The Quaternary Stratigraphic Framework & Timeline

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Rationale and Aims

- Terrestrial sequence is incomplete & fragmentary with many hiatuses – how do we produce a reliable, single stratigraphy?
- To reconstruct the history of a **single** site
- To correlate multiple **sites** across a region
- To relate regional stratigraphy to **continuous climate records**

Early terrestrial correlations

1940s-1970s: British Quaternary stratigraphy was constructed using:

- Lithostratigraphy for glacial & fluvial deposits
- Pollen-based biostratigraphy (for interglacial deposits)

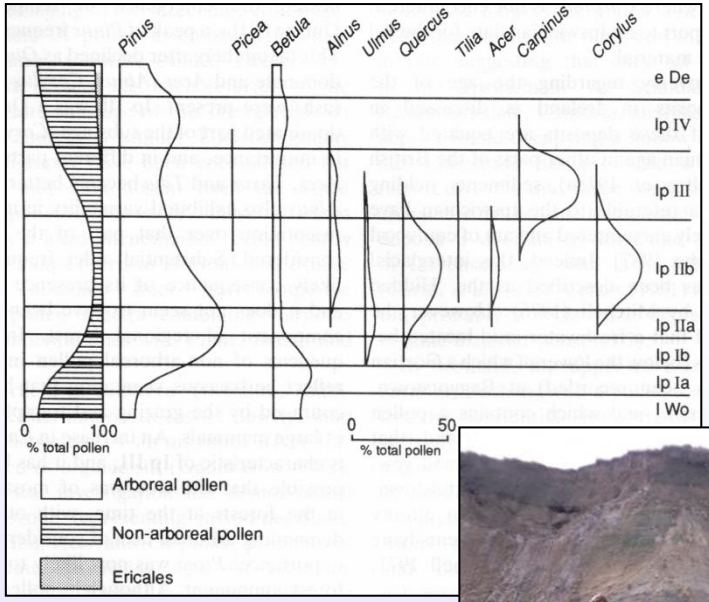
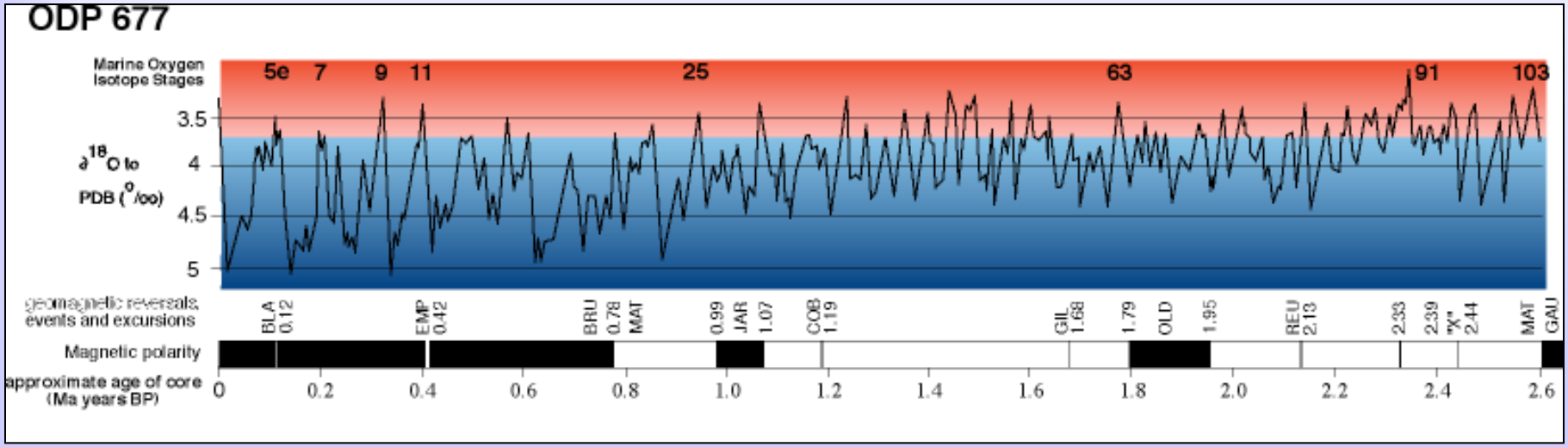


