in this paper.

Tephrochronology is now a well established dating technique in NW Europe, the USA and the Far East (Dugmore, 1991; Riehle *et al.*, 1990; Westgate *et al.*, 1987). Tephra falls create time-parallel or isochronous marker horizons that enable associated artifacts, monuments or sediments to be dated with unusual precision (Dugmore, 1991). There are currently only about twenty Quaternary tephra layers identified in the soils and sediments of NW Europe (Dugmore, 1989), but they are spread over extensive areas up to 2000km from their source, and as such they are useful in the correlation of events across a very wide area.

The Quaternary tephra found in the UK has so far all been traced to specific Icelandic eruptions (Dugmore, 1989), although it is also thought that the indirect climatic effects of eruptions, such as that of Santorini in the Aegean, can be detected indirectly in the reduced ring widths of Irish bog oaks (Baillie and Munro, 1988). Before 1986 little information was available as to the general fate of air-born particulate matter, such data as there were coming from aircraft and satellite surveys (Tucker and Matson, 1986). However, the Chernobyl nuclear accident in May 1986 initiated many more studies in this field, and because of a similarity in particle sizes, the data now available are applicable to the study of tephrochronology. Many of these studies (*eg* Erlandsson and Isaksson, 1988; Mattsson and Vesansen, 1988) concluded that small particulate matter of a size comparable to that of tephra will be carried along mainly in suspension and subsequently be deposited by washout. As such, it is possible that Icelandic tephra may have been carried as far south as North Wales and deposited there. As depressions pass over NW Europe, they transfer moist air from regions around Iceland to the UK and northern Europe (Barry and Chorley, 1982) where orographic effects cause any associated tephra to be deposited over the first high ground encountered. The possibility of tephra being deposited over North Wales is therefore reduced by the presence of the Scottish Highlands and other intervening areas of high ground to the north.

Peats and lake sediments are the best materials in which to search for tephra since both are built up sequentially (assuming no or minimal disturbance), and so any tephra falls will automatically be incorporated into the stratigraphic sequence. North Wales provides ample opportunity to look for tephra in both these types of sediments, but none has as yet been discovered as far south as Wales. Initially it was therefore decided to search for tephra in a dated lake sediment core from Llyn Cororion on the Arfon Platform in Snowdonia (Watkins,1991). This was chosen since it had a series of associated radiocarbon dates allowing the possible position of tephra from known Icelandic eruptions to be interpolated with some accuracy. This was achieved from X-radiography, inorganic material being denser to X-rays than organic material, and so showing up brighter on the X-ray plate (Dugmore, 1991).

Two Icelandic eruptions were chosen for this initial study, those of Hekla 3 (1120±50 BC) and Hekla 4 (2690±80BC) (Hammer *et al.*, 1980). Sediment of this age was located in the Llyn Cororion core and sections including the material 30cm either side of these points were removed. As can be seen in Figure 1, a thin line appears at the horizon where the tephra from the Hekla 3 eruption would be expected. The material appearing at this horizon on the radiograph was separated from the peat and analysed.

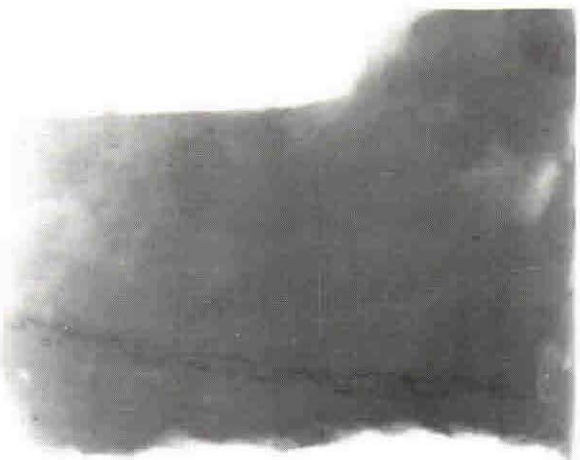

Figure 1. X-Radiograph of a section of the Llyn Cororion Core, the line appearing at the horizon predicted for tephra from Hekla 3.

The extraction process used in this experiment involved high temperature ashing (550°C) followed by weak acid digestion of the ash, designed to minimise the effects of the extraction process on the tephra itself (Pilcher and Hall, 1992). A 0.5cm^3 block of peat was removed to include the X-ray dense material and processed. After extraction and weighing it was found that the sample contained around 2-3% insoluble inorganic material. Previous experiments have demonstrated (Dugmore, 1991) that where volcanic ash falls have occurred up to 80-90% of this inorganic material can be tephra.

The material was mounted in Canada Balsam in order that a study of the optical properties (*eg* refractive index, birefringence) could be undertaken by which tephra can be identified and characterised. A sample of "Kal-Y Ash" from the Hekla 4 eruption (kindly supplied by A. Dugmore) was found to have an average particle size of approximately 100µm. Conchoidal fractures were evident and are a distinctive feature of tephra which, being super-cooled magma, is composed of glass; for the same reason small entrapped air-bubbles are also often present. However, there can be a confusing morphological similarity between some tephra particles and opaline silica phytoliths (see front cover), especially where the former have elongated air bubbles and the latter derive from irregular intercellular, rather than the distinctive intracellular, deposition. Care is obviously needed in the identification of suspected tephra particles in terrestrial deposits (D.A. Jenkins, pers. comm.). Such confusion can be resolved under the optical microscope from the contrasting refractive indices, phytoliths showing a stronger negative relief (RI ≈ 1.4 cf. 1.49-1.52 for rhyolitic-trachytic glass). Under the SEM it is necessary to distinguish the materials by EDXRA, phytoliths responding only for Si whilst tephra has an igneous composition (*eg* Si, Al, Fe, Mg, Ca, Na, K, Ti) and, indeed, can be characterised by its detailed geochemistry, for example in terms of Fe/SiO_2 (Dugmore *et al.*, 1992).

The material detected on the X-radiograph was not tephra but rather opaline silica, comprised largely of diatoms and sponge spicules (Figure 2). The species of diatoms included *Eunotia pseudoveneris, E. subtaeniata, Gomphonema acuminatum, Melosira islandica* and many fragments of *Pinnularia* species (Hustedt classification). Since a full analysis of all of the diatoms present in the sample has not yet been carried out it is not possible to assess the significance of this particular diatom assemblage.

Other samples were extracted and analysed without any tephra being found. However, the high concentration of opaline silica at this horizon raises an interesting question concerning the mobility of tephra-derived silica. Previous

studies (*eg* Jewell, 1935) have shown that the formation of normal sponge spicules under field conditions generally requires a silicic acid concentration of 0.005mM or greater, with only one instance being recorded where normal spicules were formed when only traces of silicic acid were present. A similar response has been noted in diatoms (Kilham, 1971) although they are thought to have a slightly higher threshold value (Werner, 1977).

There is some evidence (Yamada *et al.*, 1991; van der Gaast *et al.*, 1986; Guzel and Wilson, 1983) that past tephra layers in soils can be indicated by the presence of concentrations of specific clay minerals (*eg* smectites) as the tephra has weathered to release groups of silicon tetrahedra which have then re-polymerised under suitable conditions. There is therefore the possibility that diatom/sponge blooms may also indicate the presence of reconstituted tephra layers. Anomalous occurrences of smectites have in fact been recorded in Quaternary sediments in North Wales (*eg* Rampling, 1991). Dugmore *et al.* (1992) and Hodder *et al.* (1991) give evidence concerning the weathering of Holocene tephra layers in acidic peat bogs in Scotland and New Zealand respectively. They show that silica concentrations found to be higher than expected were due to the dissolution of tephra constituents. Dugmore *et al.* (1992) suggests that in a soil environment, (mafic?) tephra with lower silica concentrations could be weathered completely. The tephra deposited in Iceland from the Hekla 4 eruption (Dugmore, 1991) has been shown to have an average particle size of <100μm. Material transported as far south as North Wales may well have been even finer, and as a result weathered more rapidly. In a lake system such as Llyn Cororion the weathering of the tephra in the lake and surrounding peat bog would have led to an increase in the concentration of silicic acid, this effect being enhanced by inwash of weathered constituents from the surrounding landscape, so amplifying the effect on the diatom and sponge populations.

Future work is planned to establish whether the diatom bloom horizon is continued over a wider area. If this is the case then it will sharpen the questions concerning the stability, longevity and reconstitution of Quaternary tephra in the UK.

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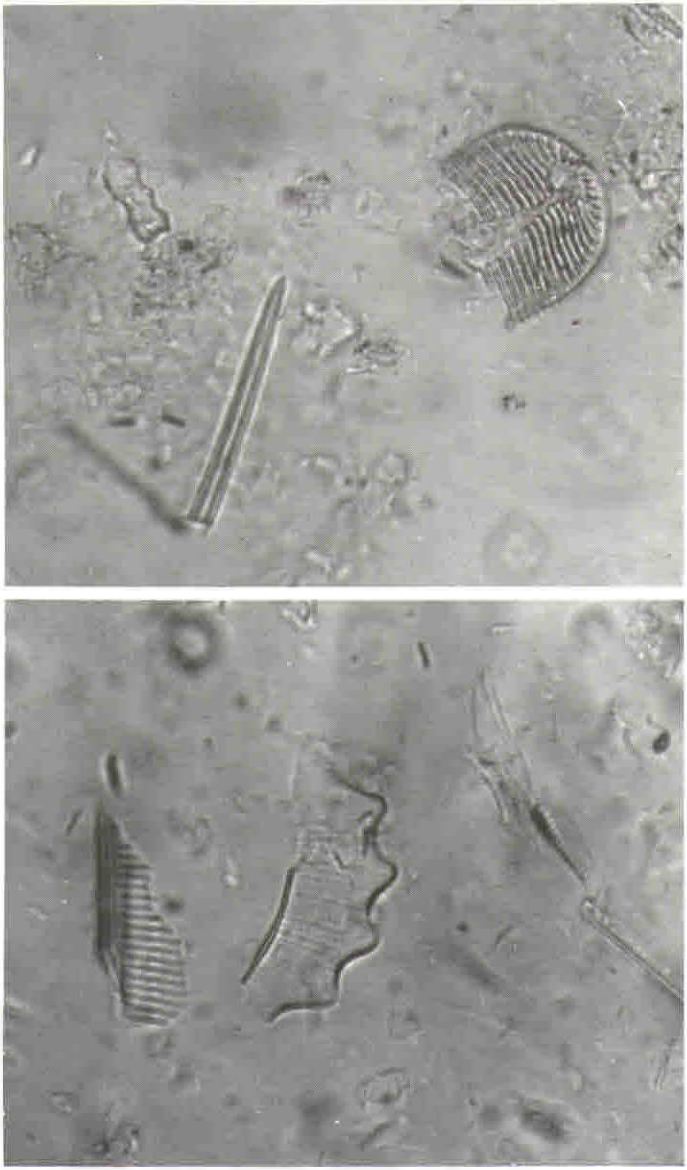

Figure 2. (a)*Pinnularia* fragment with sponge spicule and *Molinia* phytolith. (b)*Eunotia* with other opaline silica fragments.

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RAPPORTEURS

VOLCANOLOGY

Volcanic eruptions, aerosols and climate change: a post-Pinatubo assessment

On June 11th 1991 the Philippine volcano Mount Pinatubo hit the world's headlines. Several hundred people died and hundreds of thousands were evacuated as a result of the largest volcanic eruption in a populated area this century. Newspapers were filled with pictures of cars and buildings buried deep beneath layers of volcanic ash. The ash falls were highly destructive, their effects on human life dramatically obvious, and hence they afforded excellent photo-opportunities. What was less widely reported was that Pinatubo also produced what was probably the largest aerosol cloud since the eruption of Krakatau in 1883. This aerosol cloud has since been the subject of extensive research, illustrated by the 45 abstracts published from the 1992 Fall Meeting of the American Geophysical Union.

In this short résumé of current research I hope to indicate the significance of the Pinatubo event to the study of Quaternary climatic and environmental change. The links between volcanic activity and climate change have long been a subject of considerable interest, and in the public mind have been associated with the once fashionable scenario of the 'nuclear winter'. Prior to the 1980 eruption of Mount St. Helens it was the volcanic 'dust veils' that were thought to act as climate modifiers. This eruption produced extensive and rapid fall-out of volcanic ash. It became clear that ash and dust do not usually remain in the atmosphere in sufficient quantity and for sufficient duration to modify the climate, and attention then turned towards the effects of the volcanic aerosols. These can be formed in vast quantities as demonstrated by three recent major eruptions: Mt. Pinatubo (1991) produced 25-30 megatons; El Chichón (1982), 12 megatons; and Mt. St. Helens (1980), 0.5 megaton.

At heights of 15-25km, roughly the same level as the ozone layer, the stratosphere contains a mist of liquid droplets in the order of 0.1 micron diameter. This mist is composed of *c.* 25% water and *c.* 75% sulphuric acid, and gradually dissipates with time, although it is later replenished following volcanic eruptions. The aerosol mist strongly absorbs in the infra-red spectrum and scatters solar radiation back into space, thereby warming the stratosphere but cooling the troposphere.

Past climatic effects

Climatic effects attributed to historical eruptions have been well documented. The Indonesian volcano Tambora erupted in 1815; its ash and aerosols were probably forced some 35-40km into the stratosphere, and more than 50 km^3 of magma erupted in 36 hours. More than 92,000 people died as a result of crop failures brought about by ash falls and climatic cooling, and the atmospheric effects were visible in Europe. The 73.5 ka BP eruption of Toba, in Sumatra, equivalent in magnitude to 8,000 Mt. St. Helens, most certainly resulted in a surface temperature decline of 4-5°C which may in turn have intensified the prevailing trend of global cooling. The effects of the Santorini-Thera eruption (and others?) in the 17th century B.C. are thought to have brought down the Xia dynasty in China, set back the development of the Minoan civilisation in the Aegean, and cooled the climate sufficiently to cause frost damage to trees in Europe and North America.

Sulphur and acidity

The eruption of Thera merits further attention, not only for the controversy surrounding its dating which is prevalent in archaeological circles, but also for the question of sulphur. Many environmental and historical events have been attributed to the Thera eruption, as illustrated by the few examples above. Examination of the acidity record in the Greenland ice-cores has suggested that the acidity levels are too high to have come from the Thera eruption alone. Several authors have invoked multiple eruptions to explain the environmental/ climatic effects and the acidity levels. This may well be the case, but the vast quantities of aerosols seen in the studies of the Pinatubo and El Chichón eruptions suggest that the ice-core acidity could also have originated solely from one event.

Petrological estimates of Pinatubo's magma underestimated the atmospheric sulphur contribution by a factor of 20 times. For the El Chichón eruption the underestimation factor exceeded 100 times. For El Chichón the high sulphur was attributed to the occurrence of anhydrite which was believed to be exceptional owing to the presence of sedimentary evaporitic layers beneath the volcano. However the presence of anhydrite in the Pinatubo pumices led to the abandonment of this idea, and the source of the anhydrite remains to be proven. Anhydrite is an extremely soluble mineral, which tends not to be preserved in the rock record. Only samples collected within a year of the Pinatubo eruption contained anhydrite. Sulphur from the anhydrite enters the atmosphere, and ultimately contributes to the ice core acidity peaks. The higher than predicted acidity associated with the Thera eruption could have resulted from a single

eruption of anhydrite rich magma. As Santorini lies in an area of calc-alkaline volcanism this idea is supported by the apparent association of anhydrite-bearing pumices with calk-alkaline rock suites.

Atmospheric dispersal

El Chichón and Mount Pinatubo are situated at nearly the same latitude, yet satellite monitoring of volcanigenic sulphur dioxide has shown that their eruption clouds were dispersed quite differently: The El Chichón (April) plume was mainly confined to the northern hemisphere whilst the Pinatubo (June) plume was restricted more to the southern hemisphere. These observations are thought to support earlier suggestions that the timing of tropical volcanic eruptions plays an important role in governing their climatic effects. As predicted by most models the climatic effects of the Pinatubo eruption have been expressed as stratospheric warming and tropospheric cooling. Limited surface temperature data, however, has shown unexpectedly low magnitude cooling, although this may be due to climatic 'background noise'.

El Niño

El Niño events which generally occur every three to seven years are sudden changes of atmospheric and marine circulation patterns in the equatorial Pacific Ocean, which correspond to short-lived climatic warming. As the climatic effects of El Niño and volcanic eruptions are opposing, but of the same magnitude, there can be great difficulty in separating their signals. It has recently been suggested that volcanic stratospheric aerosols may enhance or trigger El Niño events, although this idea remains contentious.

Ozone

Recent observations of the biologically effective ultraviolet light (UV-BE) at the earth's surface have revealed increases in intensity immediately following the El Chichón and Mount Pinatubo eruptions. Satellite imaging of stratospheric ozone has revealed marked depletions (ozone reduced by 15-25%) at high latitudes following the Pinatubo eruption. In the following November a regional scale ozone depletion of 20% was observed over Boulder, Colorado. This and other results point to additional significant volcanogenic ozone depletion at temperate and tropical latitudes.

The original cause of post-eruption ozone depletion was thought to be volcanogenic chlorine, but this was found to be of minor significance owing to the rapid down-flushing of chlorine as hydrochloric acid. It now appears that frozen sulphuric acid droplets act in a similar way to stratospheric ice particles

in polar regions, furnishing sites for chlorine-releasing chemical reactions. These reactions involve anthropogenic CFC's and their build up in the atmosphere indicates that future volcanic ozone depletions may be even more significant.

Quaternary significance

The impact of volcanic activity on modern climatic processes is becoming more clear. Less apparent, however, is the impact of past volcanic eruptions. This, in the main part, must be due to the inability to determine precise and accurate chronologies which can link changes in environmental records to distinct volcanic events. In areas 'downwind' of volcanoes, where layers of ash (tephra) define distinct time planes, this problem can be circumvented. Micro-scale sampling of floral and faunal remains has been undertaken around such layers to determine the presence of volcanically induced changes (see Reports, *this issue*). Distinct assemblage shifts or species declines are often associated with these layers, ranging from Palaeozoic trilobites to trees in the Chilean Holocene (see Reports, *this issue*). Apparent changes in biota associated with Holocene tephras may be problematic. There can be doubt as to whether such changes are brought about by the chemical or physical presence of the tephra (thick layers can stop the burrowing activity of benthic animals) or by the impact of the supposed climate change. Frequently stratigraphic changes in flora/fauna appear to be already underway beneath the tephra. Several possibilities must then be considered: the association could be circumstantial; chemical effects linked with tephra deposition may cause degradation of organic remains; the tephra layer may have been bioturbated.

As there are historical records of volcanically-induced vegetation changes many of the changes which have been detected in the Holocene record are likely to be real. Further inter-disciplinary investigations are required to address the question of their origin. The damage to tree rings seems likely to have been caused by climatic deterioration, whilst other possible climatic effects include ground surface saturation due to increased precipitation. Some vegetational (or faunal) changes may be caused by environmental acidification, or chemical poisoning. A clearer picture of environmental responses to volcanic activity will come about by assessing information from studies of atmospheric processes, soil chemistry, catchment processes and the effects of acid rain.

One major challenge is the explanation of prolonged periods (15-0 years) of stunted tree growth visible in the dendrochronological record. These have been attributed to volcanic effects, but observations of modern climate changes following large eruptions show a climatic effect lasting 3-4 years at most.

Perhaps the tree rings are responding to a longer term effect related to chemical/ moisture changes in the soil. Time may tell.

Recent volcanic eruptions have stimulated a productive period of research spanning the last decade. Like all natural systems, the volcano-atmosphere-climate link is far more complex than initially supposed. The implications of this research are proving to be of interest to those looking at both the past and the future, and the new results and future observations will play an important role in testing and modifying predictive climate-response models.

Through the academic study of such fascinating events as volcanic eruptions it is often easy to forget their real potential for death and destruction. Statistics of the deaths caused by Pinatubo may seem removed from our existence on the other side of the world. As I write this, however, news has just arrived of the death of six volcanologists on the summit of Galeras in Columbia. Included amongst these was Prof. Geoffrey Brown, Head of the Geological Research Group at the Open University. It is deeply ironic that they died in an explosive eruption that they were attempting to predict. The death of fellow geologists perhaps reminds us more effectively of the potential danger posed by volcanoes, and teaches us to respect them even more. Our sympathy is extended to the families of those who perished.

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ECOLOGY

Quaternary Studies and Ecology in Scandinavia

A time axis covering hundreds to thousands of years is familiar to all Quaternary scientists, but is only now making its impact felt amongst ecologists. There is a vast array of ecological issues that can benefit from a Quaternary perspective, and I am overwhelmed by research projects here in Sweden where ecological research has always maintained a high profile. I would like to share the pleasure of two current projects with QRA members in branches of ecology where few Quaternary scientists have previously trodden.

1. Forestry

A new law is under debate in Sweden that gives ecological values equal weight with production values in commercial forestry. The research community is frantic. What does an ecologically sound forest look like? Fossil studies are proving to be the only way of obtaining information about natural forest composition, and I will soon be able to report the establishment of a trial commercial plantation based on a local pollen diagram. A wave of 'new forestry' thinking is sweeping northern Europe, and can be expected to reach Britain one day.

2. Conservation

Conservation theory has been in the hands of contemporary ecologists for too long. Much has been written about indicators of forest continuity, and stable refuge areas of high biodiversity have been identified based on their present species composition. A growing number of palaeoecological studies have challenged these ideas. Stability is exceptional, which has surprised many Scandinavian ecologists. A recent pollen study from a species-rich refuge packed with indicators of long forest continuity revealed that the site had been under cultivation 500 years ago, and the present forest had developed within the last 300 years.

My feeling is that there are many more environmental disciplines waiting for a migrant QRA member to come and look over their pet ideas.

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QUATERNARY RESEARCH IN WESTERN AUSTRAILIA

In 1990, in response to a letter of mine in which I bemoaned my isolation in WA from the QRA, Brian Taylor (QN 61:1) invited me to become a 'foreign correspondent' and to report To QN on Quaternary research in WA. Although I appreciated the intention behind his offer, I was also enormously amused by it for reasons which Figure 1 should make abundantly plain, particularly since I have thoughtfully included the British Isles drawn to approximately the same scale. However, I decided to accept the offer in the spirit in which is was made, but unfortunately the pressure of trying to complete a PhD on the prehistory of the middle Murchison basin, which will be submitted at the end of this year, prevented me responding to Brian's offer until now.

Perth is said to be the most isolated major city in the world. Our nearest civic neighbour is not Adelaide, as might be supposed, but Djakarta! Westwards lies the Indian Ocean, while eastwards Alice Springs is only indirectly accessible. Darwin is nearly 4500km away over a highway which is only partially sealed with bitumen and, north of 23°S, subject to severe seasonal flooding. Adelaide is 2700km away by sealed highway or train, passing through Kalgoorlie-Boulder. This isolation extends even within WA itself. The northern sub-tropical towns: Karratha, Port Hedland, Broome, Derby, seem a world away from those of the cool-temperate, forested southwest: Bunbury, Albany, Esperance. Of course everywhere is accessible by light aircraft, but until the recent deregulation of the airline industry prices were even more inflated than in the equally protected European market. Something no resident of WA can ever forget is that between them and the rest of Australia lies an inhospitable desert, which comprises over half the total area of the state. Much of it has now been given back to its original Aboriginal occupants and can only be entered with their permission. Apart from the two highways mentioned, tracks are few across this desert, fuel availability is strictly limited and natural fresh water largely non-existent. These geographic facts dominate life in WA and can make adjustment difficult for a newcomer. The Northern Territory and northern Queensland evince similar characteristics.

