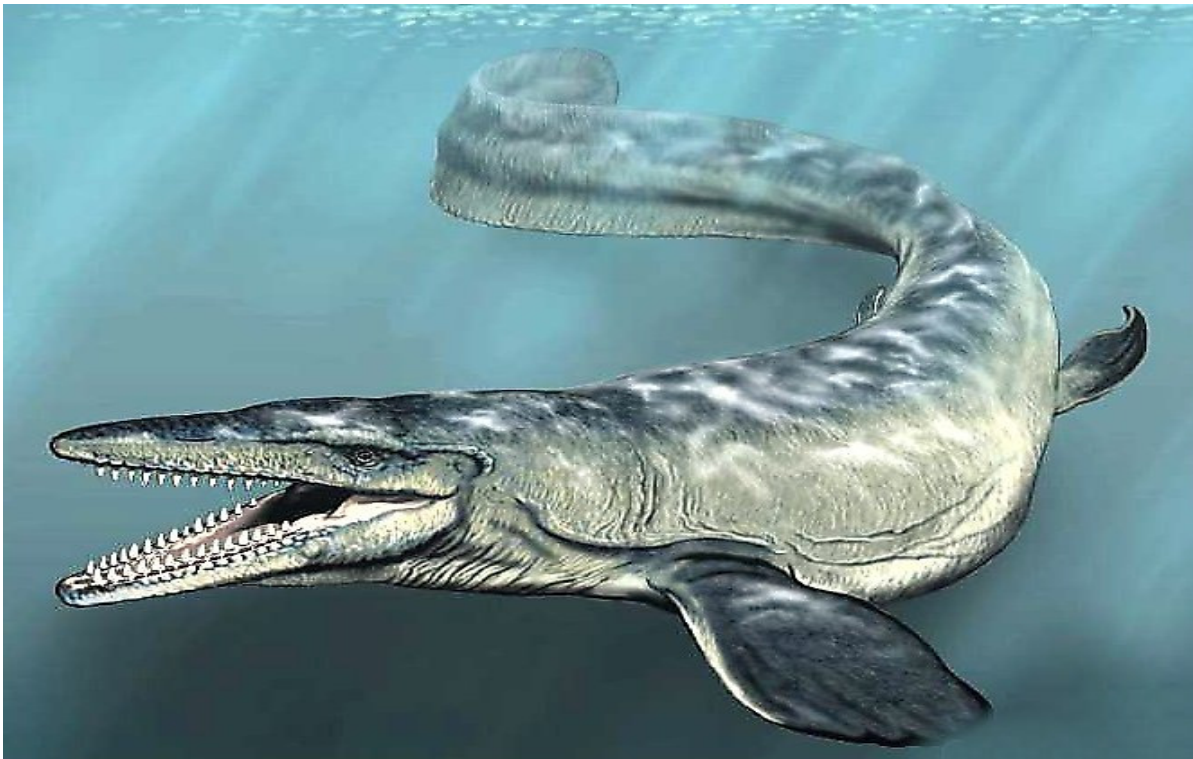


Newsletter of the Geological Society of Norfolk

(EMail Edition)

www.norfolkgeology.co.uk

Number 67, September 2006



For an explanation of this picture see inside!

This is the NEW pdf version of the Newsletter. It contains coloured photographs etc. It is being sent to you as an experiment to help you decide if you would like to have this version sent to your email address in future. You have also been sent the standard mail version. If you would prefer to receive that standard mail version (without photos) please inform the Editor. Otherwise, with the next Newsletter, this pdf version will become the default version for all members with email addresses. By using this version the Society saves money and gives you what we hope you regard to be a more valuable document.

**This Newsletter contains interpretations and proposals that may be questionable.
The author may have posed them to stimulate discussion. If you have any
comments to make please submit them to the Editor, who would like to see more
varied input!**

Notice and Appeal to members

2006 Subscriptions (£10, except £5 for students) were due in February!

Please send yours to our Treasurer (address below) if you do not use direct debit or a standing order.

But ***please*** consider using direct debit or a standing order ***if at all possible***

Name of Society's account:	"Geological Society of Norfolk"
The Society's bank:	HSBC Bank plc, Norwich, London Street Branch
Current account number:	"20376515"
Sort code number:	"40-35-09"
Subscription renewal date:	1st February each year.

Prompt payment by you helps us to pay our bills promptly! If the cash isn't in our account when we get a bill we may be obliged to increase the subscription. You get good value for your £10, don't you! Members who pay promptly are subsidising those who don't! If you have not paid your subscription for this year before its end this September Newsletter will be the last that you will receive. Your name will also be deleted from the list of members eligible for Bulletins.