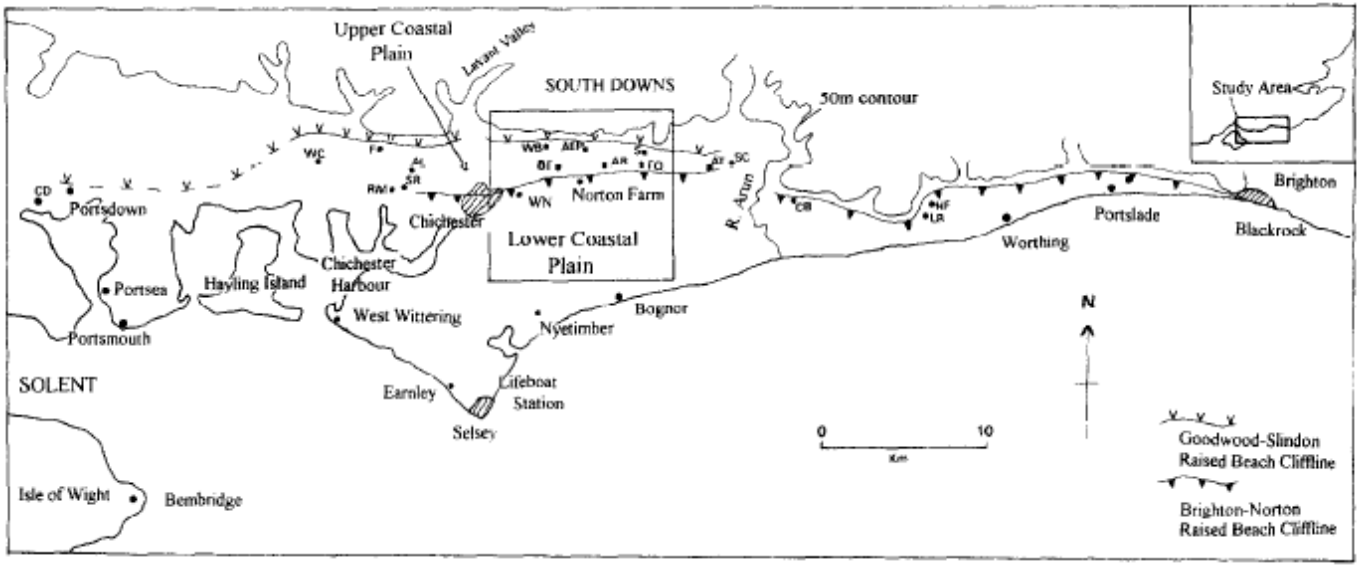
Table 1.1 Major divisions of and gross timescale for the later part of the Cenozoic. Pleistocene divisions in the British Isles: sources, Mitchell *et al.* (1973a), Funnell and West (1977), West (1977a), Funnell *et al.* (1979), Stuart (1982), Warren (1985). Additional sources: Bowen (1978), Curry *et al.* (1978), Zagwijn (1985)