The total population of WA is slightly over 1.5 million, about a million of whom live in Perth. The populations of the other towns mentioned above do not exceed 20,000. Most of the state comprises national parks, farmland and pastoral stations where population densities decline to <1 person per 1000 km^2. For example, my own study area, whose approximate boundaries are shown in Figure 2, covers about 50,000 km^2 but is inhabited by less than 500 people, including the townsfolk! Murchison shire itself is unique in Australia: it has no

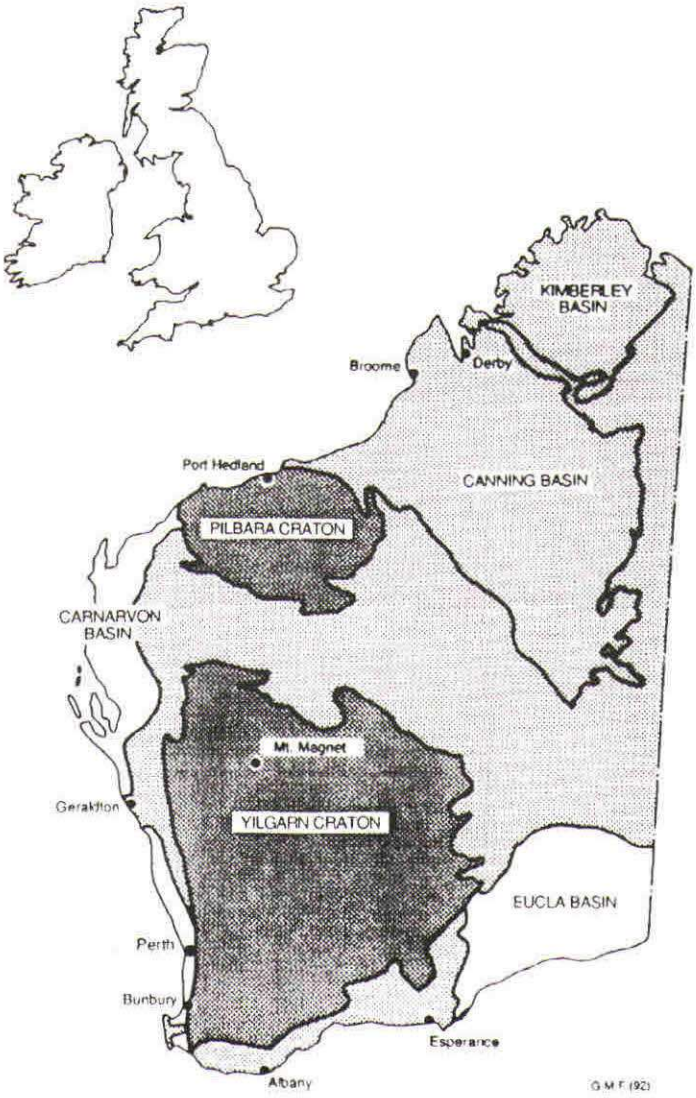

Figure 1. Sketch map of the solid geology of Western Australia showing the paucity of Quaternary deposits.

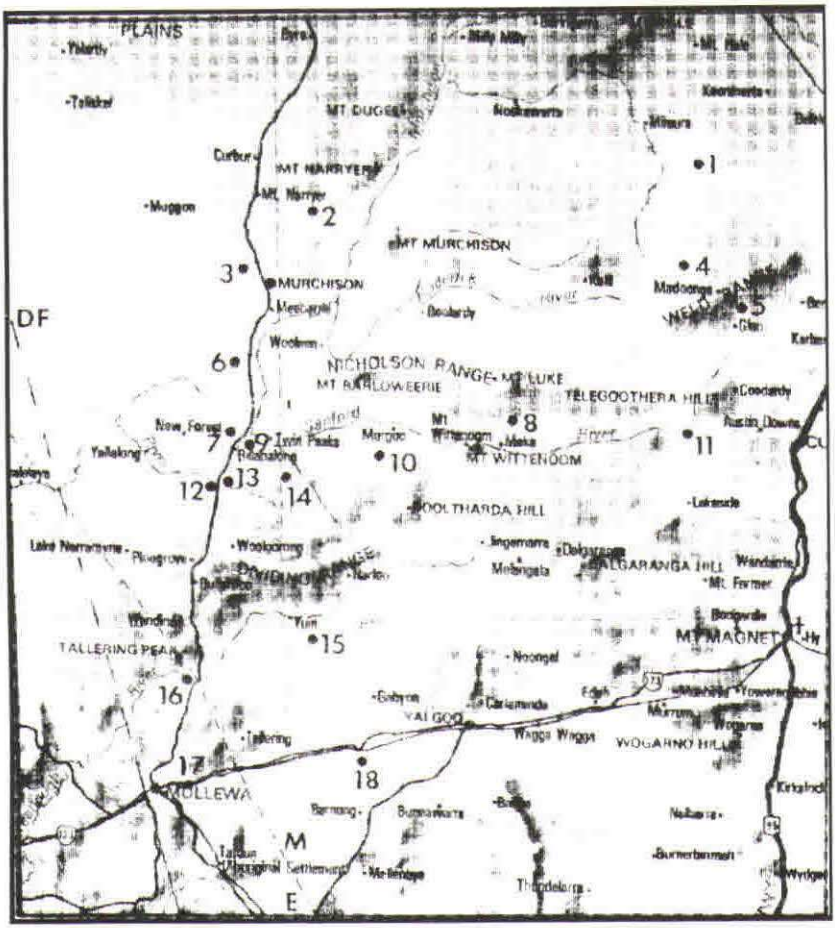

Figure 2. Sketch map showing the locations of the sites in the Murchison basin already known when I began my research in 1988 and the rockshelters I selected to excavate.

Known sites: 2 - Quailbadoo lunette, 5 - Wilgie Mia ochre mine, 9 - Billibilong spring, 11 - Walga Rock, 12 - Collurburloo pool, 13 - Ballinu spring, 16 - Pindaring rocks.

Sites I excavated: 1 - Mileura, 3 - Meeberrie, 4 - Madoonga, 6-7 - Billibilong, 8 - Meka, 10 - Murgoo, 14 - Twin peaks, 15 - Yuin, 17 - Mullewa, 18 - Wurarga.

Key: DF. Darling Fault, EM. Eucalyptus-Mulga line.

'towns'. The shire office is located next to the only roadhouse/petrol station between Mullewa and Gascoyne Junction. All the same, the Murchison is 'suburban' compared with the Pilbara, Kimberley of Western Desert regions. Most of WA's population has immigrated there since World War II, either from the eastern states, Europe, or more recently, southeastern Asia. The only state with an equivalent immigration rate is California. Hence, it is extremely rare to meet a native 'sand groper' whose ancestors arrived during the first wave of European colonisation in the mid-nineteeth century.

Geologically WA also differs greatly from Europe. As Figure 2 shows, most of WA is not merely Precambrian, but Archaean. It comprises two cratons, the huge Yilgarn block and smaller Pilbara craton, and adjoining orogens. These shield structures have remained essentially stable since Proterozoic times. To the north lie the Precambrian igneous and metasedimentary rocks of the Kimberley basin. Apart from the Eucla basin and coastal part of the Carnarvon basin which are of Tertiary age, most of the rest of WA comprises rocks of later Mesozoic (Permian to Cretaceous) age. During most of the later Tertiary and Quaternary WA was emergent, hence erosion exceeded deposition, except in selected coastal areas. The rare Quaternary deposits comprise alluvial and aeolian sediments preserved in the river valleys and on parts of the coast. It was impossible to indicate their presence in Figure 1. Some of these late Cainozoic deposits became progressively lateritised during the wetter stages of the Pleistocene, when the sea also briefly inundated some coastal areas, especially the southern part of the Perth basin. The unimportance of the Quaternary in WA is amply demonstrated in the general studies published by the Geological Survey of WA (1975, 1990; Myers and Hocking, 1988). GSWA memoir 2 devoted only 4 of its 500 pages to a discussion of Tertiary superficial deposits. The Quaternary as a separate stage was not discussed at all! GSWA memoir 3 devoted only 6 of its nearly 800 pages to the Phanerozoic, in which the Quaternary is dismissed in a few lines. This treatment is very understandable, alas. It reflects the paucity of Quaternary deposits in WA.

Therefore, for a northern European used to the freshness of landscapes formed by recent glacial or periglacial processes, WA came as quite a shock. The landscapes here are very old. For example, present river valley topography frequently bears little relation to either water volume or flow regime. Thus, the valley of the Murchison river probably took its present configuration during the late Mesozoic. Subsequent erosion has reduced the river gradient sufficiently in the middle Murchison basin so that the river now forms a series of discontinuous ponds wherever groundwater seeps into its bed, but only flows intermittently after rain has fallen somewhere in its huge catchment. Frequently

in WA what Quaternary sediments there are form no more than the thinnest skin over the Palaeozoic basement, a situation which has few parallells world-wide. Hence, the processes involved in the formation of Quaternary sediments relate more frequently to diagenesis than to active deposition. Thus, the geological and geomorphological history of WA has had profound effects on the archaeological record. These are only now beginning to be appreciated because Australian archaeologists are not usually trained in Quaternary studies, especially in WA.

Including myself in 1992 the Australian Quaternary Association (AQUA) has 14 paid-up members in WA. We all live and work in the Perth area. Most of us are attached to either the Commonwealth Scientific & Industrial Research Organisation (CSIRO), one of the universities (5 at UWA: 2 archaeologists, 2 geographers and 1 geologist, 1 at Murdoch), the Geological Survey of WA (3) or the WA Museum (3). According to a directory of people actively engaged in Quaternary research published in *Quaternary Australasia* 4 (the 'down-under' equivalent of *QN*), in 1986 there were also several Quaternary scientists who are not AQUA members. These numbers fairly reflect the perceived relevance to researchers in WA of an organisation based 'over east'. In southeastern Australia in particular, unlike WA, there are real Quaternary deposits to study. State and Commonwealth funding is difficult to obtain at the best of times. Without an 'official' affiliation it is next to impossible. Quaternary consultational work is funded by companies seeking to exploit mineral or metalliferous deposits, who are obliged to meet legal requirements concerning environmental and Aboriginal heritage impact statements before they can begin extraction. However, by definition, consultation work can rarely be research oriented.

I will now briefly summarise some of the Quaternary research currently underway in WA. This survey is necessarily incomplete and possibly inaccurate since it only comprises work of which I am aware. Karl-Heinz Wyrwoll (Geography, UWA) is a process geomorphologist (Wyrwoll, 1988). He carried out considerable research on the fluvial deposits of my study area in the 1970s. He has since transferred his interest to northwestern WA (Wyrwoll, in press), although he also has research underway on the Abrolhos Islands. His colleague, Ian Elliott, is primarily interested in coastal processes with a research student studying beach facies in the Perth region. Jane Newsome (Environmental Science, Murdoch) and Elizabeth Pickett, a research student at UWA, have recovered long pollen cores from lakes in the Perth basin which describe environmental changes since the last glacial maximum. They are about to publish some of their Holocene data (Newsome and Pickett, in press). Robert

Gozzard is one of the few Quaternary scientists employed by GSWA. He has recently been mapping the regolith of the Kalgoorlie-Boulder goldfields region. Alex Baynes (Zoology, WA Museum) is a mammalogist specialising in cave faunas, especially on the Nullarbor. He is also compiling data on the timing of the extinction of the Pleistocene megafauna in Australia and on the distribution of the lesser sticknest rat *(Leporillus apicalis)*, which was last seen in the 1930s. Like the North American packrat (*Neotoma* sp.), *L. apicalis* builds its nests from vegetation, hence they preserve the local plant macrofossil record. I found two *L. apicalis* nests in one of my sites. Charles Dortch (Archaeology, WA Museum), worked in the Kimberley in the 1970s (Dortch, 1977). He also excavated one of the oldest sites in Australia (Dortch, 1984a), Devil's Lair, a cave in Tertiary limestone southwest of Bunbury and has worked on the offshore islands of WA (Dortch, 1984b). He is now recovering Aboriginal archaeological material from lakes south of Perth. His colleague, Peter Bindon, is compiling an eagerly awaited catalogue raisonne of those native plants used by WA Aborigines for medicinal, magical and nutritional purposes. Sylvia Hallam, although retired, continues to pursue her interest in the archaeology of the Perth basin (Hallam, 1987) and the southwest (Anderson, 1984).

Research by members of the Archaeology Department of the University of Western Australia has been undertaken at Shark Bay (Bowdler, 1990), in the Pilbara, Kimberley (Bowdler and O'Connor, 1991), Western Desert (Veth, 1989) and southwest. The sites found range in age from the last glacial maximum to the recent past. I have to use this clumsy phraseology because not only do Australians distinguish the Holocene from the rest of the Quaternary, a practice borrowed from North America, but there is also no terminology comparable to the various European climatic stage name sequences. Several research students are also completing PhDs on aspects of post-contact archaeology.

My own research focusses on an area where François Bordes, University of Bordeaux, worked in the late 1970s (Bordes *et al.*, 1983). His interest in the area was aroused by finds of crudely flaked artifacts in various riverine exposures where they were possibly in association with bones of the nototherian *Zygomaturus trilobus*, which became extinct >30,000 BP. If that association could be proved, the Murchison basin might preserve archaeological sites as old as Devil's Lair. This problem was to have been the focus of my research (Webb, 1990), but proved impossible to tackle within the context of a PhD thesis. Therefore, I finally approached the problem of when the Murchison basin was first exploited by Aborigines from a different direction. I endeavoured

to establish the regional archaeological sequence in the middle Murchison basin, something Bordes' research began to address, by excavating in a series of rockshelters which had developed beneath laterite capping denatured Archaean granite. I was only permitted by the Department of Aboriginal Sites of the WA Museum to dig 1m^2 test pits in these rockshelters, but nevertheless they yielded stratified, datable artifact horizons. The positions of the sites I excavated and of the previously-known sites in my study area are shown on Figure 2. Whereas the archaeological sequence at the Aboriginal art site of Walga Rock appears to date back beyond the beginning of the present interglacial, my sites were all first occupied <3500 BP. Hence they postdate the only significant technological change which occurred in Aboriginal stone artifacts: from large core tools to 'small tools' frequently made on blades. My sites also fall within the period during which Lourandos (1985) claimed that there was evidence in southeastern Australia that Aboriginal populations markedly increased. He suggested that Aborigines also 'intensified' their economic resource base at the same time. The question of whether increased population or improved extractive efficiency come first is hotly debated in Australia (Williams, 1987). I am using my data to test the whole hypothesis on which the 'intensification debate' is founded.

Prehistoric archaeology in Australia differs rather from European practice. At present, archaeology students in WA at least are not trained in Quaternary techniques, although some do take the new environmental geoscience course. Hence, they have little knowledge of those faunal, floral, geomorphological and sedimentological methods normally used in Europe to establish the approximate age of a site before any radiometric dates are obtained. This failure to consider the chronological uses of environmental data is due largely to the fact that the harsh WA climate is usually inimical to the preservation of bone, plant macrofossils and pollen. Moreover, unlike Europe, it is difficult to use stylistic changes over time in the artifact sequence to construct rough chronologies or inter-site correlations. It is also regrettably true that, with the notable exception of Devil's Lair, few archaeological sites in WA, even rockshelters, preserve any appreciable depth of deposit. Finally, for reasons which remain unexplained, the surviving sediment in rockshelters is usually uniform in colour and texture and shows little sign of stratigraphic differentiation. Hence, in the absence of stratigraphy or stylistic changes in the artifact sequence, but in an attempt to create chronologies, over-reliance is frequently placed by archaeologists on ^{14}C dates. As I am attempting to show (Webb, in prep), the chronostratigraphies thus created are highly susceptible to error.

By now readers may be asking themselves why any Quaternary scientist in their right mind bothers to work in WA. However, despite or because of the

difficulties, there are also exciting compensations. WA is an enormous state desperately short of trained Quaternary scientists. In almost every part of WA research is still generating primary data. Hence, we are constantly having to modify our explanatory models in the light of the new data discovered. Whereas in Europe all too often one has the sneaking suspicion that one is merely dotting i's and crossing t's written by others, to continue the metaphor, in WA we are still sorting out how many letters there are in the alphabet and their order.

We know very little of the environmental history of the state since the last interglacial. I am hoping to work with Karl-Heinz Wyrwoll on this problem in the Murchison basin. We propose to study sections along the Murchison river and its tributaries and the dunes fringing the many playas and ephemeral lakes in the basin to establish whether and when this area enjoyed wetter climates than it does at present. This project may also tackle the problem of the Murchison 'cement', which was to have been my PhD topic!

Prehistoric Aboriginal behaviour is unlikely to have differed greatly from that of other hunter-gatherers, yet the archaeological record in Australia is unlike that anywhere else in the world. It is therefore worth asking why. I am applying for funding to carry out survey work aimed at trying to interpret the scatters of artifacts which litter the land surface of Australia. Apart from the pioneering work of Caroline Bird (1985), who attempted to tackle this problem in her PhD thesis, such scatters are frequently ignored because they are so difficult to interpret. Following Ross (1981), I propose to study their geomorphological context to try to distinguish chronologically different clusters from each other.

It should be clear from this brief review that there is a lot of interesting Quaternary research both underway and in the planning stages in WA. Hence, it is not surprising that I want to settle here permanently.

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REPORTS

REPORT OF CONFERENCE ON 'NEOTECTONICS: RECENT ADVANCES' HELD AT THE GEOLOGICAL SOCIETY, LONDON

16th-17th June 1992

Over 100 international specialists met at the Geological Society in Burlington House, London on the 16-17th June to participate in a conference to present and discuss recent work being undertaken in neotectonics and to identify important areas for future research. The conference was the initiative of the Quaternary Research Association who proposed a joint meeting of the Tectonics Study Group (TSG) of the Geological Society and the Neotectonics Commission of INQUA. This attracted a wide range of specialists from different disciplines and provided an international dimension. Business meetings of the Working Group on "Palaeoseismicity of the late Holocene" (International Lithosphere Programme) and the Neotectonics Commission of INQUA were held on the evenings of the 16th and 17th respectively. The timeliness of such a meeting was demonstrated by the enthusiastic response and vigour of the participants and the number of abstracts (89) which were included in the Abstract Volume (Mörner *et al.*, 1992). A series of talks and poster displays were presented over the two days.

Four main themes were addressed: i) Neotectonics and Geophysics; ii) Neotectonics and Topography; iii) Neotectonics and Climate and; iv) Neotectonics and Hazards. The rates and magnitudes of horizontal and vertical crustal displacements over the Quaternary and longer geological record were discussed to help in the understanding of crustal dynamics and mantle processes. The importance of climatic change on influencing crustal movements related to the growth and decay of ice sheets was also discussed in great depth. Applied aspects of neotectonic studies were presented to aid in hazard prediction and mitigation.

The conference opened with an address by **C. Vita-Finzi** (UCL). He outlined the multidisciplinary approach to neotectonics and the importance of the contribution of neotectonics in helping to determine rates for landscape evolution and tectonic modelling. He emphasised the need for discussion and initiating collaborative work at the conference. The first session provided an insight to the contribution of geophysics to neotectonics and was chaired by **Nils Axel Mörner** (President of the INQUA Neotectonics Commission). It was

opened by **J. Karzc** (Geological Survey of Israel) who comprehensively presented a variety of geophysical and geodetic information on the neotectonics of the Dead Sea Rift Zone, providing some important new measurements on rates of movement measured using EDMs and GPS. Next **R. Muir-Wood** showed elegantly the relationship between earthquake events and hydrogeological changes. He emphasised that this was an area of neotectonics that was rarely studied but that it had the potential to provide important information regarding earthquake mechanisms. This was followed by **J.L. Wallach** (Atomic Energy Control Board, Ottawa) who presented evidence, based on the presence of orientation of pop-up structures, for the Holocene stress field in the intraplate area of eastern North America. It was emphasised that these structures could be very effectively used as palaeostress/palaeoseismic indicators, but that they had been rarely used in previous studies. **M.K. Strecker** (Universitat Karklsruhe, FRG) then presented a model for the neotectonic evolution of the Central Kenya Rift based on structural mapping and the distribution and ages of volcanoes. He demonstrated a progressive left stepping of volcanic centres along the rift which he related to stress reorientation. The final talk of the session was presented by **R. Collier** who provided information on late Pleistocene sea-level record and rates of uplift in the Gulf of Corinth. He provided a geophysical and sedimentological model based on seismic profiles, field mapping and sedimentology.

The afternoon session was chaired by **Iain Stewart** (West London Institute) and aimed to discuss the topographic expression of neotectonic processes. The first talk was presented by **R. VanArsdale** (University of Arkansas) who showed how tree-ring work could provide an important insight into tectonic processes. This study showed how an increase in lake levels in the Reelfoot Lake produced by the New Madrid earthquakes in 1811-1812 stimulated growth of bald cypress which was evidenced by the increased thickening of tree rings. He emphasised that trees are very sensitive to changes in the environment, such as lake level changes, and that they may provide important information which can be used to reconstruct tectonic events. In addition, this work is of significance to dendochronologists who may not have appreciated the tectonic impact on trees. This talk was then followed by a fascinating paper by **R. Thomas** who described subaqueous landforms in the bottom sediments of Lake Ontario that had recently been identified using side scan sonar. Ridges and scars often over 1km long and several metres wide were shown and interpreted as fault scarps or pop-ups, while other structures had more complex geometries such as feathery plumes and chatter like marks. Their origin is problematic but they may be related to fault movements or possibly degassing of the bottom sediments.

Next **Bartolini** presented work on the tectonic geomorphology of the Appenninic chain and related structure to drainage providing a model for the landscape evolution of the region. **P.G. Silva** (UCN Madrid) presented a model for the development of Quaternary basins in the Betics of Spain and showed how the geometry of the basins and deposits were influenced by faulting. This was followed by **K.J. Kendrick** (University of New Mexico) who showed how a non-linear diffusion equation could be used to model scarp morphology and degradation in the Cajon Pass, S. California. This talk was followed by a comprehensive review of landforms and faulting along the San Andreas fault in southern California by **D.J. Rust** (West London Institute).

The morning of the second day of the conference was chaired by **C. Vita-Finzi** (UCL) and it aimed to examine the relationship between neotectonics and climate. **N-A. Mörner** (Stockholm) gave a stimulating presentation in which he reviewed the evidence for the timing of glaciation and major tectonic events. He suggested a causal link between major tectonic events and the onset of the Ice Age. This talk was followed by **A. Nelson** (USGS, Denver) who calculated uplift rates based on marine terraces and beaches and examined the evidence for uplift resulting from a number of large earthquakes in Chile. From this data he highlighted the importance of a seismic uplift in this region. This was followed by **Clark Fenton** (Glasgow) who gave an amusing talk on postglacial faulting in Scotland and presented evidence in the form of fault scarps, offset streams, sediment liquefaction, slope failures and displacements of shorelines which he believed provided evidence for neotectonic activity in Scotland.

P.A. Pirazzoli (CNRS, Marseille) then showed evidence for relative sea level changes in the Alor Islands, East Indonesia, based on raised coral reefs and sea notches. He suggested that this evidence could be used to help determine earthquake recurrence intervals. This talk was followed by **A.J. Long's** (Durham) presentation on Holocene uplift and subsidence in the UK. New data was presented from the East Kent Fens and south of the Isle of Thanet.

The afternoon session was chaired by **L. Owen** (RHUL). A series of papers on neotectonic hazards were presented. The session started with a very comprehensive review by **W. McGuire** (Cheltenham and Gloucester College of HE) of recent earth movement at active volcanoes. This was followed by an excellent paper on seismic hazard mapping conducted by the GSC in Canada. In this **John Adams** (GSC) presented detailed work on the St. Lawrence Seismic Zone to aid in the prediction of future earthquakes in that area. **C. Rogojina** (University of Toronto) followed this talk by showing details of faulting in sands along the shores of Lake Ontario and suggested that these

could be neotectonic in origin. He argued that these could be used in earthquake hazard assessment.

T.A. Dijkstra (RHUL) summarised the results of a landslide hazard assessment project in the loess of North-Central China. He argued that many of the landslides in this area were initiated by earthquakes. Their hazard mapping identified seismic zones and areas where loess was and is susceptible to failure. The final talk of the conference was given by **D. Papanastassiou** (National Observatory of Athens Seismological Institute) who presented archaeological evidence for ancient earthquakes in the Argive area of Greece.