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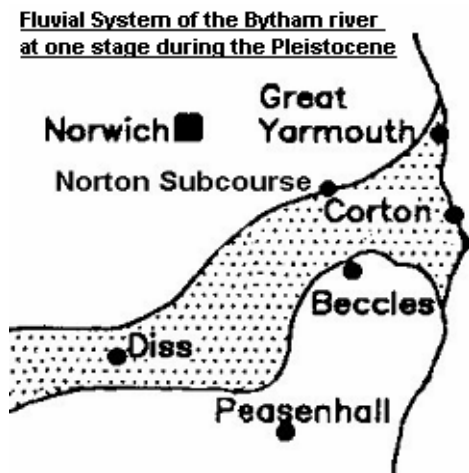
Other Committee Members (with special relevant interests) are :-

Adrian Read	(RIGS & database),
Ann Ainsworth	(Publicity)
Jonathan Lee	(BGS/Quaternary),
Nigel Larkin	(Norfolk Museums Service).

Letter from a Reader.....

This newsletter does not usually publish letters from readers, especially when the writer wishes to be anonymous, but in view of its interest I have decided to include this one: -

As a member of the GSN who has attended Society field meetings at Bramerton, Norton Subcourse, and at Pakefield I have speculated whether or not the latter two sites were part of the same river system. Certainly from a geographic point of view this is feasible (see diagram). Moreover at both sites it has been concluded that the climate was warmer than today.



However the "river bed" of the Cromerian deposits at Norton Subcourse is ca. 9 m above OD while the base of similar deposits at Pakefield is at ca. 1 m above OD. Dr Simon Lewis, in a lecture to the Society, proposed that this difference, a drop of 8m in 17km, is too great for both deposits to be part of the same river system.

Indeed, taking the modern river Waveney as a model, a height of the river of 5 m is attained 20 km from the coast. Thus only a drop of ca. 4 m is reasonable for the Bytham over 17 km, the distance of Norton Subcourse from Pakefield. This leaves ca. 4 m to be accounted for.

However, since the early Pleistocene land levels have risen, eventually bringing the Coralline, Red, Norwich, and Wroxham Crags, up above sea level in certain areas. The cause of this, neotectonic, change in land level is not certain. A contender for an adequate explanation appears to be the effect of cyclical loading of the continental crust by ice and consequent advection of the lower, warm & plastic, crust from beneath the adjacent ocean, as proposed by Westaway. A consequence of this mechanism is that inland areas should be effected more. Whether or not this mechanism is relevant there is a gravitational anomaly to consider as well, varying from -10 mGal south of Hunstanton and -8 mGal ca. 20 km west of Aylsham to $+3$ mGal near Pakefield. In other words the force of gravity is greatest at Pakefield. This implies that isostasy (*adjustment in response to different densities of crust, Editor*) may have raised land levels to the NW of Pakefield. In this respect I note that the lowest part of the Norwich Crag to show evidence of deposition in shallow water at Bramerton, 30 km from Pakefield, is now ca. 15 m above OD. The equivalent horizon is below sea level at Pakefield, as is the entire Norwich Crag. Thus, since degree of uplift has been greater inland, an uplift of ca 4 m at Norton Subcourse, 17 km from Pakefield, seems quite feasible, and well within the possible range.

Consequently I suggest that, on these grounds, a conclusion that Norton Subcourse cannot be part of the same river system as that at Pakefield is unjustified.

[name and address of correspondent withheld]

Note from Editor:-

In the next Newsletter of the Society I would be willing to publish any replies to this letter.

News Item.....

The new stratigraphy of the Norwich Crag as proposed by the BGS splits off the upper part of the Norwich Crag as the Wroxham Crag. But did you know that, having taken this into account, the BGS now do not know whether there is any Norwich Crag in Norwich?!

Lectures

Our lectures this season are the result of an effort to diversify our interests and to pay more attention to the Cretaceous. We also assess a significant advance in dating the 2nd half of the Pleistocene and face up to a problem we have now, namely predicting the climate.

Thursday 12th October, in the Friends Meeting House, Upper Goat Lane, Norwich.
Travels in Arabia Deserta: Carbonate Platforms, Oceanic Anoxic Events and Mass Extinctions in the Mecca of Rudists, Dr Peter Skelton, Department of Earth Sciences, The Open University,

The spectacularly exposed geology in and around the Oman Mountains offers a fascinatingly varied sampling of the Earth's climatic history, ranging from late Precambrian and Permo-Carboniferous diamictites of glacial origin to modern desert features. Particularly impressive are the extensive carbonate platform deposits of the Cretaceous greenhouse world, widely accessible both at outcrop and through concentrated exploration for hydrocarbons in the region. The subtle relationships between these globally episodic deposits, and the signatures of oceanic anoxia and mass extinction that repeatedly marked their terminations provide key insights on the unstable behaviour of the Earth system at that time.