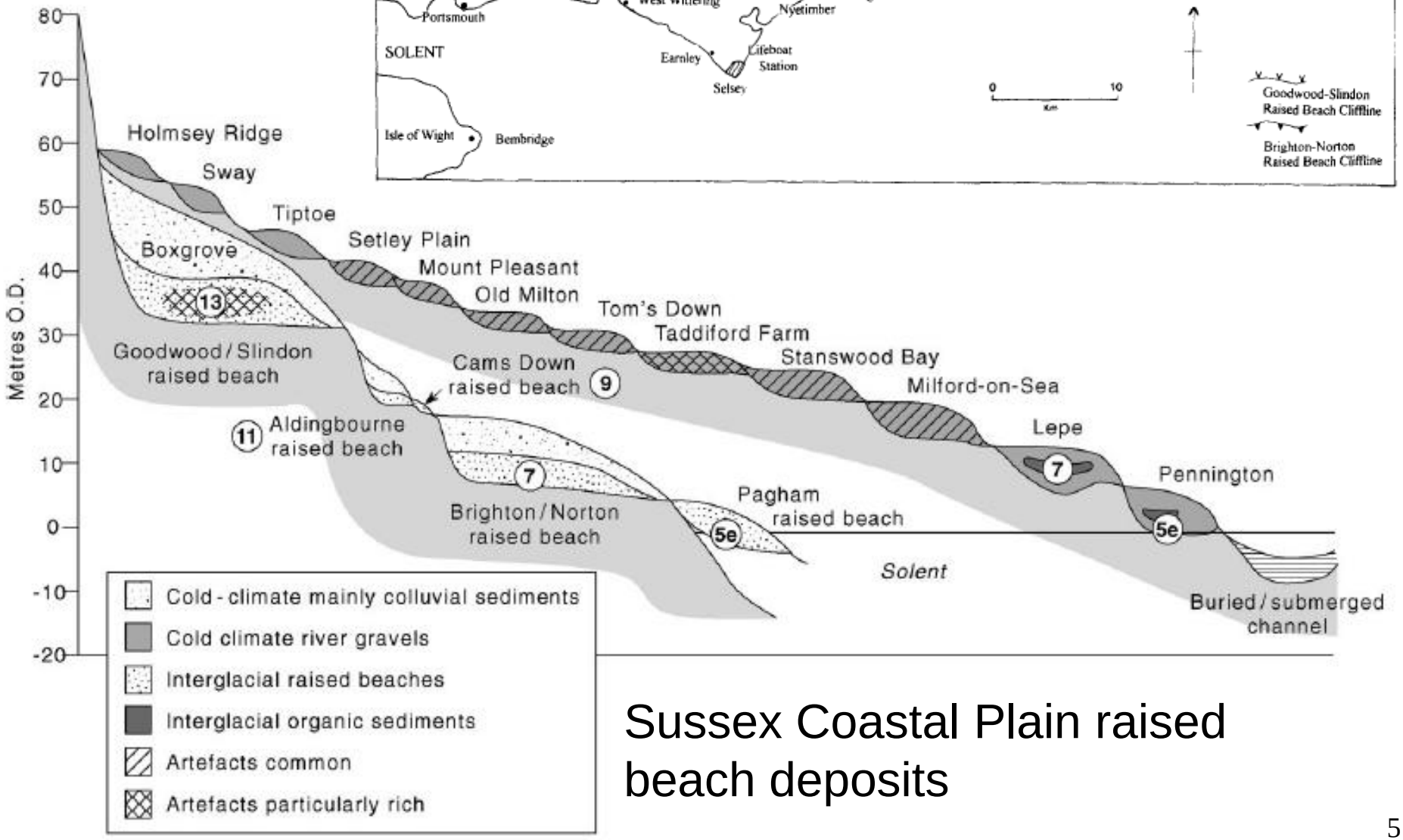
Approximate age of commencement (Ma BP)	*Epochs*			*Stages*		
				Britain	*Ireland*	*North-western Europe*
0.01	Quaternary	Pleistocene	Upper (Late)	Flandrian (t)	Littletonian	Holocene
0.115				Devensian (c)	Midlandian (Fenitian)	Weichselian — Late
				Ipswichian (t)	Last Interglacial	Eemian — Late
				Wolstonian (c)	Munsterian	Saalian — Middle
0.3			Middle	Hoxnian (t)	Gortian	Holsteinian — Middle
				Anglian (c)	Pre-Gortian	Elsterian — Middle
0.5				Cromerian (t)		Cromerian — Middle
				Beestonian (c)		
				Pastonian (t)		
				Pre-Pastonian (c)		
				Bramertonian (t)		
			Lower (Early)	Baventian (c)		
				Antian (t)		
				Thurnian (c)		
				Ludhamian (t)		
2				Pre-Ludhamian		
				t, temperate; c, cold		
		Pliocene	Late			
			Early			
5	Tertiary (Neogene)					
		Miocene	Late			
			Middle			
			Early			

- Correlation of interglacial deposits & occurrence above/below key stratigraphic units
- Glacial/interglacial stages named after type sites