The conference was successful in being multidisciplinary and in attracting many scientists from distant countries. A variety of multidisciplinary papers resulting from this conference will be published in Early January, 1993 (Owen *et al.* in press) and a second volume on fault scarps will be published early next year (Stewart *et al.*, in press).

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REPORT OF CONFERENCE ON 'CENOZOIC GLACIATIONS AND DEGLACIATIONS' HELD AT THE GEOLOGICAL SOCIETY, LONDON

18th September 1992

This International meeting, sponsored by the Statigraphy Committee of the Geological Society and the Quaternary Research Association was held at Burlington House, Piccadilly, London, and convened by Graham Jenkins and Michael Hambrey. Abstracts from this meeting are published elsewhere in this Newsletter.

The main purpose of the meeting was to place the Quaternary glaciations in a Cenozoic perspective. The central theme was to examine the evidence of pre-Pleistocene glaciations and deglaciations from high latitude areas. The earliest evidence of Cenozoic glaciation dates from at least earliest Oligocene time (c34 Ma) on the Antarctic continental shelf. In contrast, large-scale northern hemisphere glaciation appears to date from late Pliocene time.

In order to gain a better understanding of the planetary atmospheric and marine heat machine we need to address some basic questions; (i) what caused the early glaciations in the Oligocene and Miocene epochs and what was the tempo of refrigerations in the Cenozoic Era?; (ii) are there fundamental patterns to ice sheet growth and decay; (iii) why was it so late in the Cenozoic era that bi-polar glaciation was initiated?

The meeting attracted a group of internationally recognised scientists who gave fascinating accounts of the evidence or lack of evidence for pre-Pleistocene glaciation. Inevitably, Antarctica was the main focus, but the views expressed have implications that extend far beyond the limits of that continent, and should be of interest to many Quaternary scientists.

The meeting opened with a paper by **D.M. Harwood** (Nebraska) and others on "The search for consistency between several indices of Antarctic Cenozoic glaciation". Harwood compared the various lines of evidence from Antarctic drill-cores, linking biostiatigraphic, sedimentological, glacio-eustatic oxygen isotope and biogenic productivity records. He concluded that glacierization of Antarctica began in late middle Eocene, followed by major expansion in early Oligocene time. He also presented evidence for a major deglaciation in early Pliocene time, but also pointed to the inconsistencies in the evidence for this event. The late Pliocene epoch was a time when the previously highly dynamic 'temperate' ice sheet took on its present stable, cold form.

The initiation and character of the early Antarctic ice sheet was examined by **M.J. Hambrey** (Liverpool) who summarised the evidence from recent ODP

and New Zealand drill-cores from the Antarctic continental shelf. Although drilling has yielded a good record of Oligocene-Miocene glaciation, the timing of the onset of glaciation is still an open question. The style of Oligocene glaciation was quite different from the cold ice sheet of today, and a highly dynamic, temperate ice sheet is envisaged; yet ice was more advanced in at least one part of East Antarctica than at the present day.

Recent work by the British Antarctic Survey in the South Shetland Islands on the topic of early glaciation was presented by **J.L. Smellie** (with **D.C. Rex**). He examined the evidence presented by Polish geologists in connection with their claim for having the earliest indication of ice on the continent. Radiometric dating was found to be in conflict with much of the Polish data, and the evidence for Eocene and early Oligocene glaciation was weak; the main glacial deposits in the new investigation fell close to the Oligocene - Miocene boundary (26-23 Ma).

In a paper on 'The state of the Antarctic cryosphere in the early Pliocene evidence from the Southern Ocean', **J.P. Kennett** (Santa Barbara, California) came to the opposite conclusion to Harwood concerning Pliocene deglaciation. He argued that the deep-sea oxygen and strontium isotopic records, the presence of marine carbonates, the history of turbidite sedimentation and the pattern of biogenic sedimentation all point to relatively minor deglaciation in early Pliocene time and concluded that the ice sheet has remained stable.

H.J. Dowsett (USGS, Reston, Virginia) also examined the Pliocene interval in a paper 'Late Neogene marine and terrestrial records from the Northern and Southern hemispheres; implications for palaeoclimate change'. He presented a synoptic palaeoclimate model at 3Ma which has been developed in order to search for causal mechanisms. This mid-Pliocene synoptic reconstruction, combined with GCM experimental results, suggests that heat transport through ocean circulation was stronger than at present, and that the well-documented warming in the North Atlantic may also have taken place in the North Pacific and South Atlantic.

A second paper by **Harwood** (in association with **P-N. Webb**) focussed specifically on the Pliocene Antarctic deglaciation problem. Strong evidence in favour of extensive deglaciation and the development of extensive forest extending almost to the South Pole, and relatively warm seas extending into the interior of Antarctica was presented. The evidence occurs within the terrestrial Sirius Group, a diamictite widely scattered throughout the Transantarctic Mountains, with correlatives elsewhere. These deposits contain recycled marine diatoms dated as early and mid-Pliocene, as well as *in situ Nothofagus* roots, stems and wood in fluvioglacial sediment. Temperatures 15-20° warmer than at present are required to support this flora.

The Harwood-Webb hypothesis of deglaciation has been widely criticised on the grounds that the floras (diatoms and *Nothofagus*) have been incorrectly dated. However, **G. Wilson** (Wellington, New Zealand) in a paper comparing cyclicity and chronology in a Pliocene drill-core in Antarctica and a Pliocene sequence in Antarctica, presented strong evidence in the form of a well dated ash horizon that the diatoms in Sirius equivalents in drill-cores were indeed Pliocene in age. Further, BE^{10} dating techniques and palaeomagnetic stratigraphy enabled the chronology of drill-cores to be further refined, and compared to sea-level curves derived from the Wanganui Basin in New Zealand. Both data-sets indicate that there was much less ice in Antarctica in Pliocene time than at present.

All this evidence of Pliocene warming, convincing as it is, conflicts with evidence of a geomorphological nature obtained from the adjacent Dry Valleys region. **D. Marchant** (Maine) presented a new approach for determining Pliocene palaeoclimates and ice sheet history of East Antarctica. He examined an *in situ* ash, and its preservation, isotopic age and stratigraphic relationship, resting on a cold desert pavement, indicate that a cold climate has existed since at least 4.3 Ma, a view reinforced by **D.E. Sugden** (Edinburgh) and others on the basis of the morphology and distribution of landforms. Sugden's pattern of landscape evolution indicates that the main stages were completed by mid-Pliocene time. Since then a stable, polar desert climate has preserved landscapes of remarkable age.

In summary, the main topic that emerged from the meeting was of the problem of Pliocene climates. Did Antarctica suffer large-scale deglaciation at that time, or not? Was the ice sheet a highly dynamic, temperate feature prior to this time, and only stabilised into the present, cold ice sheet in late Pliocene time? Each of the scenarios presented by the biostratigraphers and the geomorphologists on their own seem equally plausible, but they are clearly incompatible. Resolution of this conflict is vitally important to understanding the behaviour of large ice masses. It has bearing on how we interpret a wide range of evidence irrespective of age, including the Quaternary Period and the Oligocene and Miocene Epochs. If the Harwood-Webb hypothesis is correct - and global warming trends suggest that Pliocene temperatures may be reached in the not too distant future - then there should be concern about the stability of the ice sheet. The evidence from the Ross Sea sector has proved difficult to reconcile. There is therefore a need for data from other parts of Antarctica. For example the Sirius Group equivalent, the 'Pagadroma Tillite' in the Lambert Glacier region of East Antarctica is likely to yield valuable information. Future drilling in the deeper marine basins of Ross Sea region are necessary to gain a more complete and better-dated sequence through the Plio-Pleistocene interval, so as to decipher more completely the onshore glacial events.

Michael J. Hambrey (Liverpool John Moores University) and D. Graham Jenkins (National Museum of Wales, Cardiff).

REPORT ON THE 2nd U.K. TEPHRA WORKSHOP, BELFAST

12th December 1992

Among British Quaternary researchers the last few years have seen a rapid growth of interest in tephrochronology. This was well illustrated by the number of participants at this, the second U.K. tephra workshop, and by their wide range of interest and expertise. In bringing together the geographers, geologists, archaeologists and palaeo-environmentalists currently involved with tephras and their applications, the meeting was extremely constructive. The meeting was supported by NERC reflecting their view that tephra studies are an expanding field.

The workshop was held at the Palaeoecology Centre, Queen's University, Belfast and its great success reflects the efforts of the organisers, Jon Pilcher and Valerie Hall, together with several of their enthusiastic undergraduate students. Like all workshops should, but so few do, this meeting managed to achieve an air of friendly informality which resulted in the active interchange of ideas and enthusiastic discussion.

In a brief introduction and welcome from Jon Pilcher it was gratifying to hear of NERC's attitude and encouragement. The first session which followed consisted of summaries of some of the main current projects by the 'group leaders' from the key research centres.

Unfortunately **Gudrun Larsen** (Rekjavik) was unable to attend owing to illness. Nevertheless a useful summary of work in progress at Rekjavik and Edinburgh was presented by **Andy Dugmore** (Edinburgh). In both Britain and Iceland attention has been mainly focussed on Holocene chronologies and a wide range of projects were referred to. 'Representative' sections of Icelandic tephro-stratigraphies have been sought as a tephrochronological framework both for Iceland and for further afield. In one of these sections a total of 77 individual tephra layers have been identified. From these and other investigations, a re-interpretation of Thorarinson's tephra isopach maps is in progress. Preliminary results indicate that tephra fall-out sectors, thought previously to have been dominantly northerly orientated, have significant southerly distributions. This is consistent with the occurrence of the many tephras in north of the British Isles. Other aspects referred to included radiocarbon dating along tephra time planes, the separation of tephras from organic sediments, and the increasingly complex Scottish tephrochronology.

Leading on from this **Kevin Edwards** (Birmingham) reported on some aspects of a multi-disciplinary project on 'environmental and cultural aspects of volcanism in the North Atlantic region'. This research is concentrating on close spaced samples of biota around the tephra layers, including studies of pollen, fungal spores, chironomids and coleoptera. In Scotland more than 30 sites of tephra recovery were reported, in addition to sites on the Faroe Islands and Iceland. The 3-D examination of tephra distribution has proved particularly useful in examining the palaeo-topography of peat bogs, and has implications for the ^{14}C dating of peats. The correspondence of a tephra layer (Hekla 4) with the pine decline was discussed, together with its dating and an assessment of its synchroneity.

This was followed by a report from **Keith Bennett** (Cambridge) in which tephras from the Shetland Islands were discussed, including the uses of tephra for establishing chronologies in sequences that cannot be dated reliably by ^{14}C methods (e.g. marl lakes). The possible palaeoecological changes associated with tephras was also examined. The early Holocene Saksunarvatn tephra was dated to 9,300 ± 70 BP and correlated to a magnetic susceptibility peak. Distal tephras in the British Isles have not previously been detected by such methods owing to their low abundance. This correspondence may be highly valuable in future studies of Shetland basins.

The first session closed with presentations by **Jon Pilcher** and **Valerie Hall** (Belfast). In the Northern Ireland peat bog record 10 - 12 tephras were reported, the oldest occurring at *c.* 8,000 BP. The most abundant tephra is Hekla 4 which was calculated to have a mass loading of one tonne per hectare! It appears that a southern limit of tephra fall-out has been identified, towards which there is a fall off of tephra abundance. Wiggle matching of radiocarbon dates was discussed with reference to a tephra dated to 1103 ± 13 AD. Geochemical analysis will characterise the tephra which could be from the historically dated 1104 AD eruption of Hekla!

The second session consisted of a series of talks from the growing number of research students who are either studying tephras directly, or utilising them in their palaeo-environmental research.

The first presentation was by **Jane Boygle** (Edinburgh) who described the difficulties in linking tephrochronology to the chronology of the Swedish varves. She then concentrated on some important results from Iceland which document the complexity of tephra distribution and re-working within Icelandic lake catchments, both subaerially and within lakes. **Anthony Newton**

(Edinburgh) followed with an examination of Icelandic pumice on the shores of the North Atlantic. This pumice can be found as far afield as Arctic Canada, Svalbard, Norway, Finland, Russia and Scotland. In the British Isles the pumice is mainly found at archaeological sites whereas the Norwegian pumice is commonly found in raised beach deposits. Of particular interest was the difference in geochemistry between the pumice and shards of the same eruption.

The next talk was given by **Jane Bunting** (Cambridge) who examined the tephrochronology and palaeoenvironment of four sites on Orkney. Here the Saksunarvatn tephra appears to coincide with the start of the hazel rise, although in two of the sites the hazel rise is found without the tephra. These interesting observations of the uneven distribution (and absence) of tephra support the idea that the presence or absence of tephra may be controlled by rainfall. Going from Orkney to Northern Ireland **Joanne McVicker** (Belfast) examined the vegetational history of the Mourne Mountains, using both tephra and radiocarbon chronologies. She stated that no notable vegetation change appeared at the position Hekla 4. It was interesting to hear of the difficulties in distinguishing some of the tephras from amorphous plant silica and phytoliths.

Not all the talks dealt with Icelandic tephras. **Suzy Lumley** (Cambridge) presented some of her work from the Taito Peninsula of Chile. Unlike the British Isles tephras, these were visible bands on mm/cm scales. Here a marked vegetational change, a massive decrease in *Pilgereodendron,* was associated with one of the tephras, although plant macro-fossils showed no sign of damage. Remaining in Chile, **Bob McCullough** (Edinburgh) looked at the uses of tephra in his investigation of Late Quaternary and Holocene climatic zones and geomorphological patterns in South America. One of the problems with tephras was their redistribution by the strong winds. Problems of ^{14}C dating were examined and raised concern, as the dates were not supported by the mutually compatible tephra/pollen data.

The final talk returned to the Icelandic tephras, but examined the Younger Dryas marine record. **John Hunt** (Edinburgh) discussed some of the problems of radiocarbon dating of marine and terrestrial sediments by the comparison of data from equivalent tephras in the St. Kilda basin (marine) and the north of Iceland (lacustrine).

Following lunch a lively and wide ranging discussion occupied the rest of the day. **Mike Baillie** (Belfast) offered some provoking thoughts on the problems of correlating the environmental records with the tephra record. The errors

associated with ice-core and radiocarbon dating prevent volcanic events from being reliably correlated with dendrochronological calendrically dated events. Problems surrounding the geochemical characterisation of tephras, probe techniques and probe correlations were described by **John Hunt.** The creation of a tephra data base was discussed following a presentation by **Anthony Newton**, particularly in respect of access and formatting. A number of other matters were discussed ranging from errors and confidence in intervals needed in palynological work, to the problems of re-working and multiple layering of tephras in Iceland. The meeting closed after a discussion on the direction of future research.

After a convivial evening over some excellent Guinness in the pubs of Belfast, the meeting continued into a Sunday field trip to some of the peat bogs referred to by Jon and Valerie. Unfortunately not everyone could attend owing to work and transport arrangements, but those who did enjoyed an entertaining and instructive day.

Several points, and much common ground emerged from the meeting, which will become increasingly important in respect to the problems of Quaternary and Holocene research. First, in particular the problems of radiocarbon dating and the advances that can be made by its combination with tephra studies; and second, the effects of volcanism on palaeo-biotas and palaeoclimates. The tephra community is growing and it may not be long, in the northern British Isles at least, before tephra isochrons will be as routinely sought as are radiocarbon dates presently.

Finally, the organisers **Jon Pilcher** and **Valerie Hall**, along with several of their enthusiastic undergraduate and postgraduate helpers, should be heartily congratulated for an excellent meeting. Hopefully the 3rd meeting, whenever it may be, will enjoy as much success!

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REPORT ON 'ISLAND BRITAIN: A QUATERNARY PERSPECTIVE' QRA ANNUAL DISCUSSION MEETING, CAMBRIDGE

6-7th January 1993

In this year of increasing European unity, members of the QRA met in Cambridge to discuss Britain's physical status as an island - a characteristic which has shown considerable variablity throughout the Quaternary. This proved to be a particularly wide-ranging and stimulating topic, attracting over 180 participants from a variety of backgrounds, including a strong contingent from France, Belgium and the Netherlands. The meeting was hosted for the first time in the Department of Zoology, where an excellent drinks reception in the museum followed by dinner in Sidney Sussex College, provided a pleasant setting for informal discussion.

In keeping with the main theme of the meeting, the first series of talks examined the timing of sea level change throughout the Quaternary and its effect on the insularity and palaeogeography of Britain. **B.M.Funnell** (UEA Norwich)set the scene, providing a detailed summary of the evolution of the North Sea in the Early Pleistocene. We learnt that as far as the British terrestrial record is concerned, there is only firm evidence for one phase of insularity (in Red Crag times), although other transgressive events certainly occurred during the Tiglian. For much of the Early Pleistocene Britain thus remained firmly connected to mainland Europe, with a coastline located in the central part of the southern North Sea at the edge of an extensive, prograding delta. **D.H.Jeffery** (BGS Nottingham) expanded on this deltaic story, adding interesting detail from seismic data in the offshore region. By tracing the extension of delta topsets across the basin, he demonstrated how patterns of coastline movement can be mapped, even back to the Praetiglian. One important implication of this work, he argued, was the lack of evidence in support of multiple major transgressions in the North Sea in the Early Pleistocene - an interpretation apparently in conflict with the observations of the first speaker. He also drew attention to the dramatic switch in depositional regime that occurred in Cromerian times, as the delicate balance between sediment supply and subsidence was upset, and the delta went into decline. Thereafter eustasy began to play a more critical role in determining coastal palaeogeography.

From the Early Pleistocene the discussion moved swiftly on to the Middle Pleistocene, with a series of talks on the breaching of that bastion of landbridges, the Straits of Dover. **P.L.Gibbard** (Cambridge) introduced the topic, presenting the now widely-accepted view that the Straits were first cut in the Anglian as water from a large ice-dammed lake escaped south through the Weald-Artois Anticline. The incision was not, in his opinion, solely the result of a single catastrophic event, but a gradual process aided by repeated phases of fluvial downcutting (during low sea level stands) and tidal scour (during transgressions).

D.H.Keen (Coventry) followed with a review of the evidence for subsequent breachings, drawing particularly on recent TL and U-series data from sites in northern France. He suggested that there were two pre-Eemian phases of breaching; the first, in oxygen isotope Stage 9, leading to the formation of the shallow marine sequence at Herzeele (also correlated with the Holsteinian), and the second, in Stage 7, forming the Sangatte Raised Beach. As is often the case with Middle Pleistocene reconstructions we were again left wondering what happened in Stage 11! This scenario also proved to be slightly at odds with the findings of **R.C.Preece** (Cambridge) and **T.Meijer** (RGD Haarlem), who showed that there is no evidence to support a spread of southern, Lusitanian marine mollusca into the North Sea during the Holsteinian - species that would surely have migrated into the basin had there been a major pathway through the Straits. These discrepancies await further clarification.

From periods of insularity during high sea level stands, the discussion moved on to examine the re-connection of Britain to Europe during regressions, particularly its effect on the behaviour of Britain's river systems. **D.R.Bridgland** (Darlington) and **B.D'Olier** (London) gave an interesting talk on the Thames, showing how seismic mapping and channel long profile recontructions can be used to re-create Middle Pleistocene linkages between the Thames-Medway and the Lobourg River of the Channel. The potential of seismic data in fluvial reconstructions was also underlined by **A.Bellamy** (Reading), who gave an excellent account of the Late Pleistocene history of the Owers Bank near the Isle of Wight. Both talks served to highlight the complexity of the offshore data and also the importance of good independent dating for accurate correlation with terrestrial sequences. These points were re-emphasized by **D.Q.Bowen** (Aberystwyth), who also stressed the importance of establishing better contraints on glaciation in Britain, particularly in those glacial 'Dark Ages', the late Middle Pleistocene and early Devensian. He suggested that the new technique of Chlorine-36 dating will go some way towards assisting this process.

Having taken a whirlwind look at the Quaternary history of Island Britain, the second half of the meeting concentrated on the fossil record, particularly the prospects for using different fossil groups for determining episodes of insularity. **R.C.Preece** began on an optimistic note, emphasising the great potential of molluscs for tackling palaeogeographical questions in a wide range of environments. **T.Meijer's** excellent data was used to provide evidence for phases of European linkage (*eg.* the presence of the 'Rhenish fauna' in the Thames and Scheldt systems during the Hoxnian) and isolation (*eg.* Lusitanian elements in Ipswichian North Sea assemblages). Molluscan data was also used by **L.van der Valk, C.Laban** (RGD Haarlem) and **C.Baeteman** (Belgian Geological Survey) to investigate the changing configuration of the North Sea during the Holocene. Supplementing their data with a radiocarbon chronology, they placed the final isolation of Britain during the period 6,500 to 3,300 years B.P. - significantly later than in previous models.

Pleistocene icthyofaunas were then considered by **B.G.Irving** (UCL London), who examined the relationship between fish species and environment in an attempt to address similar palaeogeographical issues. Using the results of extensive research, he demonstrated that unfortunately fish faunas hold very little potential because the same assemblages have remigrated into Britain during successive Pleistocene warm phases. He also showed how the present European assemblage cannot serve as an analogue, having been profoundly affected by humans with buckets !

The discussion moved on to mammal faunas, beginning with an informative paper by **A.M.Lister** (UCL London) on the impact of Pleistocene insularity on mammalian evolution. Using the example of the dwarfing of Red Deer on Jersey during the Ipswichian, he demonstrated how relatively short episodes of isolation can lead to marked changes in the population of small islands. **A.Turner** (Liverpool) extended the discussion to mainland Britain, examining the theory that some of the gaps in the fossil record may be explained by the presence of barriers between Britain and Europe during phases of high sea level. The spotted hyena, which failed to reappear in Britain between the Cromerian and the Ipswichian, was described as one possible victim of such migratory restrictions. **A.J.Sutcliffe** (BMNH London) went on to suggest that the reasons for these gaps were more complex, pointing out that the absence of horse and man from Britain during the Ipswichian is difficult to reconcile with the presence of other less mobile species like hippo. Perhaps the impenetrability of the Ipswichian wildwood severely restricted human (and indeed animal) activity. The complexity of Pleistocene human behaviour was also considered by **N.Barton** (Lampeter), who showed how climate and vegetation appear to have played a major part in influencing man's spread across Britain during the Late-glacial Interstadial.

The biological evidence was completed with an examination of fossil floras, again with a slant on their use in insularity studies. **K.D.Bennett** (Cambridge) dealt with the tree record, showing, with examples from the British archipelago, how the dispersal ranges of tree species can be deduced from Holocene fossil assemblages. The important point to emerge was that only two or three species have maximum disperal distances of less than a few kilometres. It follows that a comparatively narrow stretch of water such as the Dover Straits (now at around 34km wide) would be practically impossible to deduce from a Pleistocene flora : landbridge-builders beware! Fossil floras also formed the basis for a superbly illustrated talk by **P.Coxon** and **S.Waldren** (TCD Dublin) on the gradual loss of plant species from Ireland during the Pleistocene. Of the wide range of factors influencing depletion (including several climatic, ecological and refugia-linked variables), they found that none could be convincingly linked to the presence or absence of a landbridge between Ireland and Britain. Nevertheless, Ireland today still supports an impressive range of Atlantic and amphi-Atlantic species, whose exact mode of arrival remains uncertain.

The importance of much of the biological evidence was put into perspective by **R.J.Devoy** (Cork), who emphasised that landbridges are complex phenomena, the characteristics of which will vary from one element of the biota to another. He went on to demonstrate how neotectonic and glacial modelling have also been used to study landbridges, illustrating both approaches with examples from the Irish Sea. He concluded on a note of caution, however, stressing that in the absence of detailed, empirical data, the resolution of many of these models is still too coarse to resolve the landbridge question. **R.Wingfield** (BGS Nottingham) was more optimistic, showing how a simple, yet robust, model could be used to predict three putative landbridges between Ireland and Britain during the early Holocene. This model, which was based on the isostatic response of the Irish Sea area to changing ice volume during the Late Devensian, was validated by sedimentological and geomorphological data from offshore.