The Aptian record furnishes well-studied examples of all these linked features. The diverse rudists of the Early Aptian Shu'aiba Formation offer especially useful insights concerning the sedimentary anatomy of the platforms. Multiple stacking of relatively thin shallowing-upward cycles in the outer platform zone, containing laterally extensive biostromes of elevator rudists, are frequently capped by rudstones and grainstones dominated by recumbent caprinids. These cycles testify to the repeated inward encroachment of marginal rudist banks, 'smeared' across the platform top within limited increments of accommodation space.

The rudists of the Early Aptian suffered one of the more important of the mass extinctions that punctuated the Cretaceous history of the group, coinciding with the widely registered Oceanic Anoxic Event 1A. Recent refinements of stratigraphical correlation indicate, however, that the extinction was not globally synchronous, but tracked a pattern of progressive latitudinal restriction of platform growth suggestive of climatic cooling following an initial warming event. Consideration of the opposing *short-term* feedback effects on atmospheric CO₂ of organic-, versus carbonate-carbon burial suggests a model for this pattern of events. Rapid carbonate production could have been sustained on the growing platforms, despite already high atmospheric CO₂ levels, because of the continuous expulsion of the gas yielded by calcification from the heated waters overlying them. I call this positive feedback to greenhouse warming the 'kettle hypothesis'. However, the marked increase in organic carbon burial during OAE 1A, involving CO₂ draw-down, hence climatic cooling, would have counteracted the latter feedback, allowing the progressive inhibition of calcification, hence demise of the platforms. This fluctuating interplay between the feedback effects of carbonate- and organic carbon burial seems to have been a hallmark of the Cretaceous world, which, in its own way, was no more stable climatically than our Quaternary icehouse world.

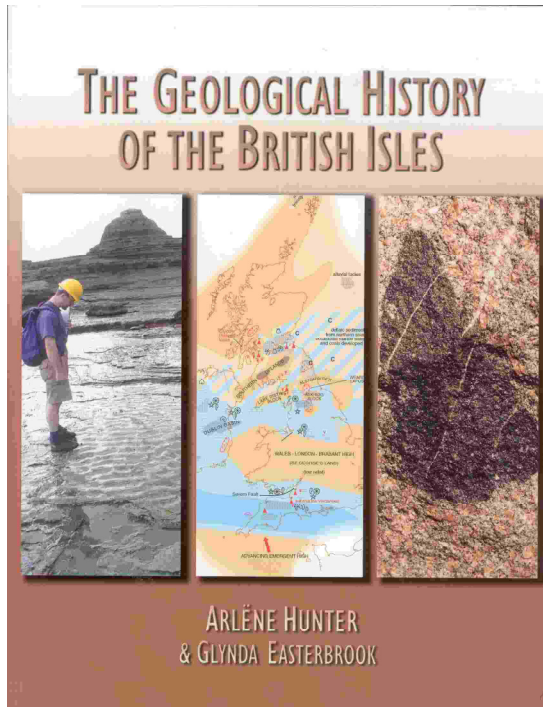
Thursday 16th November, in the Friends Meeting House, Upper Goat Lane, Norwich.
Dr Kirsty Penkman, University of York. *Dating the Pleistocene with the help of Amino Acid Racemisation*

Thursday 25th January, in the Friends Meeting House, Upper Goat Lane, Norwich
Prof. Bob Spicer, Open University. *Modelling Climate Change*

**Thursday 15th February, in the Friends Meeting House, Upper Goat Lane, Norwich
Dr Mark Woods, BGS. A Brief History of the Chalk**

The white cliffs of Dover are a familiar symbol of our national identity. Many people have a sense of what the Chalk is even though they may never have examined it in detail. Traditionally it was assumed to be a more-or-less homogeneous unit, blanketing older rocks without significant structure and lacking sophisticated subdivision. Why was this? Why is the current view so different? And why now, more than ever before, is it essential for us to unlock the secrets of this enigmatic rock?

Book review.....



That this book is published by the Open University is a recommendation in itself; students intensely criticise and search for errors in the textbooks that they are asked to read, and demand clarity. Consequently a textbook for the summer school basic geology course, SXR260, authored by one of the course tutors and revised in time for sale to the public, is bound to be good. This is certainly true of this book. It has been improved with even better diagrams since I took the course and now includes at least some material relevant to East Anglia! However, for local experts, its wide coverage of one of the most diverse geological areas of the world is bound to make it a bit superficial in places. But at the same time it's comprehensive coverage makes it an excellent primer for anyone wishing to learn the essentials of British Geology. It stays clear of controversy and all its explanations are tried and tested. Diagrams and colored photographs are plentiful and clear, and there are frequent references to palaeogeography and climate with some good maps. Incidentally many of the photographs are