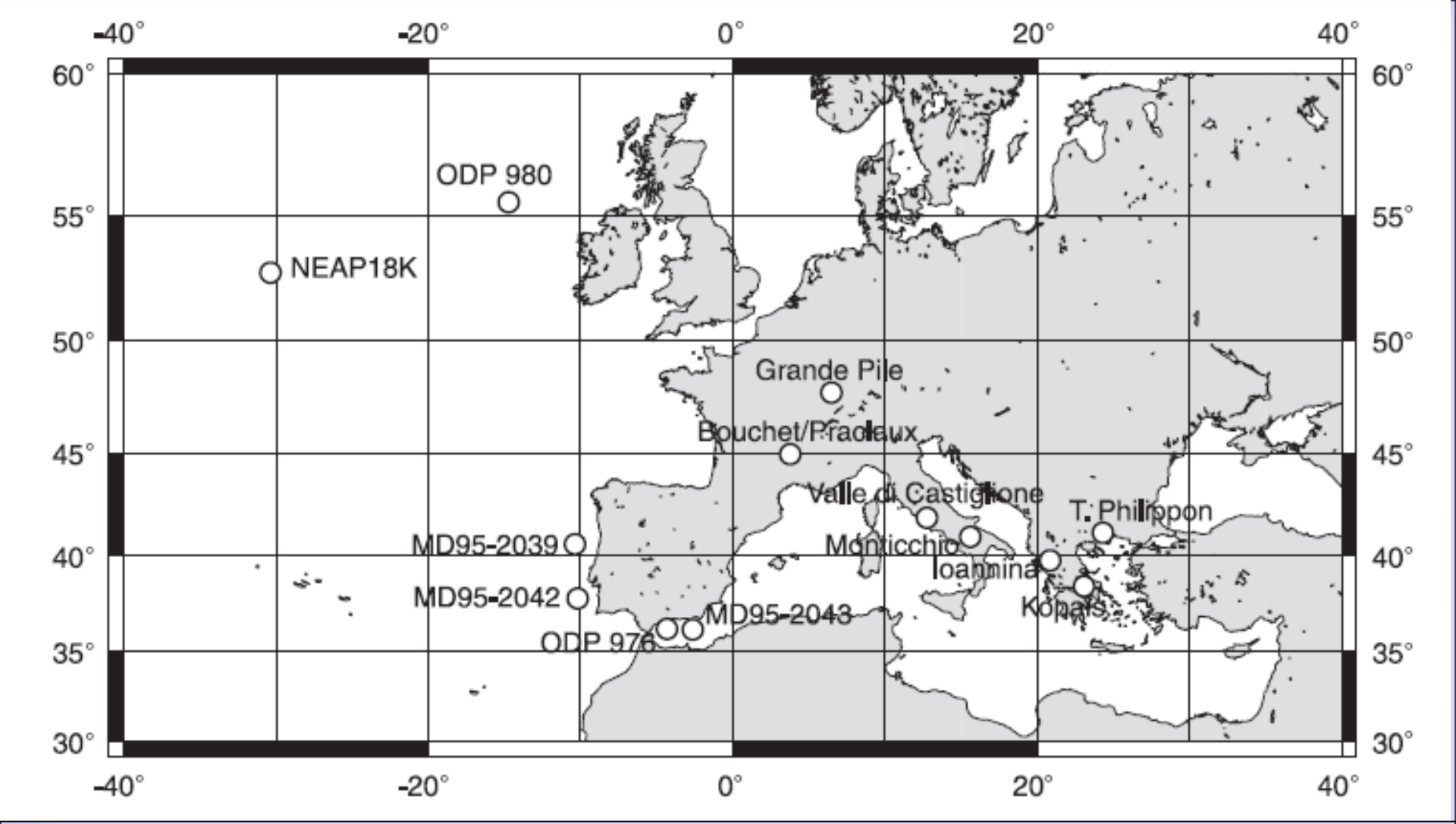
- Now, marine isotope record offers yardstick for interpreting Quaternary - stratigraphic template, to which terrestrial deposits may be correlated
- Land-Sea correlation now widely (but not uniformly) used as the basis for terrestrial stratigraphy construction
- Number/amplitude of climatic episodes