A final area where modelling studies were shown to hold considerable potential was in the field of palaeotidal reconstruction; a subject addressed by **J.D.Scourse** (Bangor) and **R.M.Austin** (IOH Wallingford). By feeding bathymetric data into a shelf-sea tidal model they demonstrated how the changing configuration of the British coastline during the Holocene has had a dramatic effect on tidal range, particularly in the area around the Dover Straits. This supported the point made earlier by **P.L.Gibbard** that once the Straits were breached they would become repeatedly vulnerable to tidal-induced erosion during high sea level stands. The same may well have been true for other important narrows, for example in the Irish Sea during the early Holocene. Tidal modelling techniques were also shown to have many other valuable applications, particularly in reconstructing patterns of sediment movement and water stratification.

Overall the meeting drew out many interesting themes and provided an excellent forum to explore a wide range of Quaternary issues. It became particularly clear that workers in this field must be aware of that critical 'window' of time at the beginning and end of interglacials when climate is sufficiently warm but the sea level is low enough to permit migration across landbridges. The timing and duration of these windows in successive temperate cycles has probably varied quite dramatically with profound consequences for the biota. It also emerged that future research in this field must be integrated, combining further offshore and onshore data collection with impoved correlation and modelling.

Congratulations to Richard Preece for organising such a thought-provoking meeting.

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REPORT OF CONFERENCE ON 'THE UK DURING THE LAST GLACIAL/INTERGLACIAL TRANSITION (14,000-9,000 YEARS BP): A CONTRIBUTION TO IGCP-253' HELD AT ROYAL HOLLOWAY, UNIVERSITY OF LONDON

8th January 1993

This discussion session was convened in order to stimulate participation in IGCP-253, 'Termination of the Pleistocene', which is concerned with global environmental changes during the transition from the last glacial stage to the present interglacial. The aim of the session was to stimulate interest in the idea of a UK community project with the following objectives: (i) synthesis of the available information from the UK for the period concerned; (ii) comparison of results with relevant data from Ireland and the neighbouring seas; (iii) development of multi-disciplinary research projects; and (iv) potential for the construction of an integrated data-base of all relevant palaeoenvironmental information.

Contributions had been invited within one or more of the following categories: (a) synthesis of available data within specific research themes; (b) development of new proxy methods; and (c) assessments of the practical aspects of database construction. Categories a and b were reasonably well covered in the programme, but the main contribution addressing data-base construction (**B. Huntley**, Biological Sciences, Durham: 'The European pollen database') was withdrawn at the last minute due to illness. Not surprisingly, there were also some significant gaps in subject coverage, such as off-shore stratigraphy, mammalian fossil records and archaeological records. Overall, though, a varied and quite comprehensive coverage of important aspects of the transition period was provided, with many new ideas and new directions introduced under the watchful eye of the Chairman, **Professor G.R. Coope** (Geography, Royal Holloway).

Reconstructions of glacier responses to climatic influences during the Loch Lomond Stadial/Holocene transition were examined by **D.I. Benn** (Geography, St. Andrews) and **M. Bennett** (Earth Sciences, Greenwich). Both speakers demonstrated the considerable potential for evaluating the sensitivity of the glaciers that occupied the Scottish Highlands and Islands at that time. **J.M. Gray** (Geography, Queen Mary Westfield) outlined the approaches used and problems encountered in the radiocarbon dating of the Loch Lomond Stadial ice advance and retreat when employing marine shell samples. **C.K. Ballantyne** (Geography, St. Andrews) reviewed the way in which periglacial phenomena

could provide palaeoclimatic data for the Loch Lomond Stadial period, assessing the precision and reliability of different indices. The focus on glacial/periglacial phenomena was then concluded by **J.W. Merritt** (British Geological Survey, Edinburgh), who turned attention to an earlier glacial phase, the Ardersier Readvance, in the Inverness-Moray Firth region.

Reconstructions of sea-level history in Scotland during the Late Devensian and early Holocene were then examined by **C.R. Firth** (Geography, West London Institute of H.E.) and **I. Shennan** (Geography, Durham). Both provided new insights into the ways by which more reliable reconstructions might emerge. Three papers then presented a variety of data from Lateglacial lake sediments in the UK which provide different slants on the climatic history of the period: **M.J.C. Walker** (Geography, Lampeter) on coleopteran and pollen records, **D.H. Keen** (Geography, Coventry) on mollusc assemblages, and **J.J. Lowe** (Geography, Royal Holloway) on inorganic and organic geochemical data. This range of information, for the first time available from a single site, is demonstrating how earlier palaeo-climatic models may have been over-simplified.

The potential for obtaining palaeohydrological information from fluvial successions that accumulated during the last glacial/interglacial transition, a hitherto much under-exploited proxy record, was admirably illustrated by **P.E.F. Collins** (P.R.I.S., Reading) and **J. Rose** (Geography, Royal Holloway). **T.C. Atkinson** (Environmental Sciences, UEA) then evaluated the basis and reliability of the Mutual Climatic Range method as applied to coleopteran records: the audience learned that the method has great potential for use with other climatic proxies. Two late additions to the programme were an examination of the sedimentary evidence for jokülhlaup flows in the Fort Augustus area, Scotland, and the ways by which palaeoflows can be estimated (**A.J. Russell**, Geography, Kingston), and a short up-date on the use of tephra deposits in the dating and correlation of Lateglacial sequences (**J. Hunt**, Geology and Geophysics, Edinburgh).

The meeting clearly demonstrated just how rapidly new information was accumulating, across a very broad multi-disciplinary front. The integration of this information is the key to improving models of the palaeo-environmental history of the period. The final part of the meeting was devoted to a discussion of the potential for developing a UK community structure to set up an integrated data-base to handle this information. It was agreed to arrange future meetings, under the aegis of the Quaternary Research Association, to explore this further.

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REVIEW

HIGH LODGE: EXCAVATIONS BY G. de G. SIEVEKING 1962-68 and J. COOK 1988

Edited by N.M. Ashton, J. Cook, S.G. Lewis and J.Rose
Published for the Trustees of the British Museum, 1992
ISBN 0-7141-13697 Price £65.00

This publication has been long awaited and is a pleasure to behold. The QRA visited High Lodge on 17th April 1973 during its memorable Clacton Excursion and Charles Turner summed up the points of controversy:

1. Is the upper boulder clay *in situ* or not?
2. Are the underlying beds *in situ* or not? (These contain the archaeological assemblages).
3. Are the lower beds *in situ* or have they been moved?

The answers given in this monograph of the site are:

1. The archaeological assemblage is contained within sediments which were deposited probably in a low-energy overbank fluvial or lacustrine environment, on a river floodplain receiving inputs of clays, silts, sands and occasional gravel clasts from Triassic mudstones, sandstones and pebble beds from Midland England.
2. These sediments were subsequently transported by glacier ice and deformed by the applied shear stress from the ice sheet during the deposition of the Mildenhall lower diamicton.
3. On lithological grounds the Mildenhall lower diamicton should be correlated with the Lowestoft Till.
4. The High Lodge clayey-silts and the flora, fauna and archaeological assemblage contained within the sediments, are of pre-Anglian age.

To this can be added that the river in question is considered to be one which had its source in the Midlands and the 'upper boulder clay' was transported down a slope on to the underlying beds. These conclusions, so pertinent to the age of the archaeological assemblages, are supported by several short but clear papers by Rose, Lewis, Francis, Davies and Hunt. There follow papers pertaining to the environmental aspects: charcoal (Cartwright); insects (Coope); and mammals (Stuart). The remainder of the volume is devoted to the flint industries. After years of controversy it is a formidable achievement to have all this to hand, in such a handsome volume, and congratulations must be given to the contributors, the excavators and the publishers.

All but one of the contributors are members of the QRA. When the project was initiated at least half of the contributors were only just about born or still at school, neither aware of what lithology meant nor yet recognised their first bulb of percussion. The others have puzzled over the site for nearly 30 years. One is sadly dead. The QRA did not then exist and Palaeolithic archaeology was to some extent in the doldrums of typology, and Quaternary geology was only just becoming respectable. Little wonder that Gale Sieveking's brave attempt to unravel the complex stratigraphy met with such problems, and we have Jill Cook and her colleagues to thank for their final efforts at resolving them. The new excavations were also visited by the QRA during the Central East Anglia excursion in 1991.

The 1963-68 Bed designations (A, B1, B2, C1 etc) have been replaced by descriptive terminology (Lower diamicton, Clayey-silts, Sands and gravels etc) and these are used throughout the various papers, although not in the archaeological sections as the former designations applied specifically to the artifacts. The plans, sections, diagrams and flint artifact drawings which profusely illustrate the volume are, without exception, all of a very high standard, even if one has to pay £65 for it. I am surprised to see the fine section drawings duplicated in Rose's paper and in Lewis's one on the stratigraphy. Perhaps the idea was that offprints of the individual papers would be near meaningless without them.

Much of the volume is understandably taken up with descriptions of the two archaeological assemblages. Ashton and McNabb have dealt separately with the Old Collections mainly collected between 1870 and the 1920's, the material excavated by Sieveking in the 1960's, and a smaller quantity of material found during the 1988 excavations. The famous High Lodge Industry of elegant scrapers comes from within the clayey-silts with a little eroded into the silty sands, lag gravels and contorted sands above. In spite of the refinement of the workmanship and their resemblance to much later Mousterian material, which has caused so much difference of opinion in the past, the scrapers are now dated to a pre-Anglian or 'Cromerian Stage'. The elegant ovate hand-axes in the Sands and gravels above are thus likely to be Anglian or earlier. Much of this flintwork has already been described by Coulson (1990) with the same illustrations as in this volume, but the standard of reproduction was much inferior and their contexts unrelated to the new stratigraphical sequence. They are superb flint drawings in the finest tradition of C.O. Waterhouse and fully justify the high quality printing and paper in the new volume. Of particular interest is the description of the techniques used to detach flakes from cores for the flake industry, with illustrations of refitted material to demonstrate five ways in which this was done, referred to as core episodes. Refitting exercises

are sometimes criticised as being of very limited value in proportion to the time and labour involved in executing them. Certainly not so in this instance, and especially informative when refits are able to demonstrate the derivation of material from one sedimentary unit to another, as has been done at High Lodge. Over 240 artifacts are illustrated, including hand-axes from the old collections found in the sands and gravels. They are printed at two thirds actual size and my only complaint is that there are no bar scales so that the slides I make of some of them will have nothing to indicate their size.

Coulson was primarily concerned with typology and not using the term 'Middle Palaeolithic' in a temporal sense, whereas Ashton and McNabb are at pains to point out that it is not tenable to link the similarity of an artifact assemblage or particular characteristic with the movement of people. Except in the very broadest of terms, there are no temporal indicators (*e.g.* hand-axes were not made in the Upper Palaeolithic, core technology as found at High Lodge can be found in Clactonian, Acheulian and almost any other industry) and by the Middle Pleistocene flint industries consisted of variations of a somewhat limited repertoire of tool types and techniques and there is certainly a danger in correlating similarities with either time or people or both. Most, if not all, archaeologists would now agree with this. High Lodge is a classic example of past misinterpretation based on such concepts and it is good that this report should emphasise it, but it is something of an exaggeration to state (page 165) that 'recent work on High Lodge has destroyed this traditional framework' (*i.e.* a framework based on similarities of assemblages). I thought this had been done already. After all, Roe (1981, 66) is pointing out that 'there are many reasons which have nothing to do with passing time or why lithic industries should exhibit marked variation: that they were made to accomplish different tasks is merely one of the obvious.' Admittedly, it would seem that Roe still hankers after something more in the old traditional manner for (on page 270) he blames the lack of clear dating that 'causes the picture to show bewildering variety rather than an orderly and predictable pattern of variation.' This is in respect of hand-axe groups, the existence of which he was able to demonstrate by metrical analysis. I share his feelings but must face reality, as he does. The concept of neat, unilinear, progressive evolution of stone tools throughout the Pleistocene, so dominant until the 1950's, has long been abandoned. The East African evidence is enough to demolish it, with the Developed Oldowan and Acheulian running side by side up through Beds II and III at Olduvai, and no one would presumably see any correlation between the scrapers of High Lodge and those found on the Plain of Gadeb which must be at least half a million years earlier, except in the technology of their manufacture. Nor do Ashton and McNabb but it is something of an imposition to be told that we need 'to

reconsider several long-held and cherished beliefs,' when we already have done so. I even spotted a comment by the great Prestwich recently that 'there were rude and badly made specimens of all ages.' Taken with Sollas pointing out that in his opinion the brickearths of High Lodge had been moved by ice, we seem to have turned something of a circle! There are also some errors or misjudgements concerning Hoxne and Clacton. There were 75 scrapers in the Upper Industry at Hoxne (not 12, page 167) and eight hand-axes (not two). As for the hand-axes with the Clactonian Industry at Lion Point, they are derived. A few miles up the coast from Clacton is Stone Point, with several hand-axes and Levallois flakes found at beach level. The hand-axe allegedly from the Lower Gravel at Swanscombe is probably out of the Middle Gravel. Not that it would make much difference for it is derived and we know from Boxgrove and elsewhere that hand-axes were being made in southern England before or at the end of the Anglian Stage. There were also three flakes from the Clacton Golf Course site, *in situ*, that could be hand-axe thinning flakes. This does not make hand-axes part of the Clactonian industry at that site. However, there is more to variation than different tool technologies: variation is the very essence of human evolution, cultural or physical, and the lithic litter we excavate is an expression of numerous factors: function, availability of raw material, individual ability, immediate circumstances and a repertoire of inherited lithic skills passed on from one generation to another. Archaeology can do little to identify anything but the last, but this should not be underestimated. Our hopes rise as sites like High Lodge are discovered, excavated and put into their context by a team of specialists, such as has been done in this volume.

There is a concise introduction to the history of the site by Ashton. There is not a single photographic plate and, although section drawings are much clearer and photographs of them somewhat irrelevant, pictures of the place (especially as a brickyard, if any exist) and of the past worthies who worked there, would have been good to see. It is such a fine volume that any criticism seems churlish. Summaries are appended in German and French. This is a major contribution to British Palaeolithic archaeology and the Quaternary of East Anglia.

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J.J. Wymer

THE COAST OF AVON

Edited by P.R. Crowther
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While entitled The Coast of Avon, the edited papers contained within this volume address somewhat larger spatial area than that defined by the boundaries of the modern County of Avon. The focus is, however, undeniably orientated strongly towards the coast. The invited authors are most successful in elucidating a broad range of coastal perspectives within a neatly presented, compact issue. Each contributor is a respected authority within those fields with which the book is concerned. Articles are well presented with plentiful maps, diagrams and illustrations.

The 'Geology of the Coast of Avon' is discussed by A.B. Hawkins, who sets the physical context within which those unfamiliar with the area may interpret later articles. He describes the Variscan structures and Permo-Triassic valley systems which underlie the Pleistocene deposits of the coastal zone. Here, alluvial sediments produced by the Flandrian sea-level rise in the post-Devensian period are described in the context of their engineering significance, as well as their palaeoenvironmental role in coastal development. The themes introduced in the opening paper are developed by J.R.L.Allen in the second contribution where he discusses the 'Postglacial Geology and Geoarchaeology of the Avon Wetlands'. The wetland environments are described as originating in the period of Holocene sedimentation of coastal valleys, resulting from a marine transgressive phase which continues through to the present day. Allen sets out to give coherence to existing knowledge of the Severn Estuary through the Postglacial period. In this objective he is quite successful, providing a stimulating blend of discussion of environmental principles which are then explained and illustrated by aspects of the Avon coastal sites.

The third paper contained in this volume is 'A History of *Spartina* on the Avon Coast' by M.H. Martin. The role of *Spartina anglica* (cord-grass) as an agent of stabilisation in unconsolidated estuarine sediments is discussed, as well as its ability to counteract erosion of intertidal deposits in threatened areas. Coastal zone management as well as the natural spread of *Spartina* are seen as the reason for the success of this plant throughout England and Wales. The

paper deals with the origin and taxonomy of *Spartina anglica* along with its history on the Avon coast. The depletion in the diversity of vegetation and bird-life is thought to be ascribable to the success of the species. The conflict between management necessities on coasts and nature conservation is considered, as well as the ecological controls which maintain the success of this vigorous plant.

The evolution of salt marsh flora is the topic addressed by A.J. Willis in an article entitled 'The Development and Vegetational History of Berrow Salt Marsh'. Looking at sites between Berrow and Burnham-on-Sea, Willis traces the history of vegetation from the initial colonisation of mud flats through to present salt marsh assemblages. The early emergence of *Puccinellia maritima* along with *Salicornia* is discussed, as well as the progression through to *Scirpus maritimus* / *Spartina* domination in the 1930s and 1940s. By the 1960s a rich salt marsh vegetation is in evidence. However, the subsequent spread of *Phragmites australis* has been responsible for a considerable loss of species diversity. An evaluation of both topographic and ecological controls on salt marsh succession makes a valuable contribution to the study of peritidal environments. A useful index of taxonomic nomenclature rounds off a worthwhile paper.

The intriguing ecological diversity of diatoms has fascinated many researchers interested in indicator species. In the article 'The Mudflat Ecosystem and Epipelic Diatoms', D.M. Paterson and G.J.C. Underwood examine the life form and ecology of these inhabitants of intertidal sediments. The seasonal distribution and abundance of various epipelic diatom species is presented. In concluding that the 'high shore sites' show a marked variation in species composition seasonally while 'low shore sites' do not, the authors introduce another fascinating aspect of diatom research. This article will be of interest to many researchers with interests spanning the coastal sciences.

The 'Animals of the Severn Estuary Salt Marshes' is discussed by C. Little in the sixth article of this collection. The special plant communities and invertebrate animal populations form the focus of this presentation. Though not immediately apparent, the nature of ecological assemblages found along the Severn Estuary is complex, involving specialist communities tolerant of salinity extremes and frequent inundations of sea-water. The author sets out to fill a perceived gap in salt marsh fauna documentation in Britain. The extent to which this article achieves that objective is open to debate. However, discussion of the amphipod *Orchestia gammerellus*, the pulmonate snail *Ovatella myosotis*, insects, spiders and broader ecological principles of salt marsh environments provides a

dimension without which this issue would be the poorer. An index for the identification of salt marsh animals is a useful bonus.

The penultimate article is provided by H.E. Rose who describes 'The Birds of the Avon Shore'. A breadth of approach which incorporates the study of mudflats, shingle, shandy and rocky environments is successful in providing an overview of bird population composition. The ornithology of the Avon shore is reviewed with particular reference to sea-birds (mainly gulls), wildfowl, waders and (to a lesser extent) land birds. This article is a significant addition to ornithological indexing for the area as well as a contribution to the ecological thrust of the volume as a whole.

Finally, M.H. Martina and C.L. Beckett assess Heavy Metal Pollution in the Severn Estuary. The estuary is described as containing solid and semi-solid industrial, commercial and domestic wastes. Contributing sources of such wastes are reviewed, as is the 'flushing period' of the Severn Estuary. The article concentrates on salt marshes and rocky shores as areas of pollution impact. In the Avonmouth salt marshes, the coincidence of the invasion of *Spartina* and the Avonmouth smelting industry has led to the accretion of heavily contaminated upper sedimentary layers. Along the rocky shores heavy metal concentrations are evident in the food chain. In particular, values for zinc and cadmium are considered high. The authors conclude probable detrimental effects on species at the top of the food chain, but indicate difficulty in ascribing definite cause-effect relationships between metal pollution and survival of individuals in the harsh estuarine environment.

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ABSTRACTS

FORMATION, DEPOSITIONAL HISTORY AND MAGNETIC PROPERTIES OF LOESSIC SILT FROM THE TIBETAN FRONT, CHINA

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ABSTRACT

The source of the constituent silt particles of the central Chinese Loess Plateau has long been considered to be the gobi and sand deserts to the north and northwest. This thesis describes the relationship between sediments from the highly active mountain environments associated with the Tibetan Plateau and the sediments of the Loess Plateau around Lanzhou. Particle size and rare earth element (REE) geochemistry indicate that the source of the Dawan loess is similar to that of silt from the Kunlun Pass, Tibet. Both sediments have REE patterns steeper than those of the crustal average. Loess found in the A'nyêmagen foothills, at Labrang, has a separate source from the Loess Plateau deposits and was probably formed within the local mountain environment.

Magnetic fabric studies have shown that loess-palaeosol sequences around Lanzhou retain a primary aeolian wind-orientated fabric probably associated with the Mongolian high pressure system. Secondary fabrics associated with slope processes are also evident. Labrang loess was found to have a primary aeolian isotropic fabric. High foliation values obtained from loessic alluvium from Sala Shan, indicating a water redeposited fabric, were not obtained from the other sites suggesting that they are of aeolian origin.

Magnetic mineralogical studies of the sediments show that the dominant mineral is cation-deficient (CD) magnetite, indicative of an oxidising environment. Loess deposits appear to contain coarse grained CD magnetite of predominantly detrital origin whilst palaeosols contain ultrafine grained CD magnetite of pedogenetic origin. Magnetostratigraphy of short sections from the Dawan and Jiuzhoutai profiles show no evidence for excursions or reversals.

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THE QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE AREA BETWEEN NEWARK AND LINCOLN

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ABSTRACT

Four altitudinally distinct sand and gravel bodies between Newark and Lincoln provide evidence of major drainage diversion during the Quaternary. In order of decreasing altitude they are: the Eagle Moor, Balderton, Fulbeck, and Floodplain Sand and Gravel. In addition a new deposit, the Skellingthorpe Clay is recognised.

The Eagle Moor Sand and Gravel is interpreted as a cold stage proximal braided river deposit of Anglian age, aggraded by a mixture of waters from a meltwater enriched River Trent and direct outwash from a glacial snout. Beneath the Eagle Moor Sand and Gravel, close to Lincoln, is the Skellingthorpe Clay which is interpreted as a proglacial lake deposit also of Anglian age.

The Balderton Sand and Gravel is interpreted as a proximal braided river deposit aggraded during diversion of the Trent through the Lincoln Gap by Wolstonian ice occupying the Lower Trent Valley.

The Fulbeck Sand and Gravel is a composite deposit aggraded by a stream entering the Lincoln area from the south. It is composed of warm stage Ipswichian sediments deposited probably in a meandering river, though to early Devensian cool interstadial sediments, deposited in a single thread channel.

The Floodplain Sand and Gravel contains a variety of depositional environments ranging from basal braided river sediments, deposited during the Devensian cold stage, through to meandering Holocene river sediments.

A new model of drainage evolution for the area is proposed starting from the Early Pleistocene and accepting the hypothesis of easterly flowing master streams draining to the North Sea through the Lincoln and Ancaster Gaps. Anglian glaciation disrupted the drainage pattern and excavated the Trent Trench subglacially. Retreat of ice to the north of Lincoln diverted the Trent towards Lincoln Gap aggrading the Eagle Moor deposit. The onset of temperate conditions (the Hoxnian) allowed the Trent to find a new course across lower

ice scoured terrain to the Humber Estuary. The Wolstonian marked a return to colder conditions and the formation of glacier ice in the Lower Trent Valley diverted the river towards the Lincoln Gap. Melting of this ice mass, associated with climatic amelioration of the Ipswichian, allowed the Trent to resume a course to the Humber Estuary which was probably stable through the Early and Middle Devensian. Development of Late Devensian (Dimlington Stadial) ice north of Lincoln diverted the Trent along the Till Valley and through the Lincoln Gap. Climatic amelioration and removal of ice from the Lower Trent Valley at the end of the Devensian allowed the course to the Humber to be re-established. The Fulbeck River appears to have long history of stability and flowed north to the Lincoln Gap from at least Late Wolstonian to Early Devensian times.

This work indirectly has implications for the stratigraphic framework of Britain. Firstly, the assignment of the Balderton deposit to a pre-Devensian cold stage indicates that it is not associated with Early Devensian ice and the development of a high level 'Lake Humber'. Secondly, the Balderton deposit indicates that for part, if not all, the Wolstonian the area was not affected by major glaciation. This is further substantiated by the lithological signature of the sands and gravels which indicate no new input of exotic material since the Eagle Moor stage (the Anglian).