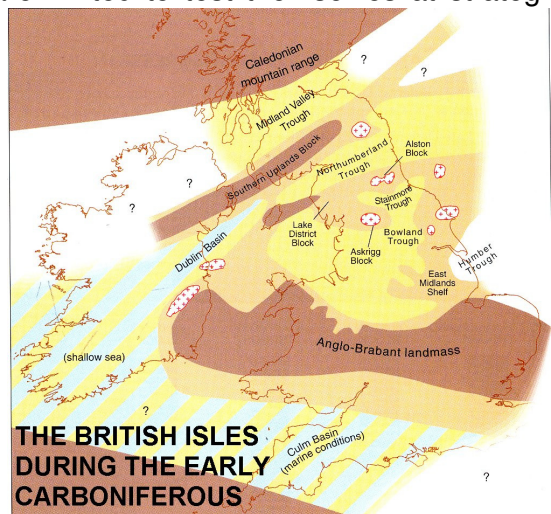
taken on OU field trips in the north of England; all persons wearing yellow safety helmets are students!

Being originally intended for students the readers are invited to test themselves at strategic points in the text. But if you are awake and consciously trying to learn you should find the questions fairly easy.

But it is not intended for raw beginners, being originally aimed at readers in their first year of a degree course. So if you feel lacking in sufficient background knowledge I recommend "*Geoscience-Understanding Geological Processes*" by Dee Edwards and Chris King; the ready availability of a dictionary such as "Dictionary of Earth Science" by would also be helpful.

I can recommend this book unreservedly; £18.95 from Amazon.com

Elvin Thurston



Announcements

In the last Newsletter we announced that a member of our Committee is now the Editor of a prestigious Journal. This time we are pleased to announce the career advancement of another member. Our Bulletin Editor, Dr Julian Andrews, is now

Professor Julian Andrews!

Perhaps being on the GSN Committee is a step to higher things! Join now!

Paper Review.....

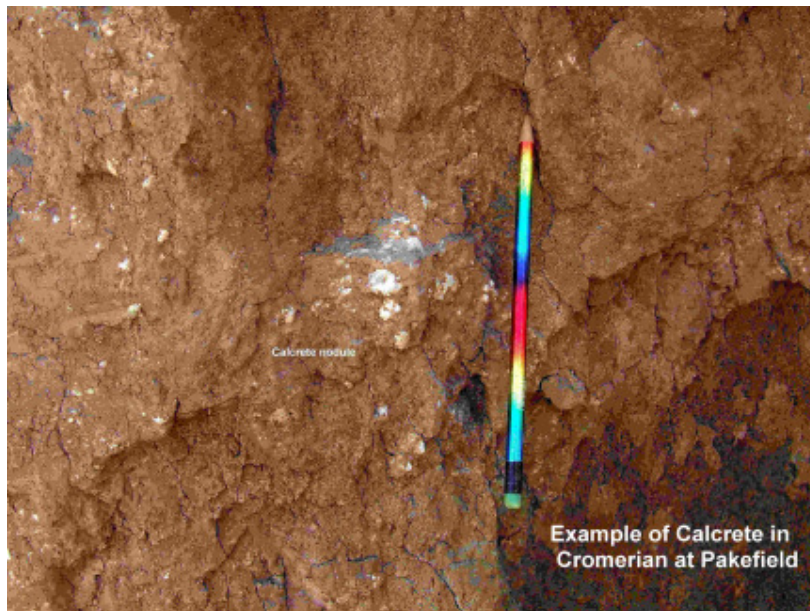
A seasonally 'dry' interglacial climate in eastern England during the early Middle Pleistocene: palaeopedological and stable isotope evidence from Pakefield, UK.

Ian Candy, James Rose, and Jonathon Lee, *Boreas* 35 (2006), pp 255-265

The Cromerian deposits, organic silts and clays, at Pakefield contain carbonate nodules (calcrete). These must have formed soon after the beds accumulated because the succeeding *Unio* bed truncates the horizons of carbonate nodules and some reworked nodules of it occur within the gravel lag at the base of the *Unio* bed.

No such large nodules are found in modern British soils. However they are found in soils where there is sufficient precipitation to dissolve and mobilise carbonate but not so much that it is leached from the soil. Such conditions occur where annual precipitation is >100 mm but not >800 mm.

The oxygen and carbon isotopic compositions of the soil carbonates were used as indicators of the environmental conditions. The two stable isotopes of oxygen, $\delta^{16}\text{O}$ and $\delta^{18}\text{O}$, when incorporated into water control its vapour pressure, the 'lighter' water evaporating more readily; thus in a different climate different levels of precipitation and evaporation would effect the oxygen isotope composition of included carbonates. Thus the $\delta^{18}\text{O}$ composition of the carbonate reflects the isotopic composition of the source water, which will in turn is controlled by temperature and evaporation. The two stable isotopes of carbon, ^{12}C and ^{13}C , are absorbed to different extents by vegetation; thus the $\delta^{13}\text{C}$ composition of the carbonate reflects the



composition of the overlying vegetation assemblage. The $\delta^{18}\text{O}$ levels of the Pakefield nodules are indeed unusually high, indicating either a 'heavier' isotopic composition of rainfall because of higher air temperatures and/or intense evaporation of soil moisture during calcrete formation. The $\delta^{13}\text{C}$ levels of the Pakefield nodules indicate carbonate precipitation under full interglacial vegetation

Although the current rainfall at Pakefield falls within the range required for nodules to form (ca. 580 mm) it is comparatively uniform throughout the year,

sufficiently so as to be unfavorable for calcrete formation; a more uneven rainfall distribution is required with evapotranspiration considerably exceeding precipitation, at least at certain times.