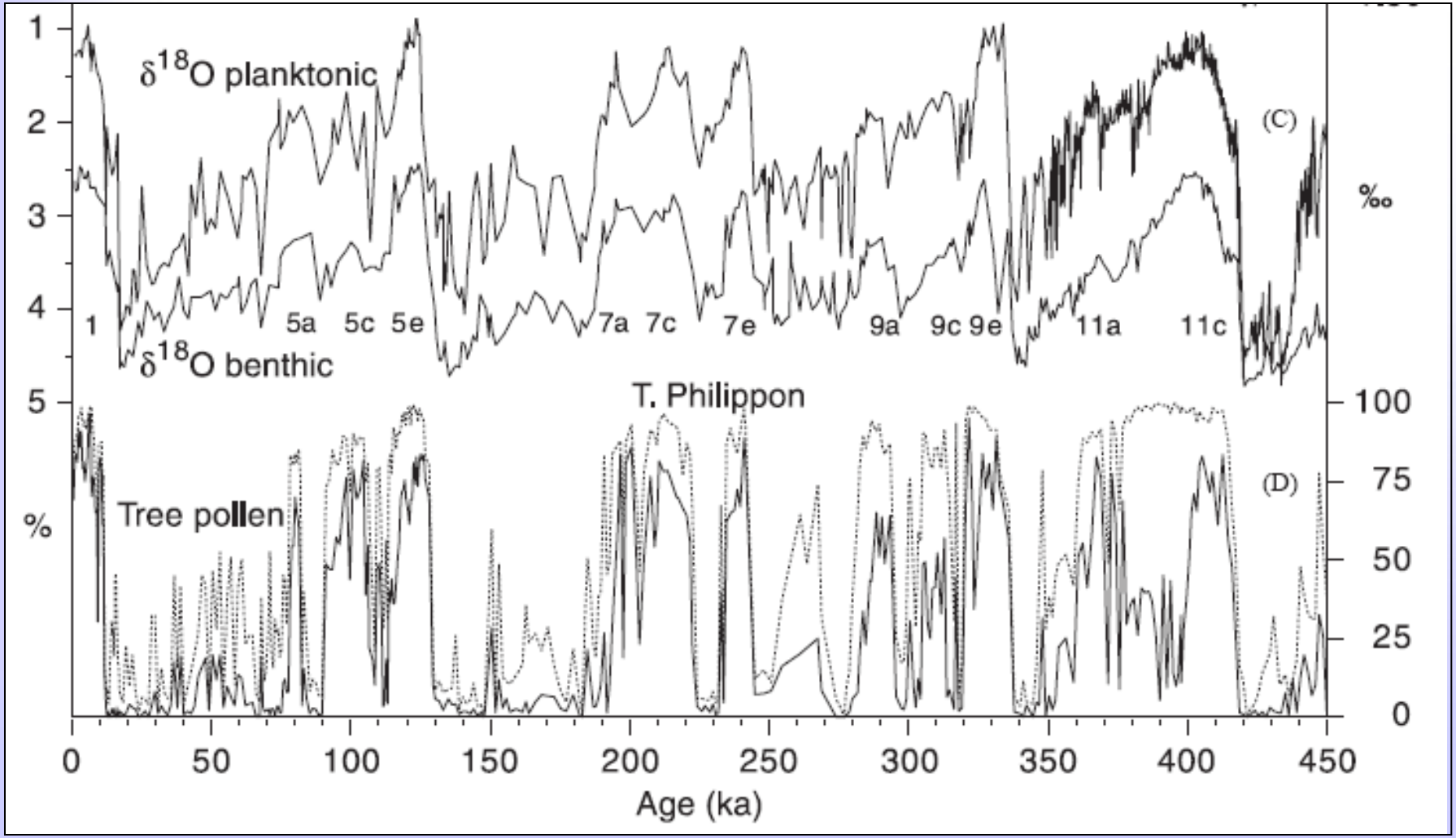


Sussex Coastal Plain raised beach deposits



Long “continuous” sediment records of Europe

Orbital tuning of long records of % tree pollen at T. Philippon and the marine record of glacial and interglacial cycles

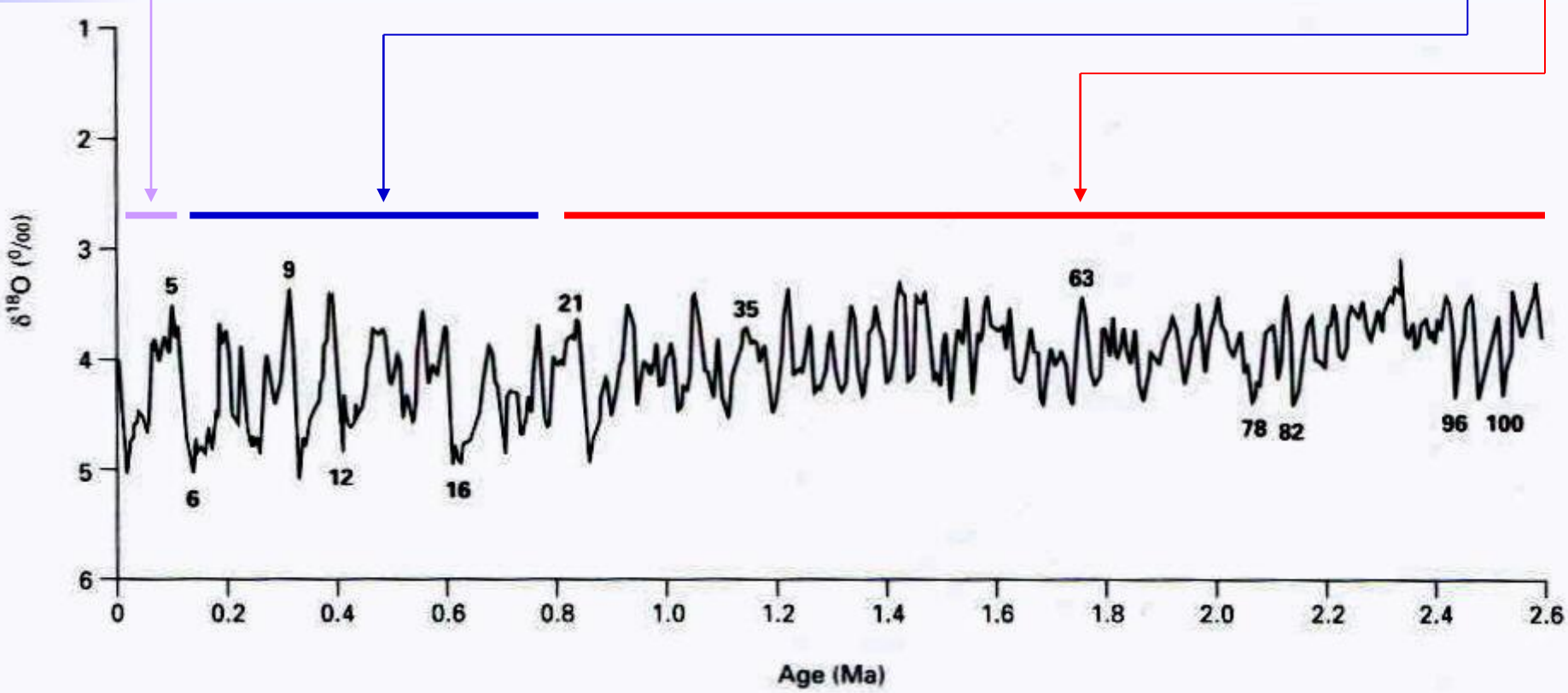


Dividing up the Pleistocene:

Early Pleistocene – 2.6 Ma to 0.78 Ma BP

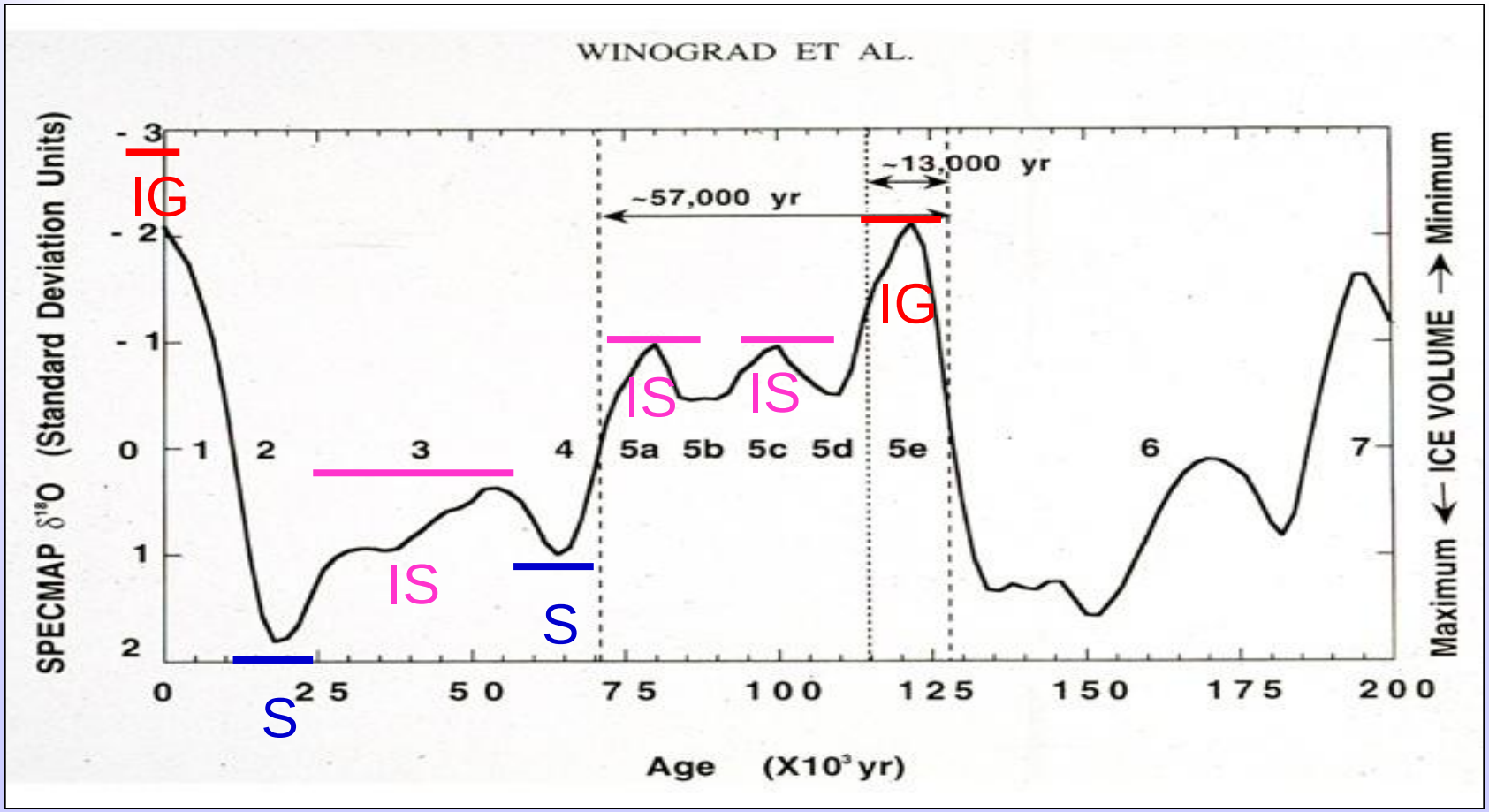
Middle Pleistocene – 0.78 Ma to 0.13 Ma BP