CENOZOIC GLACIATIONS AND DEGLACIATIONS

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ABSTRACTS

THE SEARCH FOR CONSISTENCY BETWEEN SEVERAL INDICES OF ANTARCTIC CENOZOIC GLACIATION

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Stratigraphic and paleontologic evidence from the Antarctic continent indicates a Cenozoic glacial history of the southern high-latitudes more complex than that suggested by existing interpretations of deep-sea data. Physical evidence from Antarctic drillcores and terrestrial outcrops documents the repeated growth and decay of numerous ice sheets over the last 40 million years. Recycled marine microfossils in the glacigene upper Pliocene Sirius Group and Pagodroma Tillite record periods of repeated Cenozoic deglaciation when marine seas covered vast areas of East Antarctica. This history is consistent with periods of global warmth, high-stands of sea-level, and with oxygen isotope interpretations that accommodate a progressive cooling of the deep-sea through the Cenozoic. Glacial and eustatic variations seen in long drillcores on the Antarctic shelf, such as the Oligocene CIROS-1 in McMurdo Sound, provide a good record of major changes in ice-volume and illustrate the dynamic character of Cenozoic 'temperate to subpolar' ice sheets in Antarctica. Three independent data sets - glacio-eustatic sea-level, benthic foraminiferal oxygen isotopes, and marine biogenic productivity in interior Antarctic seas - are used to infer a history of Antarctic glaciation. We attempt to find an interpretation that is consistent with all of the available evidence. Collectively, these data present a dynamic history of ice-volume change (1 to 3 m.y. frequency), overprinted on a trend of progressive cooling from middle Eocene to today. Initial covariance of eustatic and isotopic data during the late middle Eocene suggest the onset of major glaciation in Antarctica at this time. Direct evidence for (1) significant ice in the early Oligocene and (2) for an early Pliocene deglaciation to -$\frac{1}{3}$ of present ice volume, provides us with the ability

to constrain interpretation of the deep-sea oxygen isotope record. First-order change in Cenozoic eustatic and isotopic records reflects a decreasing rate of sea-floor spreading and progressive deep-sea and polar cooling, respectively. Higher frequency, second-order covariance in the two curves, as well as periodic marine incursion into East Antarctic intracratonic basins, reflects the dynamic history of Cenozoic Antarctic ice sheets that has eluded existing interpretations of deep-sea data. The survival of Antarctica's terrestrial vegetation until the late Pliocene indicates temperatures estimated at least 15°C to 20°C warmer than today for all pre-Pliocene glaciations. This climatic regime lends strong support to the dynamic ice sheet history presented above, by suggesting a 'temperate to subpolar' glacial setting where multiple deglacial/glacial cycles would be expected. The major change in character of Antarctic glaciations from 'temperate' and cyclic to the present 'polar' and permanent is thought to have occurred in the late Pliocene, coincident with other records of global cooling. Much of the oxygen isotope shift at 2.4 Ma could be attributed, not to the onset of Northern Hemisphere glaciation as is widely believed, but to the growth of the present ice sheet in Antarctica, following the early to mid-Pliocene deglaciation. The past dearth of geological evidence in Antarctica enabled the relatively free and unconstrained interpretation of Cenozoic glacial history from deep-sea records. As the volume and quality of paleo-environmental information from Antarctica increases, a considerably more complex history of warmer ice sheets is emerging to replace the simplistic deep-sea view of stable Cenozoic Antarctic ice sheets. Given this view of warmer, more dynamic pre-Pleistocene ice sheets, we need to reassess the validity of assumptions that have guided past interpretations.

INITIATION AND CHARACTER OF THE EARLY ANTARCTIC ICE SHEET

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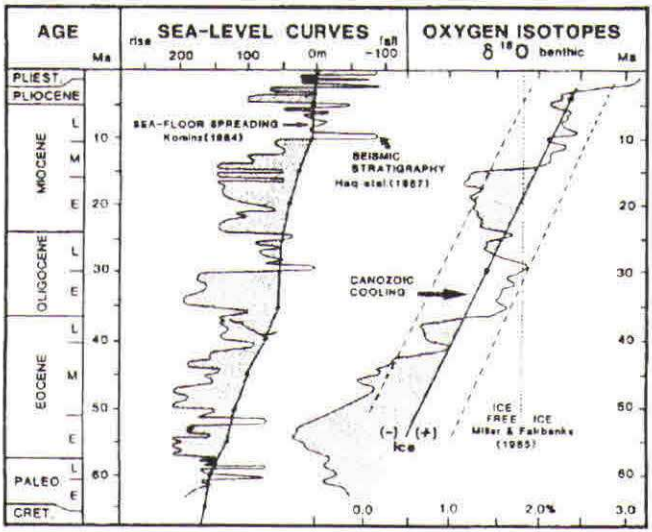
Recent drilling through several hundred metres of sediments on the East Antarctic continental shelf has provided a record of glaciation extending back to at least earliest Oligocene time (36 Ma). In the western Ross Sea the New Zealand drill-hole GROS-1 has yielded an excellent Oligocene-Middle Miocene reference section, whilst in Prydz Bay, in the Indian Ocean sector, ODP Leg 119 has provided a traverse across a glacially-dominated shelf from coast to continental slope. These drill-holes have provided the first direct long-term


AGE
SEA-LEVEL CURVES
rise
fall
200
100
0m
-100
OXYGEN ISOTOPES
δ 18O benthic
Ma
PLIEST.
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEO.
CRET.
SEA-FLOOR SPREADING
Kominz(1984)
SEISMIC
STRATIGRAPHY
Haq etal.(1987)
CANOZOIC
COOLING
ICE
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(1985)
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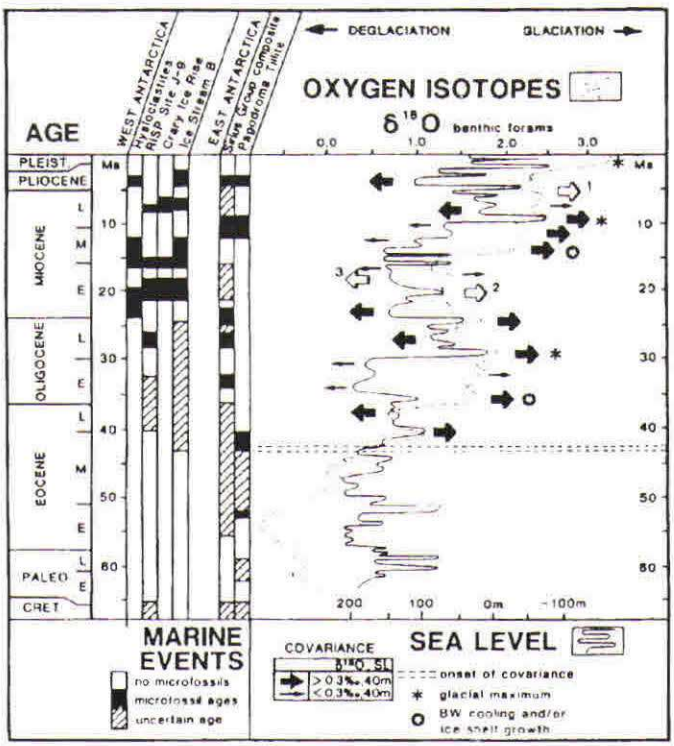
DEGLACIATION
GLACIATION
WEST ANTARCTICA
Hyalosiastites
RISP Site J-9
Clary Ice Rise
Ice Stream B
EAST ANTARCTICA
Sirius Group composite
Pagodroma Tuffite
OXYGEN ISOTOPES
δ 18O benthic forams
AGE
PLEIST.
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEO.
CRET.
Ma
0.0
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3.0
200
100
0m
-100m
MARINE
EVENTS
no microfossils
microfossil ages
uncertain age
COVARIANCE
δ18O SL
> 0.3‰ 40m
< 0.3‰ 40m
SEA LEVEL
onset of covariance
glacial maximum
BW cooling and/or
ice sheet growth

record of glaciation that reflects the early history of the ice sheet as well as supplying data for developing sedimentary models for the growth of the continental shelf. However, despite the longevity of the record, the timing of the onset of glaciation is still an open question. The style of glaciation through and subsequent to the Oligocene Epoch is quite different from the cold ice sheet of today - we envisage a highly dynamic, temperate ice sheet, with associated coastal enclaves bearing vegetation. The transformation to a cold stable ice sheet may not have taken place before the late Pliocene.

AGE OF OLDEST TERTIARY CONTINENTAL GLACIATION ON KING GEORGE ISLAND, SOUTH SHETLAND ISLANDS, ANTARCTICA

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Although the first record of a glacial influence on sedimentation in the South Shetland Islands dates from British investigations in 1949, it was not until the Polish geological work since 1979 that the importance of King George Island to glacial studies was recognised. At least four glacial periods (Krakow, Polonez, Legru and Melville glaciations) have been described and were distinguished by a variety of methods, mainly lithostratigraphical correlations (field mapping) supported by isotopic dating. The oldest glacial period (Krakow Glaciation) is represented by a single small exposure of diamictite containing marine fossils and clasts with a local provenance, and attributed to a small ice cap located on SE King George Island. A minimum Eocene age was obtained by K-Ar dating of an overlying lava (49.4 ± 5 Ma). By contrast, the younger Polonez Glaciation is represented by glacigenic sediments of the Polonez Cove Formation (PCF; part of the Chopin Group), which contain abundant, striated and faceted clasts with a provenance probably rooted in East Antarctica. The presence of likely lodgement tillite as the base of the PCF, and its exotic clast content are strong evidence for a widespread glaciation of continental proportions whose age is of critical importance for models of Antarctic ice sheet development. Previous studies suggested a middle or possibly early Oligocene age, making the PCF the oldest glacial deposit preserved in the Antarctic terrestrial record and the first direct proof of a former Antarctic ice sheet present at low elevations prior to the Miocene. Unfortunately, in common with all fossiliferous glacigenic deposits on King George Island, the sediments contain a fossil fauna with a wide range of reworked forms which make the determination of a precise palaeontological age difficult. Also, although in its type areas a minimum early

Miocene (> 23.6 Ma) age for the PCF is provided by K-Ar ages obtained on overlying lavas and a dyke, these ages were presumed reset using arguments based on lithostratigraphical relationships with supposedly younger sequences further West (the Legru Group, at Martins Head and Cinder Spur), isotopically dated as 29.5 and 30.8 Ma. In its type areas between Lions Rump and Low Head, the local basement to the PCF has been dated at 74 or 42 Ma, although elsewhere a basement correlated with that in the type area yielded ages as young as 34.4 Ma. Thus, an Oligocene age (ca. 30-32 Ma) is generally accepted for the PCF. The purpose of this paper is to review and refine the age of the PCF in its type area where, in contrast to all other outcrops described so far, the PCF is interbedded with coeval lava and lava breccia conducive to isotopic dating.

We have selected samples from the Boy Point Formation (overlying the PCF), the PCF (including the Low Head plug) and a large dyke ("Chopin dyke") which intrudes both the PC and Boy Point formations. Although the Low Head plug was formerly regarded as a much younger intrusion unrelated to the PCF, our field studies indicate a much closer, probably genetic relationship to the basal PCF (the Low Head Member, a basalt breccia). This interpretation was confirmed subsequently using high-precision element- and Sr-Nd isotopic analyses, which demonstrated that both plug and breccia are compositionally indistinguishable. Moreover, one of the two analysed lava samples from the PCF (Oberek Cliff Member) is also compositionally very similar to the Low Head lavas, further implying a close relationship. Using the Ar^{40}/Ar^{39} method, integrated ages for samples from the Boy Point Formation and the Chopin dyke (23.7 ± 1.3 and 21.3 ± 1.7 Ma, respectively) are essentially identical to those previously determined by conventional K-Ar methods (23.6 ± 0.3 and 21.8 ± 0.6 Ma, respectively) a remarkably good agreement. The K-Ar ages were previously interpreted as reset by a thermal event possibly associated with a period of intense hypabyssal activity (the Cape Syrezol Group) represented here by the Chopin dyke. However, despite some scatter at the high temperature end of the spectra, the new Ar^{40}/Ar^{39} data show good plateau ages and the ages are best interpreted as magmatic. The Low Head plug, previously dated as 14.4 ± 1.4 Ma (K-Ar), yielded a new K-Ar age of 21.2 ± 2.1 Ma, indistinguishable within error from a recently published K-Ar age of 22.3 ± 1.4 Ma for the cogenetic basaltic breccia mantling the plug. Although the reliability of the breccia age was said to be questionable, its similarity to the new age for the plug is probably not fortuitous since a provisional Ar^{40}/Ar^{39} age of 24 ± 2 Ma for the plug has just been published by some American workers. Samples of the plug and a basalt flow within the PCF are currently being irradiated for Ar^{40}/Ar^{39} dating, but we anticipate that our results will confirm an early Miocene/latest Oligocene age.

Notwithstanding the presence of plant fossils in a nearby sequence (Mount Wawel Formation) dated by K-Ar as 24.5 Ma, which we believe may be in error and deserves reinvestigation, we suggest that the true depositional age of the PCF and corresponding Polonez Glaciation falls close to the Oligocene-Miocene boundary (i.e. around 26-23 Ma). This revision has important implications, not only for Antarctic ice-sheet development (not further discussed here) but for reinterpreting the local stratigraphy of volcanic and glacigenic strata on King George Island. For example, there may now be a case for assigning to much of the Legru Group an older age than the Chopin Group (a reversal of current ideas). We also note that isotopic ages and field relationships used to infer an early Miocene (ca. 20-22 Ma) age for the Melville Glaciation are remarkably similar to those applied here to the Polonez Glaciation. Moreover, the abundant exotic clasts (dropstones) in the Cape Melville Formation have provenance practically identical to that described for the PCF. These observations suggest that, in the absence of unambiguous field relationships, we should be cautious before accepting that more than one period of continental glaciation is represented on King George Island. Rather, we should await the results of a more rigorous isotopic dating programme, ideally using the Ar^{40}/Ar^{39} method which is generally capable of identifying the detailed post-eruptive thermal history of samples.

THE STATE OF THE ANTARCTIC CRYOSPHERE IN THE EARLY PLIOCENE: EVIDENCE FROM THE SOUTHERN OCEAN

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Before ~3 Ma, during the early Pliocene, ice sheets were unipolar and restricted to Antarctica, and much evidence exists for global warmth in excess of any time since. Did the East and West Antarctic ice sheets resist this early Pliocene interval of warmth or is there evidence of instability of one or both ice sheets? This problem is of central importance in considering potential consequences of global warming resulting from increased atmospheric CO_2 and the greenhouse gas concentrations resulting from human activities.

Three distinctly different scenarios have been proposed for Antarctic cryospheric history during the early Pliocene: relative stability of the ice sheets and minor fluctuations in ice volume including the West Antarctic ice sheet; major destruction of both ice sheets; and enormous growth of the ice sheets, especially that of East Antarctica. The available evidence from the stratigraphic records

in the oceans surrounding Antarctica is largely incompatible with the models that invoke major deglaciation of the ice sheets. The marine oxygen isotopic record from the early Pliocene (4.8 to 3.2 Ma; Hodell and Venz, in press) indicates only slightly warmer climate in the Subantarctic region, and relatively minor deglaciation of the Antarctic cryosphere. The data also indicate relative climatic stability of the cryosphere during this interval, compared with the large scale fluctuations that mark the late Pliocene to Quaternary interval beginning at ~2.7 Ma.

The character of the seawater $^{87}Sr/^{86}Sr$ curve of early Pliocene (4.5 to 2.5 Ma) marine carbonates also seems to be incompatible with a model of major deglaciation and instability of the Antarctic cryosphere. Strontium isotope ratios during this interval exhibit little change, compared with the intervals that preceded and followed, and this is inferred to have resulted from global cryospheric, climatic and sea level stability during the early Pliocene. These data are compatible with a model that suggests an interval of stability of both West and East Antarctic ice sheets prior to the development of the historically unstable Northern Hemisphere ice sheets. The history of turbidite sedimentation in the Weddell and Bellinghausen Abyssal Plains are also compatible with relative stability of the West Antarctic ice sheet since 4.8 Ma.

The patterns of biogenic sediment distribution in the Southern Ocean during the early Pliocene in no way support a model of major warming that must have been associated with any massive deglaciation of Antarctica. Furthermore, the almost complete absence of calcareous biogenic sediments (including calcareous nannofossils) in Antarctic waters during this interval, and the continuing dominance of biogenic siliceous sediments, indicates that surface water temperatures close to Antarctica were similar to those of the present day, although sea ice was less extensive.

These data suggest extreme resistance of the Southern Ocean and Antarctica to temperature change during the late Neogene, even during the significant global warming that marked the early Pliocene, and are in accordance with coupled ocean-atmospheric models (Manabe and Bryan, 1985) that predict continued extreme cold of the Antarctic Ocean and imply stability of the Antarctic ice sheets in the face of significant anthropogenically caused future greenhouse warming.

LATE NEOGENE MARINE AND TERRESTRIAL RECORDS FROM THE NORTHERN AND SOUTHERN HEMISPHERES: IMPLICATIONS FOR PALAEOCLIMATE CHANGE

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A large number of marine and terrestrial records from the Northern and Southern Hemispheres have been analysed in order to produce a quantitative synoptic palaeoclimatic reconstruction at 3 Ma. These time series provide valuable insight into regional aspects of Pliocene palaeoclimate change and aid in the search for causal mechanisms. The mid-Pliocene synoptic reconstruction, combined with GCM experiment results suggest that Pliocene North Atlantic ocean heat transport, and by inference thermohaline circulation, was stronger than modern transports. Preliminary information from the North Pacific and South Atlantic suggests that the 3 Ma warming was not confined to the North Atlantic.

PLIOCENE ANTARCTIC DEGLACIATION AND HIGH-LATITUDE WARMING: SIRIUS GROUP EVIDENCE

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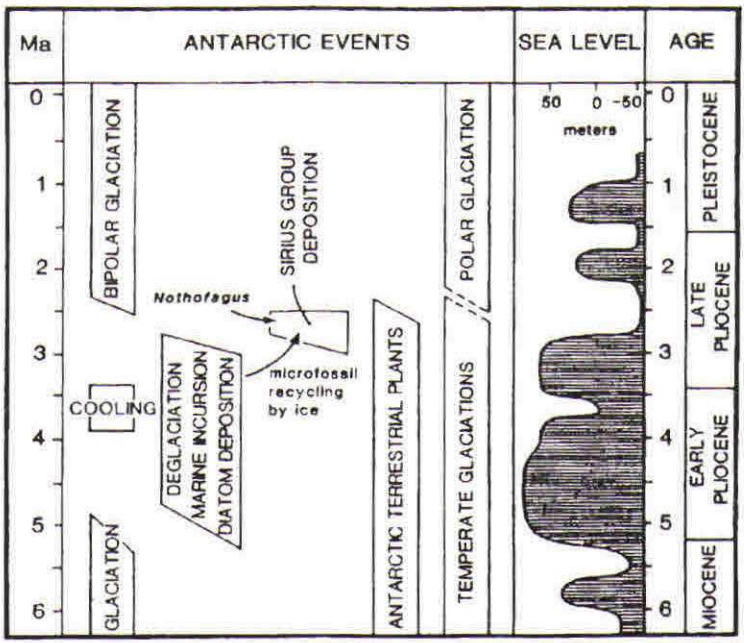
Sirius Group evidence from the Transantarctic Mountains argues for an early to mid-Pliocene Antarctic paleogeography comprising: (1) a greatly diminished, warmer and wetter ice sheet, compared to the present; (2) an extensive austral forest extending almost to the South Pole; (3) relatively warm seas extending into and across broad regions of East and West Antarctica; and (4) a weakly developed seasonal sea-ice belt surrounding the Antarctic continent.

The terrestrial Sirius Group is known at more than fifty localities in the Transantarctic Mountains. Correlatives occur in the northern Prince Charles Mts. (Pagodroma Tillite). All localities lie within 150 km of the Antarctic coastline. Based on the presence of recycled early and mid-Pliocene marine microfossils in the Sirius Group and Pagodroma Tillite, these deposits are dated as late Pliocene. Successions of alternating diamictite, conglomerates, breccias, fluvial sandstones and siltstones, lacustrine sediments and organic-rich subaerial horizons are exposed along the northern flanks of the Dominion Range, upper Beardmore Glacier near 86°S latitude.

In situ roots, stems, and transported wood of the southern beech *Nothofagus* occur at the subaerial exposure-surface contact between diamictites and overlying glacial-fluvial sand and silt units. Dense mats of *Nothofagus* leaves occur in glacial-fluvial sediments associated with one of the wood horizons, and rare leaves also occur in laminated lacustrine sediments. For survival of *Nothofagus*, minimum annual temperatures would not have been below -20°C, and for water availability, growth and reproduction, sustained temperatures above 5°C are necessary for at least 2 to 3 summer months. These temperatures provide a valuable constraint on pre-Pleistocene glaciations, with minimum temperatures at least 15°C to 20°C warmer than at present. The presence of winter deciduous *Nothofagus* in the upper Pliocene sediments of the Sirius Group indicates that Oligocene and Miocene climate in this region, and possibly in all of Antarctica, was never as cold as today's, otherwise vascular vegetation would have been extinguished much earlier. A change from dynamic temperate/subpolar to larger more stable polar ice sheets occurred in the late Pliocene, coincident with other records of global cooling. Post mid-Pliocene uplift (>1000 m) of the Dominion Range, and possibly much of the Transantarctic Mountains, is suggested by the present high elevation (~1800 masl) of the *Nothofagus*-bearing sediments. Uplift of this magnitude may have influenced the rate of onset of late Pliocene global cooling by damming ice sheet flow.



Nearshore marine deposits around Antarctica and recycled marine microfossils of Pliocene age in the Sirius Group and Pagodroma Tillite attest to a major ice-volume decrease and marine incursion into the Wilkes, Pensacola, and Amery subglacial basins between 5 and 3 million years ago. Records of global highstand of sea-level during Pliocene time, and coincident Arctic occurrence of vascular plants at 77°N (Beaufort Formation) and 83°N (Kap Kobenhavn Formation), far north of their present distribution, support the interpretation of warm polar regions and decreased global-ice volume during the Pliocene.

PLIOCENE ICE SYSTEMS IN THE ANTARCTIC: CYCLICITY AND CHRONOLOGY OF FLUCTUATION ICE SHEETS AND EUSTATIC SEA LEVELS

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Glacial deposits in the Transantarctic Mountains and sedimentation at the Antarctic continental margin are direct evidence of Antarctic ice-sheet fluctuation. Evidence for deglaciation from the Transantarctic Mountains (Fig. 1) includes the occurrence of diatom flora in Sirius Group deposits. K/Ar and Ar/Ar dating of a tuff in the CIROS-2 core dates occurrences of these flora in Antarctic interior basins and establishes a chronology of Pliocene deglacial events. Further evidence for Antarctic ice volume fluctuation is recorded by glaciomarine strata from the Ross Sea Sector cored by the CIROS-2 and DVDP-11 drill-holes (Fig. 1). Beryllium-10 provided a high resolution chronology of events in these strata.

In the Wanganui Basin, New Zealand (Fig. 1), a 5 km thick shelf margin sediment wedge, now uplifted, records Pliocene sea level fluctuation. Basin subsidence has kept pace with sedimentation; this allowed eustatic sea level fluctuation to produce a dynamic alternation of highstand, transgressive, and shelf margin systems tracts. This record of Pliocene sea level variation is unequalled in its resolution and detail. Palaeomagnetic stratigraphy provided a high resolution chronology for these sedimentary cycles as well as magnetic tie lines with the Antarctic margin record.

Both these data sets suggest that during much of the Pliocene there was less ice in Antarctica than at present, with growth to slightly larger than present size at 2.5 Ma. However, the Antarctic continent was also ice covered prior to the Pliocene, particularly in the latest Miocene, but not to the same extent as post 2.5 Ma.