The presence of tree pollen from oak, pine, and elm, indicates that total annual precipitation levels were probably similar to those of today, and the presence of water chestnut and floating water fern shows that perennial bodies of water existed. Thus it can be concluded that precipitation was very uneven with dry periods during which the calcrete formed, but with sufficient precipitation at other times to maintain aquifers sufficient to allow the vegetation and water bodies to be maintained.

Modern Europe has two regimes with such marked rainfall seasonality – central and eastern Europe, with warm wet summers and dry cold winters, and southern Europe with cool wet winters and hot dry summers. Since the remains of *Hippopotamus amphibus* have been found at Pakefield the latter regime is obviously favored! Thus it seems that there is strong evidence for a Mediterranean type climate within the Cromerian interglacials.

Although we have no reason to ascribe this to high levels of carbon dioxide we might justifiably regard this as a prediction of the climatic regime that will dominate as levels of CO₂ increase in our climate in the near future.

This reviewer noted that although the authors attempted to describe the location of all Cromerian sites in England they did not mention Norton Subcourse. This is presumably the result of there being no publication of the results of research at that site in a peer-reviewed journal.

ET

Welcome to New Members this year.....

Your Editor has been criticised for neglecting to welcome new members. Apologies all round! We are pleased to welcome the following new members so far this year:-

Roderick	Parker	Keith	Roberts
Nicholas	Varnon	David	Mayhew
John	Lister	Christopher	Goldswain
Jill	Halliday	William	Kennett
		Rachel	Newsome

The geology of Norfolk and surrounding areas is unique and special being largely confined to the Cretaceous, Pliocene, Pleistocene, and Holocene.

But Geology, as you know, is a much bigger subject than anything to do with just these time periods. Do you feel that we are missing out by not having lectures or field activities associated with these wider aspects of the subject? Perhaps you would be interested in the geology of other areas? If you share any of these thoughts perhaps you would like to contact the General Secretary, at elvin.thurston@virgin.net, at 01603 708098, or even by surface mail.

If there is sufficient response we can proceed from there and act accordingly. **How about a long weekend with the geology of the Lake District!**

Future global warming scenarios suggest that Greenland Ice Sheet may be in a state of imminent collapse (see *Geology Today*. 2006. v.22, pp.98-103). Complete melting would raise sea level by about 7 metres. So should we feel worried about this? Find out by clicking on <http://flood.firetree.net>. This addictive new website combines Google Earth maps with NASA's digital elevation data to predict changes in the world's coastline following incremental sea level rise. Simply select the desired magnitude of flooding (you can raise sea level by up to 14 metres) and zoom in on your local area. By clicking on 'flood maps', you can overlay the street map network, and see if your house is one of those scheduled for submergence!

Notes on the usefulness of evidence from voles when discussing Middle Pleistocene stratigraphy.

By David Mayhew

The recent discussions about the age of the sediments underlying the tills of the Norfolk coast have led to comments about evolution and migration of the “water” vole *Arvicola terrestris*. In respect of this discussion the following points are offered.

a) Fossil remains attributed to *Arvicola terrestris cantiana*, (distinguished by having continuously growing molar teeth, yet with the relative enamel thickness in the triangles still in the primitive (*Mimomys*) character state) are found in the Netherlands under deposits attributed to the Elsterian glaciation (Noordbergum 13/ 14 boreholes, type of Dutch Cromerian IV interglacial).

b) Remains assigned to this taxon are found in faunas at Mosbach , Miesenheim-1, Kaerlich unit Gb, and Mauer, Germany, thought to be temperate stages which definitely preceed the Hoxnian/Holsteinian, and thus date from one or more temperate stages earlier.

c) The taxa *Arvicola greeni* and *Arvicola bactonensis*, now considered also to be synonyms of *Arvicola terrestris cantiana*, were described from sites on the Norfolk coast (Bacton, Ostend). It is now clear that these localities must come from a separate stage later than the type Cromerian deposits of the Upper Freshwater Bed at West Runton, which contain the vole *Mimomys savini*, which is considered to be an earlier evolutionary stage (or sister group) of *Arvicola terrestris*.