Late Pleistocene – 0.13 Ma to 11.5 ka BP

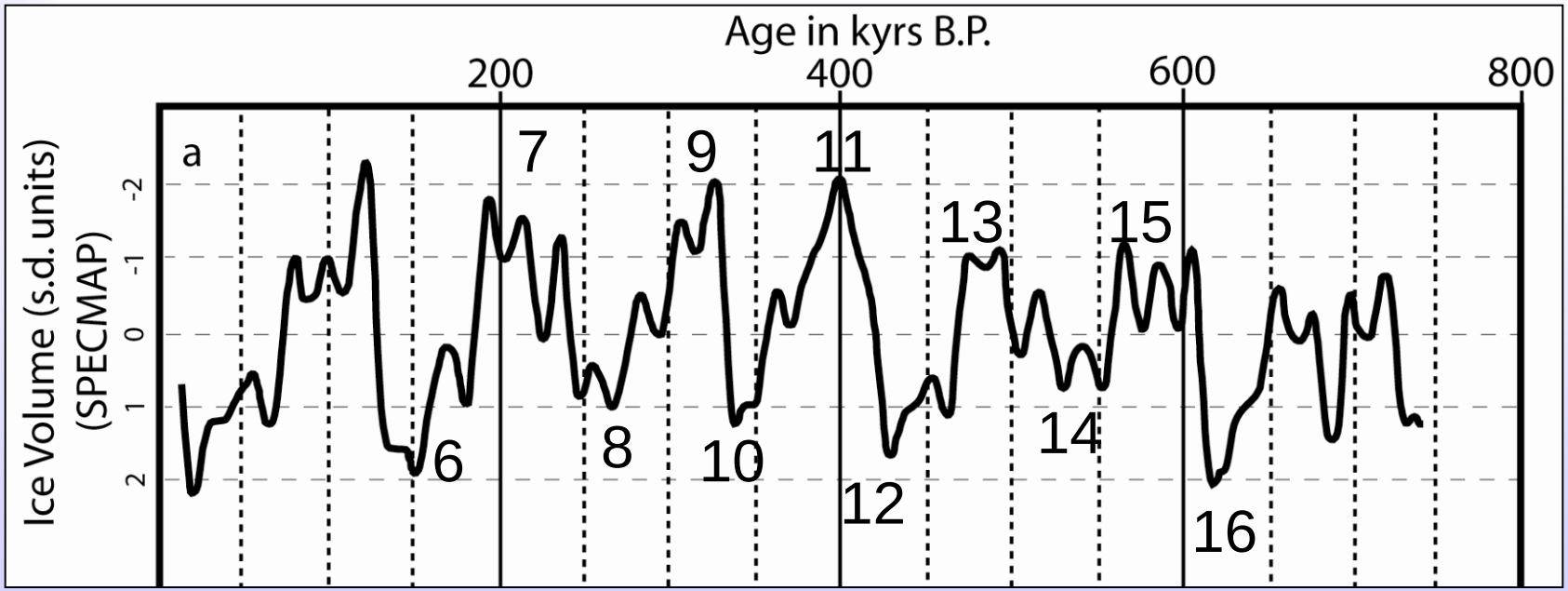


Marine Oxygen Isotope Stages

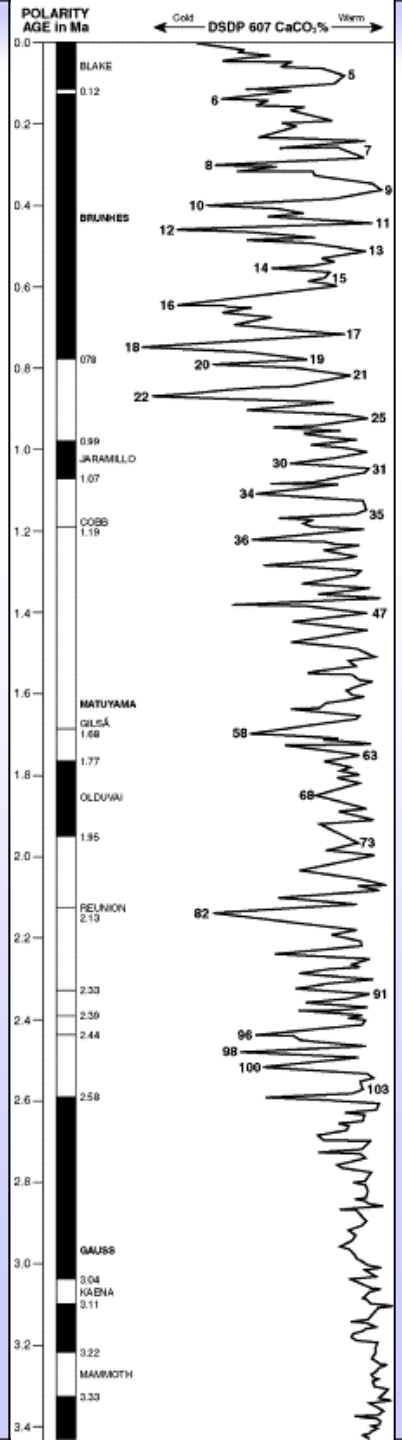
- Individual stages numbered, odd & even
- Every shift over last glaciation is numbered