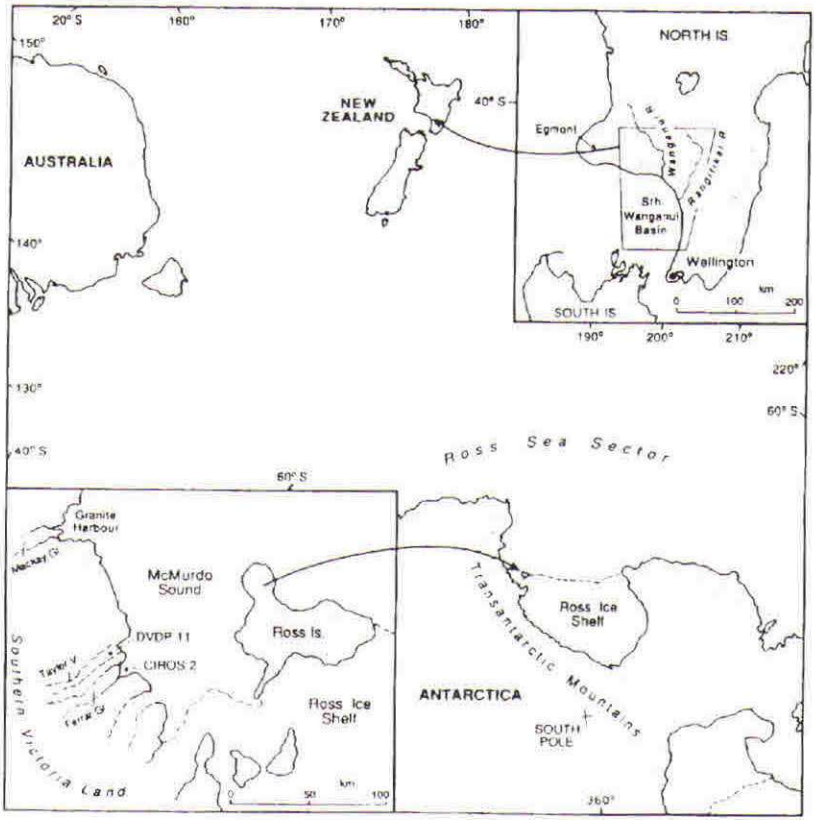

Figure 1. Location of Geologic evidence for Pliocene eustatic sea level variation (South Wanganui Basin, New Zealand) and ice sheet fluctuation (CIROS-2 and DVDP-11 drillholes in southern Victoria Land, and the Transantarctic Mountains, Antarctica).

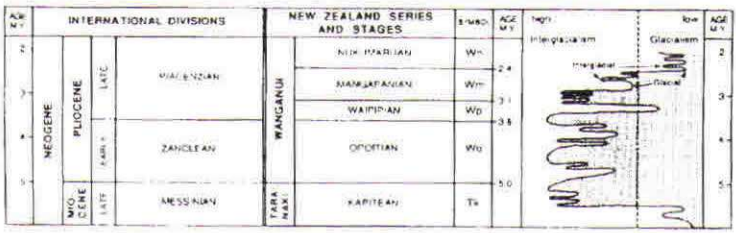

Figure 2. The record of Antarctic ice sheet fluctuation and associated eustatic sea level variation in the Pliocene Epoch.

Decay of major ice sheets (in this case partial deglaciation of the Antarctic ice sheet), raising the baseline for minor sea level fluctuation, is defined here as *interglacialism*. Growth of major ice sheets (in this case reglaciation of the Antarctic ice sheet), lowering the baseline for minor sea level fluctuation, is defined as *glacialism*. Glacial and interglacial periods are defined as minor sea level fluctuations.

From the present study, latest Miocene (pre. 5.5 Ma) and latest Pliocene (post 2.5 Ma) are glacialisms, with a major cooling at 3.3 Ma. The intervening period (5.5 - 2.5 Ma) is an interglacialism (Fig. 2). Glacials and interglacials showing cyclicity on a 600 Ka scale with limited cyclicity on a 100-300 Ka scale, are apparent in periods of both glacialism and interglacialism. Milankovitch cyclicities (100 Ka and shorter) are not apparent in this record until post 2.5 Ma.

A NEW APPROACH FOR DETERMINING PLIOCENE PALEOCLIMATES AND ICE SHEET HISTORY OF EAST ANTARCTICA

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We report the discovery of an *in situ* airfall ash (Arena Valley Ash) from the Dry Valleys region of southern Victoria Land, Antarctica. The preservation, isotopic age, and stratigraphic relationship of the Arena Valley Ash with an underlying *in situ* desert pavement, along with the absence of warm-desert geomorphic features superimposed on nearby unconsolidated deposits, indicate that a cold-desert climate has persisted in Arena Valley since at least 4.3 Ma. Our climatic reconstruction, which implies an enduring East Antarctic Ice Sheet since at least 4.3 Ma, has important implications for postulated Pliocene ice sheet deglaciation from elevated atmospheric temperatures.

There are two widely divergent hypotheses of Pliocene paleoclimate and coeval East Antarctic Ice Sheet dynamics. The first, based on the ecology of warm-water marine diatoms and *Nothofagus* (Southern Beech) wood within glacial deposits (Sirius Group) in the Transantarctic Mountains, postulates atmospheric temperatures 15°C - 20°C above present values, with extensive East Antarctic ice-sheet deglaciation as recently as 3.1 Ma. The second, based predominantly on interpretations of the marine-oxygen isotope record, postulates persistent cold climate and East Antarctic Ice Sheet stability since around 14 Ma. Our new data from the Arena Valley Ash bear directly on Pliocene paleoclimates and coeval East Antarctic ice sheet dynamics subsequent to 4.3 Ma.

LANDSCAPE EVOLUTION IN THE McMURDO DRY VALLEYS AND IMPLICATIONS FOR CENOZOIC GLACIATIONS

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This paper uses the morphology and distribution of landforms and volcanic ash dating to reconstruct the landscape evolution of the McMurdo dry valleys. The main conclusion is that the evolution has followed the normal patterns for a passive continental margin. Following a period of erosion surface development, there was a phase of valley downcutting which accompanied mountain uplift, and this was achieved by a combination of river and glacier activity. The main stages of landscape evolution were completed by the mid-Pliocene. Since then the stable, polar desert climate has preserved landscapes of remarkable age.

MODELLING LATE CENOZOIC ICE SHEETS

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Numerical models of the dynamic behaviour of ice sheets have proved successful in simulating their three-dimensional form and flow and the internal temperature distribution of modern ice sheets. Used in the time-dependent mode, these models can also be used to simulate changes in ice sheet volume, changes in the isostatic response of the lithosphere to loading, and changes in the oceanic isotopic composition as a consequence of ice sheet growth and decay. It is also possible to use them in an inverse mode by reconstructing ice sheet volume and dynamics from the record of mean isotopic composition of the oceans. A series of simulations will be presented in which different scenarios of ice sheet build-up over the last 3 million years are used to generate reconstructions of the ice-sheet volume and extent over the Antarctic, Greenland, North American and Northwest European continents. These simulated histories are then compared with other evidence of Late Cenozoic ice sheet fluctuation.

'ISLAND BRITAIN: A QUATERNARY PERSPECTIVE' ANNUAL DISCUSSION MEETING, UNIVERSITY OF CAMBRIDGE

6-7th January 1993

ABSTRACTS

GLOBAL AND REGIONAL INFLUENCES ON THE (PEN-)INSULARITY OF QUATERNARY BRITAIN

Brian M. Funnell (Norwich)

In the Pliocene Britain was surrounded by warm temperate seas which received limited clastic input, accumulated mainly biogenic sediments, and appear to have allowed free circulation of marine waters between the North Sea and the Atlantic around or across southern Britain.

At the onset of the Quaternary (NW European definition, *c.* 2.6 million years ago), the first major global sea-level falls associated with northern hemisphere glaciation occurred. At approximately the same time associated climatic changes seem to have accelerated the principal rivers flowing into the southern North Sea. The combination of sea-level fall and progressive deltaic progradation into the southern North Sea converted Britain into a European peninsular.

By the Cromerian the delta-top was sufficiently moribund and subject to settlement to allow interglacial sea-levels to encroach southwards across it again. During the subsequent Anglian glaciation impounded glacio-marine waters may well have escaped southwards, across the delta top and the bounding Dover-Calais Chalk ridge into the English Channel.

Subsequently that connection between the North Sea and the English Channel (Atlantic) has been alternately established and broken, as sea-level rose and fell synchronously with interglacial and glacial periods, cyclically converting Britain from island to peninsula and back.

GEOLOGICAL EVIDENCE FOR THE PALAEOGEOGRAPHY OF THE CENTRAL AND NORTHERN NORTH SEA

D. Long (British Geological Survey, Edinburgh)

Seismic and sample data collected by BGS as part of the offshore regional survey indicates substantial fluctuations in North Sea environments during the Quaternary. However, the size and abundance of recovered material restricts environmental interpretation and permits a greater degree of speculation than from onshore sites. Some samples indicate that near the Plio-Pleistocene boundary the northern North Sea was narrower and shallower than at present. The current seismo-stratigraphic interpretation suggest that for long periods of the Middle and Late Pleistocene large parts of the North Sea were dry and that the land we now know as Britain was just an ice covered upland area on the edge of a vast flat tundra plain. The greatest detail is known from the last glacial period when it is believed that extensive tracts of the northern North Sea were exposed with several large shallow basins which received meltwaters from much of the north European river systems. The subsequent marine transgression may have been so rapid that coastal environments could not develop sufficiently to be preserved in the geological record. For example, the relative flatness of the North Sea contrasts with the Norwegian Trench where beaches are preserved but are absent at equivalent position on the North Sea Plateau.

ISLAND BRITAIN: ONLY A 10 TO 12 PERCENT TRUTH DURING THE QUATERNARY PERIOD - THE GEOLOGICAL EVIDENCE FROM THE NORTH SEA BASIN, AND ITS POTENTIAL CONSEQUENCES FOR DISTRIBUTION OF BIOTAS

D.H. Jeffery (British Geological Survey, Keyworth)

Even when different definitions of the beginning of the Quaternary period (*ca.* 1.6 Ma or 2.4 Ma) are adopted, Britain has been completely separated from the European mainland for only a small portion of Quaternary time. BGS/RGD seismic-profile interpretation and borehole data, largely unpublished, demonstrate that not only did the Lower and Middle Pleistocene deltaic deposits of the Low Countries expand enormously in area, such that a single continuous landmass ('Ur-Frisia') was created across the North Sea Basin, but also that the growth of this new delta lowland was largely independent of climatic oscillations and unaffected by regional transgressions or regressions.

At *ca.* 0.4 Ma, however, Ur-Frisia was destroyed by the late Cromerian Complex transgression, which converted much of the delta land surface into a shallow sea of similar size to today's North Sea. Since then, successive seas have occupied more or less the same area during the warmest parts of interglacial intervals but may have become generally deeper through time. Degree of insularity of Britain, and water temperature and tidal régimes in the seas have probably varied according to whether or not there has been a southern connection to the Atlantic Ocean *via* the English Channel. During glacial intervals, the ancestral North Seas shrank or disappeared altogether from much of the basin. Thus, as a heat sink (affecting ambient climate in the basin), and as a physical barrier or passageway to faunal and floral migration during interglacials, the North Sea and its ancestors have occupied a variety of geographical roles throughout Quaternary time. These roles, particularly during interglacial intervals, need to be considered in assessment of preserved terrestrial biotas.

FORMATION OF THE DOVER STRAIT

P.L. Gibbard (University of Cambridge)

The surface of the Channel is underlain by a thin sheet of mobile sediment, beneath which bedrock, predominantly of Mesozoic age occurs. Cut into this bedrock is a complex anastomosing system of narrow valleys or channels, many of which are filled by sand, gravel and clay. These valleys are interlinked to form a drowned drainage system and are thought to have originated by combined fluvial processes and tidal scour. The valleys can also be linked to present rivers that enter the Channel on both the British and French sides. A central (Lobourg) valley can be traced to the Dover Strait. The age of this system is not known precisely but probably dates from the early Middle Pleistocene.

Considerable evidence suggests that the Dover Straits did not exist throughout most of the Pleistocene. Instead a Chalk barrier was formed by the Weald-Artois anticline. Advance of the continental ice sheet across the North Sea in the Anglian-Elsterian Stage apparently dammed the southern part of the basin and therefore water discharging into it would have been prevented from reaching the Atlantic to the north. The resulting lake appears to have drained by overspilling through the Dover Straits area. This is supported by the occurrence of sediments at Wissant, France.

Overflow from the lake was interpreted by Smith as having been catastrophic. This he invoked to explain the apparent similarity of the Channel floor valley pattern to that formed during a catastrophic outburst in NW USA. However, although the initial overflow might almost certainly have been 'catastrophic', it is highly probable that the modern valley system is multigenetic, resulting from repeated fluvial and marine erosion and deposition rather than representing a single, short-lived event.

Once formed, the rivers of central western Europe seem to have repeatedly flowed through the Dover Strait and into the Channel river system during periods of low eustatic sea level, whilst the narrows seem to have been progressively enlarged by marine tidal scour during high sea level periods.

PALAEOCEANOGRAPHIC AND PALAEOTIDAL IMPLICATIONS OF OPENING AND CLOSURE OF THE STRAITS OF DOVER

J.D.Scourse (UCNW, Bangor) and R.M. Austin (Institute of Hydrology, Wallingford)

A numerical tidal model of the M2 tide on the NW European continental shelf has been used to examine the effects of opening and closure of the Straits of Dover on tidal elevation amplitudes, sand transport paths and the position of tide-generated fronts in the English Channel and North Sea. Bathymetric and coastline change inputs to the model based on geological evidence have been chosen for two Quaternary timeslices: the Holocene and Middle Pleistocene interglacial phases. For the Holocene uniform depth changes of the order of eustatic variation simulate conditions between 9000 and 5000BP during which time the Straits of Dover became re-established. The Southern Bight of the North Sea develops from a quiet, shallow sea with low tidal amplitudes (<0.5m) to the present state of vigorous tidal action with coastal amplitudes around 2m. For the Middle Pleistocene the bathymetric input incorporates a subtraction for tectonic uplift recently established for the central English Channel, and the model has been run with the Straits of Dover closed and open. Both runs indicate the presence of stratified water in the English Channel unlike the present tidally-mixed condition, but with an increase in the extent of stratification with the Straits open. This is supported by coccolith data from early Middle Pleistocene marine interglacial deposits in the English Channel which indicate the presence of stratified water at this time.

SEA LEVELS IN THE STRAITS OF DOVER DURING THE MIDDLE AND LATE PLEISTOCENE AND THEIR BEARING ON THE ISOLATION OF THE BRITISH ISLES

D.H. Keen (Coventry University)

The level of the sea in the Straits of Dover is the key to the isolation of the British Isles. Prior to the excavation of the Straits, which occurred in Middle Pleistocene times, it is likely that a continuous chalk ridge extended from Kent to Picardie thus allowing free movement of fauna and flora from Britain to the rest of Europe. The cutting of the Straits was probably by the agency of glacial meltwater during the Anglian glaciation, although the exact time of separation is uncertain due to the lack of sites close to the Straits which can be adequately dated.

Problems are particularly posed by the site of Swanscombe (Kent), conventionally dated to the Hoxnian and thus post-dating the cutting of the Straits. This site has, however, elements of its mollusc fauna unlike those of other Hoxnian sites in East Anglia, and although Swanscombe is in the 'new' post-Anglian course of the Thames, an age prior to that of the type-Hoxnian may be a possibility. The exotic Mollusca at Swanscombe may therefore indicate continuing connection between Kent and Picardie even after the Anglian excavation of the Straits.

Whatever the age of the cutting of the Straits, each temperate stage following separation allowed their flooding and the faunal and floral isolation of the British Isles. Evidence from the sea levels of the Ipswichian/Eemian along the coasts of the English Channel suggests a period of isolation which lasted for much of this temperate stage and allowed connection to the rest of Europe only late in Stage 5 or early in Stage 4.

BRITAIN AND SCANDINAVIA: COMPARATIVE ICE-SHEET HISTORY

D.Q. Bowen (UW, Aberystwyth)

After allowing for the geochronometric imprecision in constraining the timing and extent of the Scandinavian and British ice-sheets, an attempt is made to compare the relative history of advance and retreat during the Middle and Late Pleistocene. Provisional data shows that, in terms of relative ice-volume, the Scandinavian and British ice-sheets were not always in phase during the ice ages of the Middle and Late Pleistocene. The probable causes of this will be explored.

THE PLEISTOCENE EVOLUTION OF THE THAMES AND RHINE DRAINAGE SYSTEMS IN THE SOUTHERN NORTH SEA BASIN

D.R.Bridgland (Darlington) and B. D'Olier (formerly City of London Polytechnic)

During most of the Middle and Upper Pleistocene, sea level has been very much lower than at present and the southern North Sea has been dry land, drained by the same rivers that today issue into the sea from Britain and North-West Europe. Evidence from onshore in Britain suggests that the Thames did not drain into the Southern North Sea Basin until the early Middle Pleistocene; prior to that it flowed across East Anglia and northwards across the area of the present North Norfolk coast. It is thought that the lowland between East Anglia and the Continent was at this time drained by the 'Lobourg River' which arose on the northern flanks of the Wealden ridge and drained northwards into what is now the southern North Sea. The early Medway is thought to have joined this Lobourg River in the area that now lies offshore from south-east Suffolk. It seems that by the early Middle Pleistocene the Thames had adopted the former course of the Medway and thus flowed into the Lobourg valley.

It is widely believed that Anglian/Elsterian ice sheets caused proglacial ponding in the southern North Sea basin and that a large lake formed, fed by the Thames and Rhine river systems. It has also been suggested that this lake overflowed to the south-west into the English Channel basin, breaching the Chalk ridge and initiating a through route via the Straits of Dover, a route that was used by the Rhine-Thames drainage system during all subsequent low-sea-level episodes. Middle and Upper Pleistocene deposits of both the Thames and Rhine systems are preserved in the areas immediately offshore from Britain, Holland and Belgium and can be traced from both sides towards the central valley - the drowned Lobourg valley. Although the Rhine deposits, in particular, appear to follow a route that heads southwards, towards the Straits of Dover, there are no surviving sediments that demonstrate a Late Pleistocene fluvial course either through these Straits or, conversely, into the North Sea.

A comparison of the elevations of the fluvial sediments on both sides of the North Sea with the longitudinal profiles of the floor of the Dover Strait and the drowned Lobourg valley raises doubts about whether the Rhine-Thames system can have occupied the southern route during the last glacial. The sub-drift surface and the sea-floor at the present time slope from south to north, from the Straits of Dover (height -55m O.D.) towards the North Sea (below -60m), implying that any future decline in sea-level comparable with those characteristic of previous cold episodes will result in the extension of Rhine and Thames

drainage into the North Sea basin, not into the English Channel. Moreover, if these rivers flowed into the English Channel during the last glacial, it is necessary to invoke considerable differential subsidence/uplift of Flandrian age.

EXTENSION OF THE BRITISH LANDMASS: EVIDENCE FROM SHELF SEDIMENT BODIES

Andrew Bellamy (University of Reading)

Mapping and interpretation of high resolution shallow seismic and vibrocore sample data for the infilled valley of Owers Bank, at -20m to -40m C.D., eastern English Channel, indicates sediment body formation by multiple cut and fill events. Interpretation suggests these occurred in a combination of diachronous gravel bed river, estuarine and peat bog environments with subsequent marine planation (forming ravinement surfaces) and formation of a sea bed veneer. These environments are associated with cyclic, large scale sea level and (inferred) climatic changes forcing land-shelf subaerial integration during cold stages, repeatedly interrupted by interglacial shelf submergence.

A model of sediment body evolution off the south coast of England, based on the Owers Bank findings, shows that subaerial and not submarine processes have dominated sedimentary history within present-day submerged, infilled valleys. Interfluves are possibly associated with subaerial condensed sequences, removed or reworked by marine processes during transgressions.

Relative to the Quaternary as a whole, global ice volumes are presently unusually low (as indicated by the deep ocean oxygen isotope signal), implying that present eustatic sea levels are unusually high. Subaerial integration of present-day southern England with the adjacent inner shelf has therefore persisted for most of Quaternary time with the notion of 'Island Britain' applicable to only a relatively small part of the Period.

MOLLUSCAN EVIDENCE RELATING TO THE INSULARITY OF THE BRITISH ISLES

T. Meijer (RGD Haarlem) and R.C. Preece (University of Cambridge)

Molluscs are a group of organisms well suited to answer the critical question of when Britain was (and when it was not) an island. In the first place they occur in all the three critical environments, on land, in freshwater and in the sea.

Second, unlike insects, they cannot fly and unlike pollen they cannot be blown great distances across water (at least in areas not subject to hurricanes). The critical taxa in this debate are the southern marine molluscs, the fluvial prosobranchs and certain land snails of closed forest.

The marine faunas of the Dutch Middle Tiglian, Eemian and Holocene are diverse both in terms of species numbers and biogeographical composition. In contrast, those from temperate stages from the Late Tiglian up to and including the Holsteinian are restricted to a mere 20 or so taxa, which include no southern species. In the Late Tiglian, 'Cromerian' and Holsteinian, there is evidence of fluvial exchange and in the Holsteinian, there is also evidence that a distinct community of land snails (with *Lyrodiscus*) occurred over large areas of NW Europe. These facts indicate that Britain was not isolated during temperate stages between the Late Tiglian and Holsteinian but that it was insular during previous and subsequent stages.

INSULARITY AND THE QUATERNARY TREE FLORA OF THE BRITISH ISLES

K.D. Bennett (University of Cambridge)

Holocene forest histories are now available from most of the larger islands in the archipelago of the British Isles. The islands were isolated from Great Britain, and Great Britain from the continent, at different times relative to the arrival times of the trees. This provides an opportunity to assess the dispersal abilities of the members of the Holocene tree flora, and hence the significance of sea-crossings as barriers to dispersal. Most species that have crossed stretches of sea appear to have done so with no delay, and there is no evidence to suggest that dispersal across distances of tens of kilometres is a limiting factor in controlling distribution limits. These findings will be discussed in the light of evidence about the timing of the origin of the Straits of Dover for interglacial tree floras.

FORESTS AND FORAGERS: WAS BRITAIN PERMANENTLY OCCUPIED DURING THE LATEGLACIAL INTERSTADIAL?

R.N.E. Barton (St David's University College, Lampeter)

In this paper I review the currently available evidence for human presence in the British Isles during the Devensian Lateglacial Interstadial, covering the

period 13-11,000 radiocarbon years ago. In raising the question whether or not England and Wales were permanently occupied during this period, I suggest that two patterns of subsistence organisation can be identified in the archaeological record. The first, linked to the early phase of the Interstadial and characterised by 'Creswellian' type assemblages, represents a response to relatively stable, evenly distributed resources across the landscape. The second is associated with greater instability in the later part of the Interstadial when site distribution evidence seems to suggest a shift towards the use of a wider variety of physical settings.

COLONISATION OF THE BRITISH ISLES BY THE MIDDLE AND UPPER PLEISTOCENE ICHTHYOFAUNA

Brian G. Irving (Institute of Archaeology, London)

The colonisation of the British Isles by the freshwater (stenohaline) ichthyofauna during the middle and upper Pleistocene has been controlled mainly by abiotic factors. These factors, which include sea level fluctuation, directional change of river courses and species distribution within the European mainland have all affected rates and patterns of colonisation. Biotic factors, most importantly the salinity tolerance of certain species, also has a major bearing on their migratory patterns and subsequently their distribution. Fishes surviving in refugia within the British Isles during cold stages is thought unlikely, due to a number of physiological factors. This situation means that warm stage species suites are due to complete recolonisation within warm events.

Using analogues from the present (Holocene) ichthyofaunal distribution we can achieve a model of colonisation which is applicable to a number of late glacial / post glacial events. However, there are many problems associated with constructing a sequence of events based on the present British ichthyofaunal distribution. This is due to anthropogenic influences redistributing the ichthyofauna for angling and aquaculture and the biogeographical problems caused by canal systems.