d) The deposits at Pakefield described as containing *Mimomys savini* and *Mimomys pusillus* must definitely pre-date (i.e. were deposited one or more stages earlier than) the type Cromerian deposits (UFB, West Runton) in which *M. pusillus* is absent. *M. pusillus* “disappears” all over Europe before *M. savini*, and the last record is said to be before the Don till.

e) The “changes” in voles seen in Western Europe appear in general to have resulted from replacement of one form by more “progressive” forms returning from the East due to environmental change. Return of progressive forms (or less evolved forms) from a Western refugium is not ruled out, but many of the evolutionary changes (increase in crown height, loss of roots) are considered a response to increasing aridity, more likely in the East. So evolutionary changes most probably did not occur in situ in Western Europe.

f) Allocation of an assemblage of vole teeth to *Mimomys savini* or *Arvicola terrestris cantiana* is solely possible on the basis of presence or absence of roots in mature specimens; young teeth may be unidentifiable. Intermediate populations would have had root formation delayed so much that only very few individuals had rooted teeth. The age composition of fossil assemblages is influenced by the taphonomy. Currently, *Mimomys savini* and *Arvicola terrestris cantiana* (i.e. populations with or without rooted molars) are not considered to overlap in space or in time, but its not ruled out over a (very) large geographic area for a limited time (one climatic cycle).

g) Spread or migration of rodent populations can be considered immediate in geological time. (i.e. kilometers per year). Therefore we could assume uniform distribution during migrations, however.....

h) There is actually quite a lot of geographical diversity in recent *Arvicola terrestris*, even in relative thickness of enamel of the triangles. The detailed changes in *Arvicola* through time in the late Middle and late Pleistocene are not necessarily simple, uniform or unidirectional.

i) If a hypothesis requires strange distributions of animals, reverse migrations and backward evolution, my conclusion is that the hypothesis needs checking.

j) Translated to OIS. If the Hoxnian interglacial is considered to be OIS 11 and the Anglian and Elsterian are both considered to be OIS12, then *Arvicola terrestris cantiana* was already present in OIS 13 (or earlier). *Mimomys savini* latest occurrence was OIS 15 (or earlier). Pakefield deposits (with *M. pusillus*)

would be OIS 17 or earlier. The occurrence of *M.savini* in sediments above and below the Don till (said to be OIS 16) can be accommodated in this scheme.

However, the occurrence of *Arvicola terrestris cantiana* in deposits supposed to be OIS17, underlying the deposits of the Happisburgh Formation assigned to OIS 16, is inconsistent, as already noted by e.g. Preece (2001), and requires investigation.

Affiliation: Dr D.F. Mayhew, Natuurhistorisch Museum Rotterdam

Contact: d.f.mayhew@wanadoo.nl

Reference: -

Preece, R., 2001, *Molluscan evidence for differentiation of interglacials within the Cromerian complex*. Quaternary Science Reviews, 20 (2001), 1643-1656.

More papers published recently

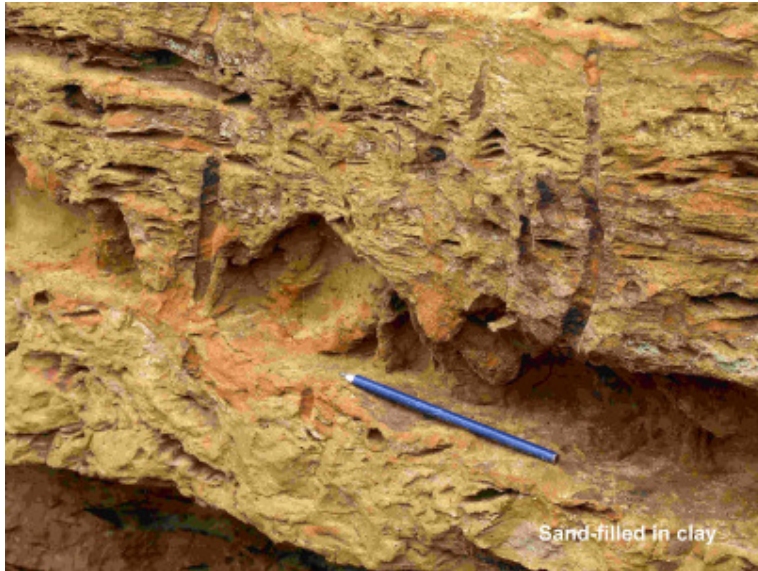
J. Rose (2006), *Context. A perspective on D. R. Bridgland's paper 'The Middle and Upper Pleistocene sequence in the Lower Thames: a record of Milankovitch climatic fluctuation and early human occupation of southern Britain'*, Proc. Geol. Assoc, 117, pp 277-280

D. R. Bridgland (2006): *The Middle and Upper Pleistocene sequence in the Lower Thames: a record of Milankovitch climatic fluctuation and early human occupation of southern Britain*. Proc. Geol. Assoc, 117, pp 281-306

Members are aware that recent interpretations of Pleistocene chronology in this area depend heavily upon interpretations of the age of river terraces, notably those of the Bytham River. For this reason alone they will be interested in these two papers that explain how by use of the Bridgland Model, now used in many parts of the globe, it is possible to explain river activity in terms of Milankovitch-scale climate forcing. The background principle is that the extensive erosion that takes place during cold periods as a result of solifluction etc. in the absence of soil-stabilisation by vegetation causes land levels to rise isostatically (i.e. by removing some of the load on the lithosphere). Consequently river terraces are formed at successively lower levels. Mammal assemblage zones developed by Schreve have reinforced the results of this work. Your editor has not yet read Bridgland's paper in detail (the illustrations are interesting enough!) but it is obvious that an up to date understanding of the middle and late Pleistocene in Norfolk and Suffolk requires more than a nodding acquaintance with the Bridgland model. This is particularly important for those who support or disagree with Rose's recent mid-Pleistocene chronology!

Members may also be interested to know that Prof. Rose will be giving a lecture to the Eastern Region of the OUGS in Cambridge early next year.

Field trips



We have had some excellent, well attended field trips this year, Dunwich and Covehithe to see the Norwich Crag exposures, Pakefield to observe the stratigraphy that has helped date the human artifacts found there, and to Happisburgh where an excellent pre-glacial hand axe was found. Although the policy of combining with other societies for such activities has been continued, that to Pakefield was purely a GSN activity; in spite of that we still had 27 attendees. Not bad for a Society with only ca. 120 members! Similar numbers attended the other trips. The "Chillesford beds" of the Norwich

Crag at Covehithe appear to be shallow water marine deposits laid down in shallow off-shore and beach conditions. They are usually described as indicating rising sea level. However your correspondent thought that there was more than one period of marine transgression to account for the observed thickness. So there was plenty of stratigraphic detail to see, with shallow water current bedding, mud-draped ripples etc. For me the bioturbated horizon at 1.5-2 m above the base of the cliff was particularly photogenic. There were sand in-fills of burrows in clay-rich sand, clay-rich infills of burrows in almost pure sand, and, more interesting, infills of iron-free sand in iron-containing sand.



In spite of many constraints and difficulties our Field Secretary has once again this year done us proud!

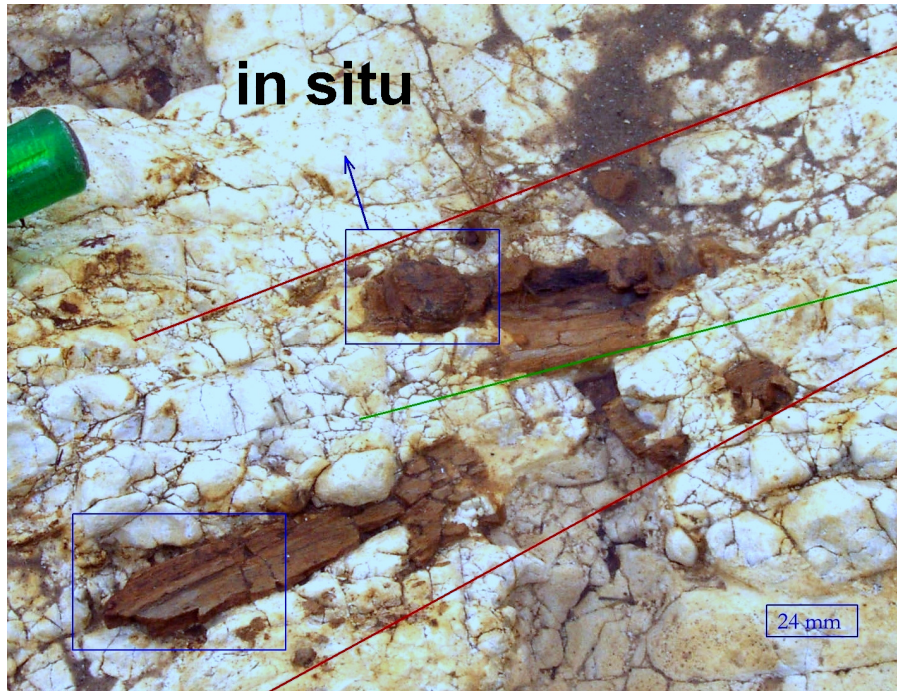
Thank you, Peter.

We hope your other activities in earth science do not distract you too much from the GSN!

An important reptile find from the Chalk on the north Norfolk coast: Its collection, conservation, taphonomy and taxonomy

See illustration at the front of this newsletter!