The present 'natural' ichthyofauna of the British Isles is typically impoverished when compared to the European mainland, with Ireland receiving no recorded primary freshwater species. Finally, a small number of 'exotic' species have been identified from British Pleistocene deposits which beg further analysis as to their migratory routes across NW Europe.

INSULARITY AND QUATERNARY VERTEBRATE FAUNAS IN BRITAIN AND IRELAND

A.J. Stuart (Castle Museum, Norwich)

Terrestrial vertebrates (mammals, reptiles and amphibians) from the Middle and Upper Pleistocene of Britain and Ireland are compared with faunas from adjacent Continental Europe. Reduced diversity in certain British and Irish faunas provides evidence of insularity. Problems arise from uncertainties in correlation before the Last Cold Stage.

British cold stage faunas are very similar to those of the adjacent Continent indicting unimpeded migration consistent with lowered sea levels. British temperate (interglacial) faunas older than the Last Interglacial also show little evidence of insularity. They show high species diversity and close similarity to Continental faunas.

The earliest indications of separation of Britain from the Continent occur in faunas from the Last (Ipswichian) Interglacial. Pine voles *Pitymys* spp., the extinct rhinoceros *Dicerorhinus kirchbergensis*, roe *Capreolus capreolus*, and humans *Homo* sp. which occur in approximately contemporaneous faunas in Continental Europe are not found in Britain. However, the absence of horse *Equus* from the British faunas is enigmatic, as the expectation is that it would have survived from the previous cold stage.

Severance from the Continent in the early Holocene is reflected in the absence from Britain of a number of amphibians and small mammals which occur today on the adjacent Continent as far as the Channel coast; e.g. spadefoot toad *Pelobates fuscus*, white toothed shrew *Crocidura russula*, pine vole *Pitymys subterraneus*, and common vole *Microtus arvalis*. Other thermophilous species, e.g. natterjack toad *Bufo calamita*, arrived before the flooding of the Straits of Dover.

Irish Pleistocene vertebrates are unknown before the Last (Midlandian) Cold Stage. In marked contrast to Britain, insularity is apparent in Irish Last Cold Stage faunas. Many species present in Britain, e.g. woolly rhinoceros *Coelodonta antiquitatis*, bison *Bison priscus*, are absent from Ireland. Moreover, people did not reach Ireland until the Holocene.

Irish Holocene faunas are also very impoverished. The absence of e.g. all species of voles and snakes, most shrews, and aurochs *Bros primigenius* suggests continued isolation from Britain. Remarkably, however, wild boar *Sus scrofa* and wood mouse *Apodemus sylvaticus* were present in the early Holocene.

MAMMAL EVOLUTION ON OFFSHORE ISLANDS

A.M.Lister (University College London)

Offshore islands provide interesting and instructive case-histories of evolutionary change in mammalian species. In the Quaternary of the British Isles, distinctive endemic forms of several taxa evolved, including voles *(Microtus)* on Guernsey and the Orkneys, and shrews *(Crocidura)* in the Scillies. On Jersey in the Last Interglacial, a dwarfed form of red deer *(Cervus elaphus)* developed. Based on the sea-level history of the area, the jersey deer must have evolved rapidly, probably within six thousand years of the stranding of full-size ancestors.

EVIDENCE FOR PLEISTOCENE CONTACT BETWEEN THE BRITISH ISLES AND THE EUROPEAN CONTINENT BASED ON DISTRIBUTIONS OF LARGER CARNIVORES

Alan Turner (University of Liverpool)

The generalised ecological tolerances of larger terrestrial carnivores, reflected in their wide distributions in fossil and living faunas, make them good potential indicators of the changing pattern of links between Britain and the continent of Europe over time. Extensive contact is indicated until the earlier part of the Middle Pleistocene, that is prior to the Anglian-Elsterian glaciation. The pattern after that is more complex, with evidence for some form of barrier by the time of the Hoxnian and for complete isolation during the Ipswichian.

WHY DID MAN AND SEVERAL OTHER ANIMALS, PREVIOUSLY PRESENT IN THE BRITISH ISLES, FAIL TO REAPPEAR DURING THE LAST INTERGLACIAL?

A.J.Sutcliffe (Natural History Museum, London)

When trying to reconstruct Britain's island history we must take into consideration not only positive evidence such as fauna and flora and sea level data but we must also look out for discontinuities in the evidence, which may be equally important.

One such discontinuity, during the period of time not very long before the 'Last Interglacial', is apparent from faunal evidence and is worthy of scrutiny over a broader field of disciplines than has so far taken place.

Before discussing this it is first necessary to define what is implied by 'Last Interglacial' here. It has long been recognised that, during the upper Pleistocene, there was an interglacial episode during which hippos spread over England and Wales as far north as Durham. That this is unsurprisingly equivalent to deep sea oxygen isotope stage 5e, about 120,000 years ago, seems to be well established from uranium series dating of stalagmite from Victoria cave, Yorkshire (Gascoyne *et al.*, 1981). It is widely assumed, from pollen and insect evidence, that the Ipswichian stratotype at Bobbitshole represents the same event, although unfortunately paucity of mammalian remains there limits that line of comparison. Nevertheless, from the evidence of the insects, Coope (1974) found the coleopterous faunas of Bobbitshole and the hippopotamus-bearing deposits of Trafalgar Square so similar that he had little doubt that the two deposits were of the same age; making it likely that, had the Bobbitshole mammalian fauna been richer, hippopotamus might have been found there also. The contemporaneity of the Ipswichian and the hippopotamus episode has not, however, received universal acceptance. Currant (1989), observing an apparent absence of beaver from the British 'hippopotamus fauna', points out that this was one of the few animals represented at Bobbitshole, raising the possibility of that site dating instead from an earlier interglacial.

For the purpose of the present discussion we need not be concerned with the precise use of the term Ipswichian. The 'hippopotamus fauna' is of very constant composition and of widespread occurrence and, unless it should be shown at some future time that it was repeated (for which there is currently no evidence), it does provide a most excellent temporal marker, to which other events can be related. Characteristic faunal elements include hippopotamus, straight-tusked elephant and narrow-nosed rhinoceros (*Dicerorhinus hemitoechus*), together with pig, other herbivores and carnivores. There are also some very remarkable apparent absences - Man, horse and, among the molluscs, *Corbicula fluminalis*.

It would not be appropriate to enter here into a discussion of the climatic complexity of that period of time preceding the hippopotamus episode that was formerly known as the 'Wolstonian'. Evidence for additional interglacials after the Hoxnian has been outlined by, for example, Shotton (1983), then UK International Correspondent of IGCP Project 24; Man's occurrence reviewed by Currant (1986) and Wymer (1988).

From such evidence it is apparent that we do not have to go back in time too long before the hippopotamus episode to find earlier sites with Man present during cold phases (*e.g.* at Crayford, Kent), steppe and interglacial phases (*e.g.* Stoke Tunnel, Suffolk, a site with pond tortoise, *Emys orbicularis*, Stuart,

1979); horse a constituent of almost every fauna; and *Corbicula* widespread. The Neanderthal remains, found by Green in Pontnewydd Cave, Wales (Green and Walker, 1991), have a uranium series date apparently placing them in oxygen isotope stage 7.

Whereas the hippopotamus had subsequently been so successful in colonising the British Isles during stage 5e, whatever happened to the missing animals previously listed? It might be argued that Man and horse could not live in a forested environment; but not everywhere would have been forested. The logistics of hippos and beavers sharing the same pond is a challenge to the imagination; but, if both had been present, the occasional mixing of remains in the same watercourse would have been inevitable.

We must conclude that something very drastic occurred to the British fauna some time preceding stage 5e. It is tempting to look at oxygen isotope stage 6, which is known from the deep sea record to have been extremely cold, as a potential cause of faunal disruption, after which some of the species lost did not reappear until the Devensian. Arriving ahead of these, the hippopotamus had not been present since the lower Pleistocene.

How the hippopotamus episode graded into the Devensian still remains obscure. Studies in Minchin Hole and Bacon Hole caves, Gower (Sutcliffe *et al.*, 1987), suggest the continuation or reappearance of some warm species after stage 5e; and a mammalian fauna of cold character, with wolverine, from Stump Cross cave, Yorkshire, dated by the uranium series method, suggests a cold phase about 80 - 85,000 years ago (Sutcliffe *et al.*, 1985). But Man may not have reappeared in the British Isles until less than 40,000 years ago.

The suggestions presented here are based on the evidence of only a few disciplines. They need to be scrutinised and checked by a broader field of workers.

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THE FLORISTIC RECORD OF IRELAND'S PLEISTOCENE TEMPERATE STAGES

P.Coxon and S. Waldren (Trinity College, Dublin)

The authors have compiled a data base of all the floristic records from Irish Early, Middle and Late Pleistocene temperate stages. Of the total of 281 taxa recorded 37 are now absent from the modern Irish flora. Certain elements of the flora have been retreating prior to the Pleistocene, and this has continued right through to the Holocene. We will present a synthesis of the data by looking at the Pliocene, montane/Arctic-alpine, Atlantic and amphi-atlantic elements, recent extinctions (from Ireland), American species and continental species.

The long temperate stage and Holocene records of atlantic species and especially uneven amphi-atlantic species such as *Najas* and *Eriocaulon* suggests that a glacial refuge may have existed somewhere on land to the south or south-

east of Ireland, as has often been suggested. This may be additionally supported by the apparent westwards restriction in the range of *Najas* (and others?), and the difference in chromosome number of European and the majority of American *Eriocaulon aquaticum*. The apparent western European restriction of the atlantic species is in contrast to the interglacial continental species, which have often retreated a long way to the east, and the arctic-alpines which have retreated to the north. None of the atlantic species present in the Irish temperate stages have failed to recolonise Ireland, and neither have any of the amphi-atlantic species, save for the arctic-alpine *Athyrium distentifolium* and the anomalous *Nuphar pumila*. However, the absence of three previously amphi-atlantic species *Azolla filiculoides*, *Brasenia schreberi* and *Nymphoides cordata* suggest that any refuge may have been relatively limited in extent. In addition, one of the Atlantic/Mediterranean species now present in Ireland but absent from Britain may have been introduced in historical times *(Erica erigena)*, while another *(E. mackaiana)* rarely sets seed in Ireland.

BULGES, SINKS AND EARTH CRUSTAL BEHAVIOUR - THE ROLE OF SEA LEVEL IN DETERMINING INSULARITY: A PERSPECTIVE FROM IRELAND

R.J.N. Devoy (University College Cork)

In the Proceedings of the Postglacial Colonization Conference, held in October, 1983 (Sleeman, Devoy and Woodman, 1986), assessment was made of the likelihood of the existence of former landbridge links between Ireland and Britain in the Quaternary. On the basis of sea-level and related coastal data, information about the bathymetry of the shelf seas around Ireland, the pattern of glacio-isostatic recovery and of glaciation in the region, it was concluded that no good physical evidence existed to support the idea of a former 'land link' with Britain in the Late Quaternary. The best that could be hoped for was a 'low, soggy, shifting and partially discontinuous linkage' (Devoy, 1985).

Since that time new data has been produced on all of these areas of Ireland's Quaternary environment: upon sea-level changes, glaciation and earth crustal recovery in the region. The question of Ireland's insularity is now re-assessed in the light of this work.

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A MODEL OF SEA-LEVELS IN THE IRISH AND CELTIC SEAS DURING THE UPPER PLEISTOCENE AND HOLOCENE

Robin Wingfield (British Geological Survey, Nottingham)

Lateglacial sequences around the Irish Sea have been attributed to proximal glacimarine deposition to more than 150m above present sea level. In contrast bedforms and a limited number of sediments from the seabed of the Irish and Celtic Seas indicated that during parts of Lateglacial and Early Holocene times palaeo-sealevels lay 120m and more relatively lower than at present. The widespread preservation of undistorted raised beaches from the Last Interglacial parallel to present sea level indicate that sea level controls since have acted cyclically, returning effectively to the same condition, rather than by producing permanent distortions. The cycle controls modelled were glacio-eustasy, glacio-isostasy and hydro-isostasy. Glacio-eustatic changes were taken from the established graphs based on coral reef studies. Glacio-isostasy was modelled as a simple conical depression, centred in Scotland, and with a annular forebulge of equal volume. This form was expanded or contracted in size, while retaining the same proportions, to model the dilation and later contraction of glacio-isostatic effects of the ice sheet centred in Scotland. In the seas considered no effects of other ice sheets were modelled. Since the offshore evidence demonstrated that Early Holocene sea-level changes had the form of a wave progressing from south to north through the Celtic and Irish seas, and that the lowest levels, though progressively smaller, each were lower than the contemporary glacio-eustatic levels, it was modelled that this was a phase of forebulge contraction. Hydro-isostatic effects were modelled to have increased both the relative falls and the relative rises of sea-level, resulting from the combined glacio-eustatic and glacio-isostatic effects, by up to 210%. This full hydro-isostatic enhancement would only have applied where full transgression or regression occurred relative to the present mean sea level. Using this simple, crude, model provided a four dimensional framework that was manipulated to provide a best fit of the empirical data. The best fit model was solved to provide spatial and temporal parameters, and the results are presented (i) as a series of graphs of sea-levels against time from about 27 to 7 ka BP for points between Scotland and Iberia and (ii) as maps of palaeo-coastlines for the Irish and Celtic seas from the Last Interglacial to the Early Holocene.

'THE UK DURING THE LAST GLACIAL/ INTERGLACIAL TRANSITION (14,000-9,000 YEARS BP)'

8 January 1993

Royal Holloway, University of London

ABSTRACTS

RECONSTRUCTING GLACIER RESPONSE TO CLIMATIC CHANGE USING GEOMORPHOLOGICAL AND STRATIGRAPHIC EVIDENCE

D.I. Benn (St. Andrews)

Recent work has shown that in many areas of the Scottish Highlands the retreat of glaciers from their Loch Lomond Readvance maximum positions was interrupted by numerous stillstands and readvances. For the Island of Skye, the pattern of glacier retreat is particularly well known and data from 9 pollen sites have allowed a relative chronology of deglaciation to be established. These data suggest that: (1) glacier retreat was initiated during the Loch Lomond Stadial, possibly as the result of declining precipitation; (2) final deglaciation was by uninterrupted retreat or stagnation, possibly due to rapidly rising temperature; and (3) deglaciation was complete by the early Flandrian *Juniperus* maximum on the island.

Further work is planned to establish the timing and style of deglaciation in other parts of Britain, and to model temperature/precipitation relationships during the Loch Lomond Stadial and early Flandrian. Potential study sites have been identified on the Hebridean islands of Mull and Harris. A major objective will be to determine whether temperatures remained low during the initial stages of deglaciation, by searching for evidence of permafrost or deep seasonal freeze-thaw inside Loch Lomond Readvance limits (*eg* fragipans, ice-wedge casts, soil wedges and soil microstructures). However, many problems remain to be solved before the driving mechanisms of deglaciation can be established with confidence. In particular, reliable data on the timing of deglaciation need to be established, requiring details studies of high resolution cores in key areas.

PATTERNS OF DEGLACIATION DURING THE LOCH LOMOND STADIAL: AN EXAMPLE FROM THE NORTHWEST HIGHLANDS

M. Bennett (Greenwich)

When viewed from the air, Scottish 'hummocky moraine' appears to consist of a series of linear ridges which resemble those found at the margins of modern glaciers which are decaying actively today. Recent work has shown that Scottish 'hummocky moraine' contains a wide range of ice-marginal landforms deposited at actively-retreating ice fronts. These landforms can be used to map the pattern of decay.

This interpretation is applied to the northern part of the main Loch Lomond Stadial ice cap within the Scottish Highlands. The pattern of deglaciation established appears to be strongly controlled by both topography and the connectivity of the valley system. The distribution of landforms within this part of the ice cap is also examined leading to important insights into its dynamics during decay. In conclusion the palaeoenvironmental significance of active deglaciation is assessed.

RADIOCARBON DATING OF MARINE SHELL SITES ASSOCIATED WITH THE LOCH LOMOND READVANCE IN THE SCOTTISH HIGHLANDS

H.W. Borns (Maine, USA) and J.M. Gray (Queen Mary, Westfield)

A research group from the Institute for Quaternary Studies, University of Maine (Harold Borns, George Jacobson and Jim Fastook), in collaboration with some British researchers, is currently undertaking a US National Science Foundation funded project entitled 'A high-resolution case history: the Loch Lomond Ice Sheet in the Scottish Highlands'. Part of the project involves radiocarbon dating of existing and new shell sites over-ridden during the ice advance, and 15 such sites around the western and southern margins of the ice-sheet were sampled in July 1992. The sites include over-ridden and glacio-tectonised 'Clyde Beds', shelly tills and glaciofluvial sediments. Resampling of BGS cores from the Loch Lomond area is also being undertaken. Funding for both AMS and Conventional dating is available, and the samples are currently being assessed and prioritised prior to dating at the University of Arizona. In addition the project will involve AMS dating of bog macrofossils from critical horizons at sites in the Eastern Highlands (Jacobson), and computer modelling of ice-sheet growth and decay (Fastook and Sugden).

THE BRITISH CLIMATE DURING THE LOCH LOMOND STADIAL: IMPLICATIONS OF PERIGLACIAL PHENOMENA

C.K. Ballantyne (St. Andrews)

A number of climatically-diagnostic periglacial phenomena are known or inferred to have developed during the Loch Lomond Stadial of *c.* 11-10 ka BP. In upland areas these include protalus rock glaciers, protalus ramparts and large-scale relict sorted patterns. Lowland forms include ground-ice depressions (pingo scars), soil wedges, frost cracks, cryoturbation structures, active-layer detachment slides and coversands. The case for permafrost cracking and ice-wedge development during the stadial remains equivocal on present evidence. Ground ice depressions, cryoturbations and active layer detachment slides indicate the development of widespread discontinuous permafrost in southern Britain, and suggest that during the coldest part of the stadial mean annual air temperatures (MAAT) in central England were *c.* -5°C. A corresponding MAAT of -8°C is inferred for NE Scotland. The period of glacier expansion was dominated by a vigorous westerly circulation, evident from the eastwards transport of blown sand and an eastwards and northeastwards rise in the average altitude of protalus ramparts across the Scottish Highlands. The altitudes of protalus rock glaciers suggest that precipitation in the Western Highlands may have been slightly less than at present, but did not exceed 375-550 mm yr^{-1} at 920 m in the Cairngorms, implying that those areas of eastern and NE Scotland that lay in the lee of the Grampian Icefield experienced marked aridity. It is possible that the thermal minimum of the stadial was achieved *after* the main period of glacier expansion, possibly in response to a brief reassertion of easterly airflow, so that glaciers initially retreated slowly in response to diminished snowfall in the final centuries of the stadial.

THE ARDERSIER READVANCE RE-ESTABLISHED

J.W. Merritt, J.W. Auton (BGS, Edinburgh) and C.R. Firth (West London Institute)

The deglaciation chronology of the Late Devensian ice sheet in eastern Scotland is controversial. Proposed stillstands and/or readvances, for example those at Aberdeen and Perth which were said to have occurred prior to the Loch Lomond Stadial, have all been challenged or refuted. The recognition that a small local readvance of a tidewater glacier occurred at Ardersier, during the deglaciation of the inner Moray Firth, has implications for modelling of the

decay of the Late Devensian ice sheet. The glacier over-rode fine-grained glaciomarine sediments and formed a crescentic push moraine at Ardersier, composed of faulted, folded, tilted and thrust bodies of sand and silt, locally capped by flow-till. The glaciotectonic structures within the moraine show a consistent translation of the strata northeastwards; minor dislocations are recorded several kilometres beyond the moraine ridge.

Subsequent rapid southwestward retreat of the ice front took place by iceberg calving, accompanied by the deposition of gravels as glaciomarine deltas; an ice-contact delta at Alturlie Point formed during a stillstand in the retreat. The glacial advance and retreat must have occurred early in the deglaciation of the area, prior to the formation of the earliest recorded Late Devensian raised shorelines in the district, which are taken to predate the Main Perth Shoreline.

LATE DEVENSIAN - EARLY HOLOCENE SCOTTISH UPLIFT PATTERNS: SHORELINE EVIDENCE

C.R. Firth (West London Institute), D.E. Smith (Coventry), R.A. Cullingford (Exeter) and A.G. Dawson (Coventry)

Detailed studies of glacio-isostatically tilted shorelines in Scotland have produced isobase maps for local areas. The evidence from these shoreline studies is combined for the first time to outline the changing patterns of Scottish glacio-isostatic displacement between 14000-6000 BP.

Shoreline data from local studies were correlated on the basis of radio-carbon dates, morphological evidence and proposed gradients to identify two major shorelines; the Main Lateglacial Shoreline and the Main Postglacial Shoreline and to tentatively identify one other significant feature; the Main Deglacial Shoreline. Isobase maps for these three features, produced using trend surface analysis, indicates a shift in the centre of uplift. Between the Younger Dryas and the mid Holocene the shift was 50 km towards the SSE. These changes may reflect the impact of crustal loading during the Younger Dryas.

Comparison of patterns of uplift associated with the Late Devensian ice sheet and with Younger Dryas events suggests that glacio-isostatic redepression occurred as a result of ice-loading during the Younger Dryas. This evidence contrasts with the uplift histories proposed by geophysical models.

LATE DEVENSIAN AND EARLY HOLOCENE RELATIVE SEA-LEVEL CHANGES AND CRUSTAL MOVEMENTS IN WESTERN SCOTLAND - NEW DATA

I. Shennan, J. Innes and A. Long (Durham)

Six sites from western Scotland, between Kentra Bay and Loch Morar, provide stratigraphic, morphological, pollen, diatom and radiocarbon data. From this information Late Devensian/Holocene relative sea-level changes are described. Coastal vegetation changes are inferred from the pollen and diatom data. Models of the magnitude and pattern of glacio-isostatic uplift can be tested against the new chronostratigraphic data. Palaeogeographies of the sites include tidal marshes, dune/beach systems and isolation basins.

LATEGLACIAL CLIMATIC GRADIENTS

M.J.C. Walker (Lampeter), G.R. Coope and J.J. Lowe (London)

Pollen-stratigraphic, coleopteran, molluscan and geochemical evidence from a network of Late Devensian Lateglacial sites provides the basis for the reconstruction of the pattern of environmental and climatic change in the British Isles during the last glacial-interglacial transition. At the thermal maximum, which occurred around 13,000 years BP, mean July temperatures in central and southern England and in Wales were at least 18°C, while in southern Scotland, maximum July temperatures may have exceeded 16°C. These values are 1.5-2.0°C above those of the present day. Between 12,500 and 12,000 BP, summer temperatures fell by more than 4°C and a further fall of 5-6°C occurred in the period from 12,000-11,000 BP. Short-lived, but clearly-defined oscillations in temperature are apparent throughout the latter time interval. During the Loch Lomond Stadial, summer temperatures in southern Britain were around 10°C, but a degree or so lower in central England and Wales, and up to 2°C lower in southern Scotland. The rapid climatic amelioration at the onset of the Flandrian (around 10,200 BP) saw summer temperatures rise by up to 10°C in less than 700 years. These data are compared with other proxy records from the British Isles and north-west Europe, and with evidence of Lateglacial oceanographical changes from the North Atlantic and Norwegian Sea.

EVIDENCE FOR CHANGES IN RIVER CHARACTER AND VEGETATION TYPE IN THE KENNET VALLEY, SOUTH-CENTRAL ENGLAND, DURING THE LATE GLACIAL/ INTERGLACIAL TRANSITION

P.E.F. Collins (Reading)

Exposures in a thick fluvial sequence beneath the present floor of the Kennet Valley in an aggregate quarry near Woolhampton, Berkshire, provide evidence of a series of major environmental changes on both a local and regional scale. These extend from prior to *c.* 14ka BP and continue well into the Flandrian.

A major channel fill with an 'interstadial' flora, including *Betula* cf *pendula*, is sandwiched between coarse, sandy gravels containing minor fossiliferous beds indicative of stadial conditions (high Cyperaceae, Gramineae and Herb frequencies). The assemblage of plant remains within this bed (pollen and macrofossil) indicates a correlation with the Windermere Interstadial and this is supported by two ^{14}C age estimates. The sedimentology of this bed suggests deposition under much lower energy conditions than the under- and over-lying gravels. This may reflect a major change from a braided fluvial regime, although a simple shift in main channel position cannot be ruled out.

Dating control on the basal gravels is currently unavailable, though they are likely to be of Last Glacial Maximum age. The gravels above the interstadial channel can be ascribed to the Loch Lomond (Younger Dryas) Stadial.

Above the upper gravels, silts and peats reflect a second reduction in the river's capacity and competence. A significant increase in arboreal pollen within these sediments suggests this is due to climatic amelioration associated with the beginning of the Flandrian, though a possible complication through the impact of *Castor* sp. cannot be ruled out.

LATEGLACIAL MOLLUSCAN ASSEMBLAGES IN NORTHERN BRITAIN AND THEIR CLIMATIC IMPLICATIONS

D.H Keen and J. Houghton (Coventry)

Non-marine molluscan assemblages from Lateglacial contexts are reasonably well known from the chalklands of southern England, but very few faunas have been described from northern Britain. Because of the recent nature of deglaciation

and the intensity of periglacial effects in the north in Lateglacial times, the molluscan evidence is almost exclusively from freshwater contexts. Despite the restricted numbers of species recovered from such sites as kettle lakes or other hollows on the surfaces of till sheets, Mollusca can provide valuable data on local environments. Such detail as water depth, water temperature and degree of vegetation growth are major controls over molluscan ecology and thus can be used as environmental indicators. The sensitivity of some bivalves to water turbidity can also give an indication of rates of sediment input into water bodies and thus rates of run-off from the surrounding land surfaces.

Because of the rapid colonisation by some 'pioneer' species of new water bodies, molluscs provide early indications of climatic warming, and are similar in this way to insects. Detailed examination of faunas from lakes in Yorkshire, Scotland and Northern Ireland allow the beginnings of a faunal and thus climatic transect across northern Britain to be established.

BIOGEOCHEMISTRY OF LATEGLACIAL SEDIMENTS

J.J. Lowe, G.R. Coope, J.Ll.S. Pridham (London) and M.J.C. Walker (Lampeter)

Very little is known about variations in the organic geochemistry of Lateglacial lake sediments, yet an understanding of this may be vital in assessing the reliability of radiocarbon measurements, the nature of the organic flux during deposition and environmental or site conditions during deposition. In combination with studies of inorganic chemistry, biochemical measures may provide novel approaches for deriving palaeoclimatic inferences.

We present here provisional results of studies of organic compounds (lipids, carbohydrates, carotenoids, etc.) and of ICPMS measures of element chemistry of the Lateglacial succession at Gransmoor, East Yorkshire. Marked variations in the type and abundance of chemical compounds or elements often bear close relationships with independently determined litho- and/or biostratigraphic variations. There are, however, marked differences between organic compounds in their relationship with organic carbon content. Some of these compounds appear diagnostic in determining the source of the organic flux. These results will provide the basis for a discussion of the potential of such studies in future Lateglacial palaeoenvironmental research.

THE THERMAL CLIMATE IN LATEGLACIAL BRITAIN

T.C. Atkinson, K.R. Briffa (Norwich), G.R. Coope (London), and K.J. Sinka (Norwich)

A numerical reconstruction of Lateglacial climates in Britain has already been published (*Nature*, 352, 587-92, 1987), based on applying the Mutual Climatic Range Method to radio-carbon dated insect remains. Our present contribution will present unpublished details of how that reconstruction was made, how living species of coleoptera were calibrated against climate, and how the Mutual Climatic Range Method was tested and verified with modern data. Diagrams showing the annual cycle of temperature for different times in the lateglacial will be derived and compared with estimates made from other evidence such as periglacial phenomena. British Late-glacial climates have modern thermal (*not* precipitation) analogues in Britain itself, north Germany/ Denmark, northern Finland, northern Russia and the Gulf of Ob. The sequence of these analogues will be demonstrated. Finally, the likely ranges of diurnal temperature fluctuations will be discussed, and the number of days per year estimated on which temperature passed through the freezing point. This index may cast light on the varying intensity of frost weathering in the Lateglacial period.

LATEGLACIAL AND EARLY HOLOCENE RIVER ACTIVITY IN BRITAIN

J. Rose (London)

Evidence for river activity in lowland Britain during the Lateglacial and early Holocene is relatively abundant, being represented by fluvial sediments and channels, and associated lake marls and muds dated by pollen, mollusc and beetle biostratigraphy and radiocarbon dates. In general, a simple pattern exists with relatively low energy fluvial conditions characterising the Windermere Interstadial (13,500-11,000 ka BP) and early Holocene, and high energy erosion and gravel sedimentation characterising the Loch Lomond Stadial (11,000-10,000 ka BP). During the former, rivers mainly adopted a single thread mode and deposited gravelly sands, sands and silts with a high organic component. Shallow lakes developed in pools and behind levees, and the mineral component is often very low. These conditions are attributed to a vegetation cover and soil development regulating the runoff and sediment supply. During the Loch Lomond Stadial the rivers were dominated by channel erosion and braided river sedimentation attributed to high snow-melt discharges

and high sediment yield driven by gelifluction, minimal vegetation cover and possibly a high aeolian sand flux. Typically, the sediments formed at this time are at a valley bottom location and are buried by fine grained Holocene overbank deposits and peat.

In detail, however, the pattern is far more complex. In the uppermost parts of all the catchments erosion must have been continuous but proof is absent. Close to the upper parts of lowland catchments aggradation was dominant throughout, although rates were less during the interstadial. In lowland regions influenced by glacio-isostatic rebound following Late Devensian glaciations, patterns of aggradation and incision are developed in relation to glacial meltwater and sediment supply irrespective of the isostatic tendency, but erosion dominates the non-glacial conditions of the later part of the Windermere Interstadial, the early part of the Loch Lomond Stadial and the early part of the Holocene. In these areas sediments may have been dissected and form terraces in the typical long, low-relief stretches, scales of erosion and aggradation may vary from as little as c3 m to $\geq$ 14 m. Hitherto, few sites exist with sufficient temporal and palaeoenvironmental resolution to link the changes in discharge and sediment supply with detailed fluvial geomorphology, but those that do suggest a complex lead and lag relationship that would significantly modify the general model given above. Hitherto, no catchments have been studied in sufficient detail to determine the varying responses throughout the network and evaluate the effects of *complex response* that dominate fluvial systems experiencing major changes in energy and sediment flux over short periods of time.

The paper concludes with a set of models proposed to represent the relationship between climate and river activity during the transition between the last glaciation and the Holocene, and proposes a scheme by which these models may be tested in terms of spatial sampling, palaeoenvironmental reconstruction and luminescence dating.

SEDIMENTARY EVIDENCE OF LOCH LOMOND STADIAL JÖKULHLAUP FLOWS, FORT AUGUSTUS, SCOTLAND

Andrew J. Russell (Kingston)

The presence of ice-dammed lakes in Glen Roy and Glen Spean during the Loch Lomond Stadial has long been established on the basis of morphological and sedimentological evidence. The evidence for sudden drainage of these lakes is primarily based on the presence of proglacial fluvial outwash. High

level terraces near Fort Augustus have been attributed to jökulhlaup deposition graded to temporarily raised levels of Loch Ness (Sissons 1979; Firth 1984, 1986).

This study examines sedimentary sequences exposed in a gravel pit within the area of hypothesised jökulhlaup outwash. Present day jökulhlaups frequently drain into proglacial lakes providing an analogue for former jökulhlaup deposition near Fort Augustus. Examination of sedimentary characteristics within the Fort Augustus pit provides valuable information regarding the magnitude, frequency, and direction of palaeoflows. This new information therefore permits further consideration of the validity of the jökulhlaup hypothesis at this site.

NOTICES

1. WOLSTON GRAVEL PIT SSSI 'OPEN Day'

QRA members who have visited the Wolston Gravel Pit SSSI in the last few years will no doubt be familiar with the problems encountered in attempting to maintain a permanent section at the site. Problems with the slumping of faces and with the rapid growth of vegetation have meant the Wolston sequence has only been available for study when faces are specially cleaned (e.g. QRA visit in 1989).

However, as part of an ongoing landfill restoration project at Wolston, English Nature have now been offered the opportunity to arrange for a permanent, open section to be cut. At present, two sections have been cut by JCB at the site as part of a trial project to secure a permanent exposure. A section cut in the Thrussington Till appears to have suffered no visible degradation and no problems have been encountered. A section cut in the Wolston Clay, however, has slumped badly and it has proved impossible to maintain a permanent exposure.

In order to preserve as much of the Wolston sequence as possible, English Nature hope to make the sections available for study on Friday 12 March 1993. In addition to the two sections already open there will be the opportunity to study the Bagington Sands below the base of the present exposure. We also hope to hand-clean the sections of Wolston Clay and Sand with a view to establishing a permanent exposure of the sediments above the open till section. Any members of the QRA or other interested parties are invited to inspect the sections on this day, commencing at 11 am. Members advice of future conservation measured at the site would also be welcomed.

Anyone interested in attending should contact:

Neil Glasser
Earth Science Branch
English Nature
Northminster House
Peterborough PE1 1UA or telephone (0733) 318308.

2. TRENT VALLEY SURVEY

Trent and Peak Archaeological Trust is conducting a six month survey on the geomorphological and archaeological development of the River Trent from the Late Devensian to present day (Holocene). The survey area extends from Alrewas (Staffordshire), downstream to the River Idle confluence (north of Gainsborough). We would be pleased to hear from any researchers who have undertaken work, or are presently studying topics relevant to this area.

Further information and details can be obtained from either Dr. D. Knight or Dr. A.J. Howard, at Trent and Peak Archaeological Trust, University Park, Nottingham N67 2RD, or telephone 0602 515151 ext. 8614.

3. LITHIC STUDIES SOCIETY - ANNIVERSARY CONFERENCE
St.Hilda's College, Oxford
2-4 April 1993

LITHIC STUDIES: LOOKING BACKWARDS AND LOOKING FORWARDS

Twelve years after the formation of the Lithic Studies Society a conference is being organised looking at the advances made in lithic analysis, reviewing current work and discussing the way forward. The contributions will reflect the full breadth of interests of the Society with overviews of past work. A provisional programme has been organised which includes the following sessions, chairpeople and speakers.

	Session	Chair	Speakers
1.	Dating and Scientific Techniques	Prof. Mike Tite	Nick Debenham, Robert Ixer, Pat Phillips
2.	Raw Materials and Petrology	John Wymer	Peter Berridge, Mark Edmonds, Nora Moloney, Alan Saville
3.	Resource Management	Andy Brown	Amanda Chadburn, Robin Holgate, John Schofield, Rosemary Seagreaf, Frank Wenban-Smith
4.	Functional Analysis and Technology	Nick Barton	Linda Hurcombe,Alison Roberts
5.	Typology	Roger Jacobi	Nick Ashton, Elizabeth Healy, John Mcnabb, Michael Reynier

Registration will start from 6.00 pm on the Friday evening followed by dinner with an introductory talk by John Wymer. The main conference will start at 10.00 am on the Saturday with Session 1 before lunch. Sessions 2 and 3 in the afternoon will be followed by a wine reception and the conference dinner. Sessions 4 and 5 will take place on the Sunday morning and the conference will disperse after lunch. It is hoped that an exhibition of twentieth century lithic illustration will also be on display in the conference room foyer.

All arranged accommodation and conference meals are in St Hilda's College, Cowley Place, Oxford (near Magdalene Bridge).

It is planned to publish the proceedings of the conference as an Occasional Paper of the Lithic Studies Society. This will be published soon after the conference.

Further details can be obtained from:
Nick Ashton, Hon. Treasurer, Lithic Studies Society, British Buseum, Franks House, 38 Orsman Road, London N1 5QJ.

4. UNIVERSITY OF GLASGOW
Department of Geography and Topographic Science

DRUMLIN SEMINAR
Tuesday 27th April 1993

09-15-15.00	Short field trip around the drumlins of the Glasgow area. Leave from University of Glasgow Main Gate.
15.30	Professor Jim Rose, Royal Holloway, University of London. *'The Central Scotland Drumlins: Their contribution to Glacial Bedform Theory.'*
16.30	Tea and coffee
17.00	Dr. John Menzies, Brock University, Canada. *'Glasgow's Drumlins Revisited, Twenty Years On'.*
18.00	Retire to the 'Brewery Tap' for further informal discussion.

SCOTLAND QUATERNARY LECTURES
Wednesday 28th April 1993

UNIVERSITY OF GLASGOW
Department of Geography & Topographic Science

SQL 1	
14.00	Professor Jim Rose, Royal Holloway, University of London *'The Middle Pleistocene of Central and Southern Britian'*.
15.00	Tea and sandwiches.
SQL 2	
16.00	Dr. Phil Gibbard, University of Cambridge *'The Late Middle Pleistocene in Southern England'*.
17.00	Retire to the College Club for continued informal discussion followed by a meal somewhere close to the University campus.

Further details of both the Drumlin Seminar and the Quaternary Lectures can be obtained from:
Dr. David J.A. Evans, Department of Geography and Topographic Science, University of Glasgow, Glasgow G12 8QQ. Tel. 339 8855 Ext. 4786.

5. QUATERNARY RESEARCH ASSOCIATION

INTERNATIONAL CONFERENCE ON THE LAST GLACIAL/ INTERGLACIAL TRANSITION

A meeting held under the auspices of the QRA in collaboration with IGCP-253 and the Joint Association for Quaternary Science

May 4 1994

Following on from the Royal Society/IGCP-253 Workshop held in Edinburgh in January 1992 and the one-day Discussion Meeting on the above theme on 8 January 1993 at the Institute of British Geographers' Conference at Royal Holloway, University of London, Egham, Surrey, and International Meeting on the theme of the Last Glacial/Interglacial Transition will be held on May 4, 1995 at the Geological Society, Burlington House, Piccadilly, London.

This will be a one-day international meeting, commencing at 10.00 a.m. and will consist of a series of papers from invited speakers. The meeting will immediately precede the William Smith Meeting on 'Quaternary Climate Change' to be held at The Geological Society on May 5th, 1994 at which the keynote address will be given by J.E. Kutzbach (University of Wisconsin). The organisers of the meeting are Professor Jim Rose and Dr Alastair Dawson. Further details of these meetings will be given in the QRA June Circular.

6. SYMPOSIUM

QUATERNARY STRATIGRAPHY IN VOLCANIC AREAS

Rome, September 20-22, 1993

SECOND CIRCULAR

The Meeting will take place in Rome, Italy, from September 20 to 22, 1993. It will be held in the 'La Sapienza' University Congress Center, Via Salaria, 113, Roma.

Organisation of the Symposium

The Meeting will include plenary lecture, presentations and poster sessions. The official language of the Meeting is English.
It is proposed that the Symposium should address the following general topics:

1. Stratigraphy (Bio-, Litho-, Tephro-, Magneto-, Chronostratigraphy, etc.);
2. Stratigraphic and Geochronological Methods: Their applications and integrations;
3. Neotectonics & Geomorphological Evolution;
4. The Role of Long Sequences: Calibration and correlation of the Quaternary.

Abstracts for proposed oral papers and posters are invited for presentation at these sessions. Separate specialist lecture sessions may be considered, if appropriate, following submission of papers.

Proposed papers will be submitted for consideration by the Organising Committee. Authors should indicate whether they wish to make an oral or poster presentation, and under which of the topics listed above. The Organising Committee reserve the right to select the papers for presentation in the light of the total number received. It is intended to publish the accepted papers as a Symposium Volume in an appropriate scientific journal.

Post-Congress Field Excursions

September 23-24

Colli Albani and Monti Vulsini volcanic districts
Cost: $ 180 It.Liras 200.000

September 25-26

Pontine Islands
Cost: $ 220 It.Liras 300.000

(Fees for the excursions are based on the cost of double room accommodation, transport in the field, guidebook and meals.)

REGISTRATION FORM

Deadline for the registration form is **February 28, 1993.**

Further details and copies of the Second Circular can be obtained from:

Secretariat of the Symposium
'Quaternary stratigraphy in volcanic areas'
Centro di Studio per il Quaternario e l'Evoluzione Ambientale
c/o Dipartimento di Scienze della Terra, Università 'La Sapienza'
P.le Aldo Moro, 5 - 00185 ROMA - ITALY
TELEFAX; 0039-6-4468632

7. BIBLIGRAPHY OF EUROPEAN PALAEOBOTANY AND PALYNOLOGY 1990-1991

The Bibliography of Palaeobotany and Palynology, compiled by Thomas, B.A., Pardoe, H.S. and Fraser, H.E. is now available. The report consists of a list of papers published in 1990 and 1991. The report also includes a list of papers in press and contributors' current research interests. The aim of the report was to produce a comprehensive list of publications from all European palaeobotanists and palynologists. Contributions have been received from Britain, Austria, Denmark, Sweden, Norway, Hungary, Greece, the Netherlands, Czechoslovakia, Poland, Bulgaria, Belgium, France, Switzerland, Spain, Portugal, Germany and some from states formerly included in the U.S.S.R. The 227 page report is divided into sections according to geological periods.

If you would like to purchase a copy of the report please send a cheque for £6.00 (inc. P and P) to Dr B.A. Thomas, Department of Botany, National Museum of Wales, Cardiff, CF1 3NP, making your cheque payable to the **National Museum of Wales**. The report is also available on disc at the same price. If you wish to purchase the report on disc please specify the file type that you require. We will provide the file either in the format specified or as an ASCII file.

8. INQUA COMMISSION ON GLOBAL CONTINENTAL PALAEOHYDROLOGY

An INQUA commission on Global Continental Palaeohydrology GLOCOPH has recently been established. The main objectives of the commission are as follows:

i) to establish the major changes that have occurred in the waterbalance of the humid tropics, arid and semi-arid, temperate and polar zones in the last 20,000 years;
ii) to reconstruct the major trends and sequences of runoff for selected rivers in these zones.

The commission is composed of several working groups which are responsible for various parts of the project (*e.g.* palaeoflood hydrology, palaeochannels and palaeodischarges, and the inter-relationships between the water cycle, biomass and carbon cycle).

An international global database to support the work of the commission, and which can be used to determine palaeo-runoff, is being developed at the GeoData Institute, University of Southampton. One of the working groups specifically deals with the database. This working group will be a forum for both the 'data providers' and 'data consumers' and will advise on how the database should be designed and disseminated, and also the type of data that researchers would like to be available. We are setting up the working group at the moment and would like to hear from anyone who would like to participate in it, particularly those who have had experience of developing or using environmental databases.

If you would like any other information about GLOCOPH or would like to join the database working group please contact:

Julia Branson
Secretary, GLOCOPH Database Working Group
GeoData Institute
University of Southampton SO4 3SQ

9. QUATERNARY STUDIES IN THE SCHOOL CURRICULUM

As a consequence of the tremendous changes in the curriculum for primary and secondary education and, especially, the competition for curriculum time, the QRA has set up an Education Subcommittee to look into methods of promoting Quaternary studies. We are aware of the possibility of students not being exposed to the subject during school work and hence not finding their way into Quaternary studies post-school. We want to make every effort to ensure that the supply of future students and young research workers does not run dry.

The Publicity Officer is currently in negotiation for financial sponsorship so that the QRA will be better placed to meet new demands, of which educational support is top of the list. But first we need to know the thoughts of those who are active in the field of pre-tertiary education. The National Curriculum, together with the traditional A-level syllabuses, are now so wide that we would like to hear from workers at all levels on how and where aspects of the Quaternary might be promoted. The following are just a few questions on which we would value some feedback. For example:

Would you find it useful if the QRA could provide teaching resources to support particular curriculum areas?

Do you have teaching materials which you have developed which use aspects of Quaternary Science to illustrate curriculum topics?

If so, would you be willing to share these as part of a Quaternary development package?

Would you be interested in the development of interactive software packages for teaching through the medium of the Quaternary?

There are many other avenues which we might explore - finance permitting. Please write to give us an indication of potential support for this venture to:

Mrs Hilary Davies, Pharm House, Neston Road, Willaston, South Wirral L64 2TF.

10. JOINT ASSOCIATION FOR QUATERNARY RESEARCH (JAQR)

The following notice was received from the Executive Secretary of the Geological Society on 14 October 1992:

SECURITY IN BURLINGTON HOUSE

You will doubtless be aware of the resumption of bombings in central London which according to today's press the IRA has announced will continue. The West End of London has been their main target to date and this is calling for extra vigilance from everyone in the area.

As a result the Society has no alternative to increasing its security measures despite some inconvenience to users. Until further notice the following procedures will therefore apply.

When scientific meetings are held requiring access through the main door on Piccadilly conveners are asked to nominate a member to sit in the main entrance from the time the door is opened until 15 minutes after the meeting has begun. The main door will then be locked by the House Services Manager. All delegates for meetings who are not known by the nominee of the Group/Joint Association should be challenged on arrival at the Main Entrance to ascertain their business in the Society.

Groups/Joint Associations are asked to adopt a similar procedure for the afternoon sessions and evening meetings. Exit will be by the Courtyard Entrance of the Society. Latecomers during the day will be able to gain access to the meeting via this entrance. It is regretted that it will not be possible to admit those who come later than 15 minutes for evening meetings unless Groups/ Joint Associations are able to arrange the manning of the Main Entrance for a longer period. These procedures apply whether or not there is a formal registration procedure.

Council has commissioned a report into security within the Society which is expected to be received shortly and its recommendations will be considered as a matter of urgency.

It is regretted that in order to improve security some burden is having to be placed upon Groups/Joint Associations but no alternative can be seen in present circumstances.

QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. Most members reside in Great Britain, but membership also extends to most European countries, North America, Africa and Australasia. Current membership stands at *ca.* 1000. Membership is open to all interested in the objectives of the Association. The annual subscription for ordinary members is £10.00 and is due on January 1st for each calendar year. Reduced rates apply for students and unwaged members.

The main meetings of the Association are the Annual Field Meeting, usually lasting 3 or 4 days, held in April, and a 1 or 2 day Discussion Meeting held at the beginning of January. Additionally, Short Field Meetings may be held in May or September and occasionally these visit overseas locations. Short Study Courses on the techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter* issued with the Association's *Circular* in February, June and October; the *Journal of Quaternary Science* published in association with Wiley, and with four issues a year, the monograph series *Quaternary Proceedings*; the Field Guides and the Technical Guide series.

The Association is run by an Executive Committee elected at an Annual General Meeting held during the April Field Meeting. The current officers of the Association are:

President: *Professor G.S. Boulton FRS:* Grant Institute of Geology, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW

Vice-President: *Professor W.A. Watts:* Provost's House, Trinity College, Dublin 2, Ireland.

Secretary: *Dr. M.J.C. Walker:* Department of Geography, St. David's University College, University of Wales, Lampeter, Dyfed SA48 7ED, Wales.

Assistant Secretary (Publications):
Dr. D.R. Bridgland: 41, Geneva Road, Darlington, Co. Durham DL1 4NE

Treasurer: *Dr. J.E. Gordon:* Scottish Natural Heritage, 2, Anderson Place, Edinburgh EH6 5NP

Editor, Quaternary Newsletter:
Dr. J.D. Scourse: School of Ocean Sciences, University College of North Wales, Menai Bridge, Gwynedd LL59 5EY

Editor, Journal of Quaternary Science:
Dr. P.L. Gibbard: Subdepartment of Quaternary Research, Botany School, Downing Street, Cambridge CB2 2TF

Publicity Officer: *Mrs H. Davies:* Pharm House, Neston Road, Willaston, South Wirral, Merseyside L64 2TF.

All questions regarding membership are dealt with by the Secretary, the Association's publications are sold by the Assistant Secretary (Publications) and all subscription matters are dealt with by the Treasurer.

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