In early April I was fortunate enough to find a piece of reptile bone at the Water Lane Major Omission Surface, West Runton. This location is close to the famous “West Runton Bone Bed”, but there are several beds in the vicinity that yield scarce vertebrate material. The specimen and the chalk in which it was embedded were very badly fragmented. In fact, the chalk could be described as having the texture of clotted cream: some harder nodules amidst the softer parts! I took the first photograph reproduced here



before trying to extract it. I envisaged a nightmare 3-D jigsaw puzzle ahead of me, and I was not far wrong! That aside, these photos are useful for showing other collectors the sort of damage that these rare fossils tend to suffer from and what they look like when found in situ.

It took me about an hour to extract the specimen; I used a pruning saw to create pairs of channels (wide enough to take a chisel) around the specimen. The intention was to try and isolate a rectangular block of chalk containing the specimen and then to undercut this to release it. Unfortunately, the intensely

fractured nature of the chalk and even worse condition of the specimen meant that this exercise was only partially successful. So, whilst a block was isolated (the channels around which continually filled up with chalky seawater so that it was difficult to see anything!) it had insufficient structural strength to be collected as a single unit. The “block” such as it was, was detached from its underside and the resulting melange of chalk fragments were scooped into a plastic shopping bag and packed as carefully as possible for transport home. Any specimens collected from the coast must be soaked in fresh water to flush out the salt (otherwise this crystallises, expands and then shatters your specimen). With the specimen and its matrix by now in umpteen different pieces the prospect of washing this did not appeal.

When I finally got the specimen home any obvious “rubbish” was isolated and discarded, and the remaining material was carefully washed and a moderately dilute solution of wood glue (Evo-stik wood adhesive + water) was painted along the edges of the fragments to strengthen them whilst they were being desalinated. (It is also possible to paint “bandages” around a specimen to hold it together, much as one might tie string around a parcel. These thin glue bandages are easily peeled off once they are no longer needed.) When the desalination process was complete, a dilute solution of wood glue was permanently applied to all exposed, clean bone surfaces to soak in and protect these.

Continued preparation using water and fine paintbrushes gradually removed the softer chalk, progressively exposing fragments of the specimen, (it was very broken up). Dissecting needles and fine scalpels (cheaply available from toy and modelling shops, e.g. Langley’s in the Arcade, Norwich) were employed against the harder chalk. As before, any newly exposed bone was painted with dilute wood glue. Because the specimen was highly fragmented, in order to reassemble it various orientations would need to be experimented with to try and identify matching fracture surfaces. The extra strength imparted by the dilute wood glue was essential to protect the surfaces of various fragments as they were manipulated and matches sought.

(N.B. It is considered “best practice” by conservators not to use or apply any technique to an object being conserved that cannot be reversed. For any conservator reading this there is an audience in the GSN who is prepared to listen and learn about which products to use, where to obtain them from, how

much they cost and how to use them. I dare say that this newsletter's editor will cheerfully publish one or a series of articles on this topic.)



The specimen *in situ*

The main photo (previous page) shows two blue boxes; these indicate regions of the specimen that survived the journey home intact. The arrow on the upper box indicates the orientation of a tooth socket, (parallel to the strata). The pair of red lines indicates the boundary of the area within which fossil material was apparent on site; the green line indicates a line along which the specimen, which is mainly a (left, lower?) mandible, had split and seemingly rotated. The erosion that had exposed the specimen had also undercut and removed many bone fragments (as can be inferred), and the higher bits of bone were covered with pungent algal slime. A quite substantial piece of bone and part of the jaw was not visible on site and was only found during later preparation.

Taphonomy

The second set of photos (this page) shows a selection of material that had been cleaned. These include those shown in the blue boxes in the first photo; the almond shaped tooth socket is clearly visible). A tooth that was discovered during preparation is shown; its recurved profile confirms that the specimen is part of a broken and crushed mosasaur jaw and possibly part of the skull too. A broken segment of a solid, elongate bone was also found; its function is not yet known, it may be part of the underside of the jaw. Finally, close-up shots are given of bioerosion of the bone surface. Radiating scratch marks attributable to the jaw apparatus of regular echinoids cover much of the upper surface (as found *in situ*); these belong to the trace fossil *Gnathichnus pentax* Bromley 1975.



Taxonomy

Specimens of major vertebrates are very rare in the East Norfolk Chalk, it is rarer still for these to be sufficiently complete to be identifiable below family level. Specimens from the Upper Campanian are always severely bioeroded whereas Maastrichtian examples are usually nearly pristine, even when incomplete. The recurved tooth has been compared with recent monographs of European Late Cretaceous mosasaurs. The tooth is the best clue to the probable identity of the specimen. It is triangular in cross section with an anterior keel, it is gently recurved with a worn tip and the posterior of the tooth is flattened. This suggests that it might have affinities with the mosasaur *Leiodon sectorius* (Cope, 1871), but this is an Upper Maastrichtian species and the specimen comes from significantly older upper Upper Campanian strata. The small size of the teeth sockets and tooth (11 mm high) suggest that this was a juvenile individual, perhaps 1.25 – 1.5 m long.