- Further back in time, lower resolution due to compaction
- Fluctuations not as clear so only glacials & interglacial numbered
- Ice volume below/above mean



- Interglacial typically refers only to first warm peak, eg. 7e, 5e



Magnetostratigraphy

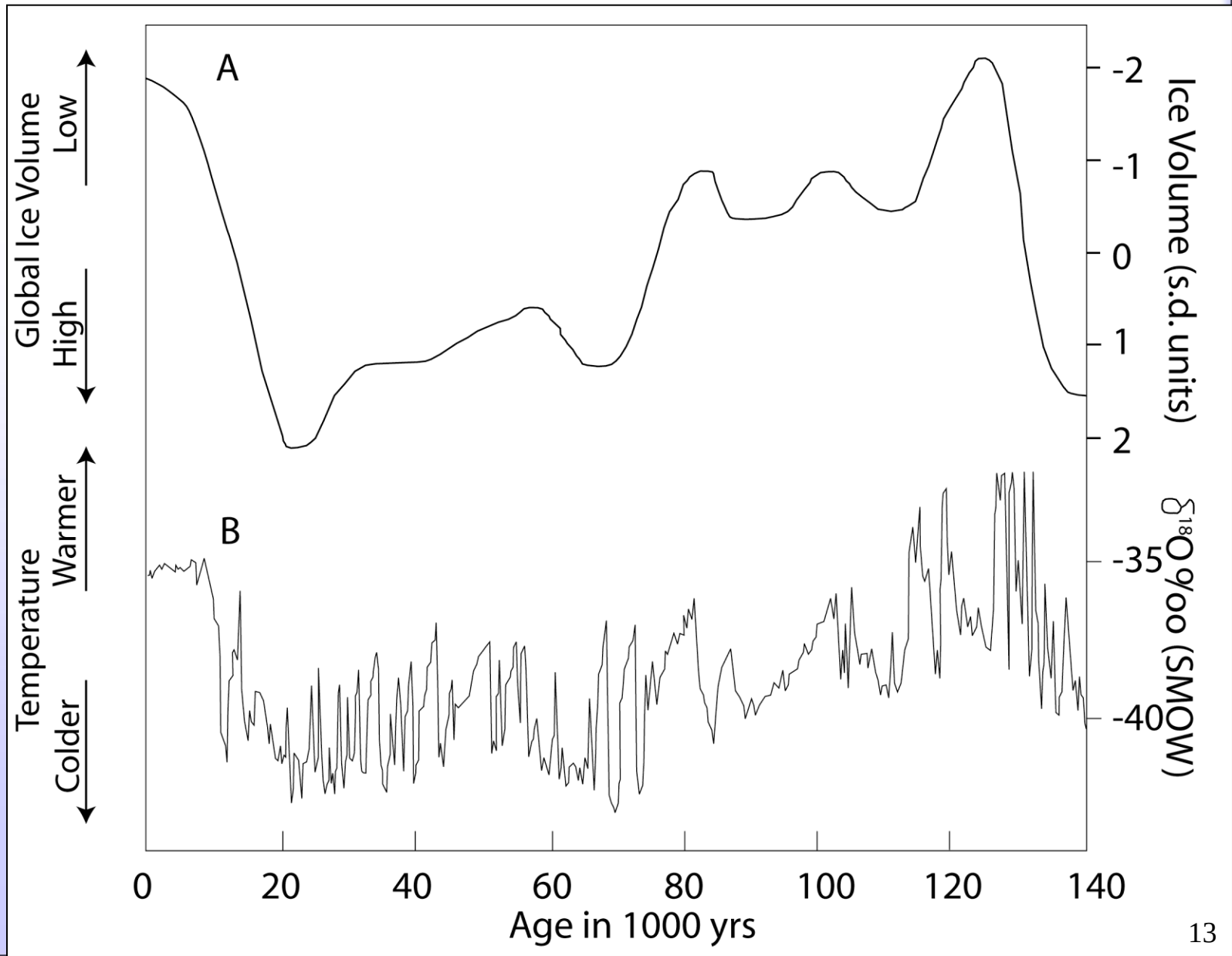
- A broad stratigraphic tool, based on magnetic reversals
- We currently have “normalised magnetism” and we are in the Brunhes Chron (since ca 0.78Ma BP)
- Prior to this “reversed magnetism”, the Matuyama Chron (0.78-2.6 Ma BP)

Ice cores – a more detailed stratigraphy for last 130kyrs – annual laminated bands

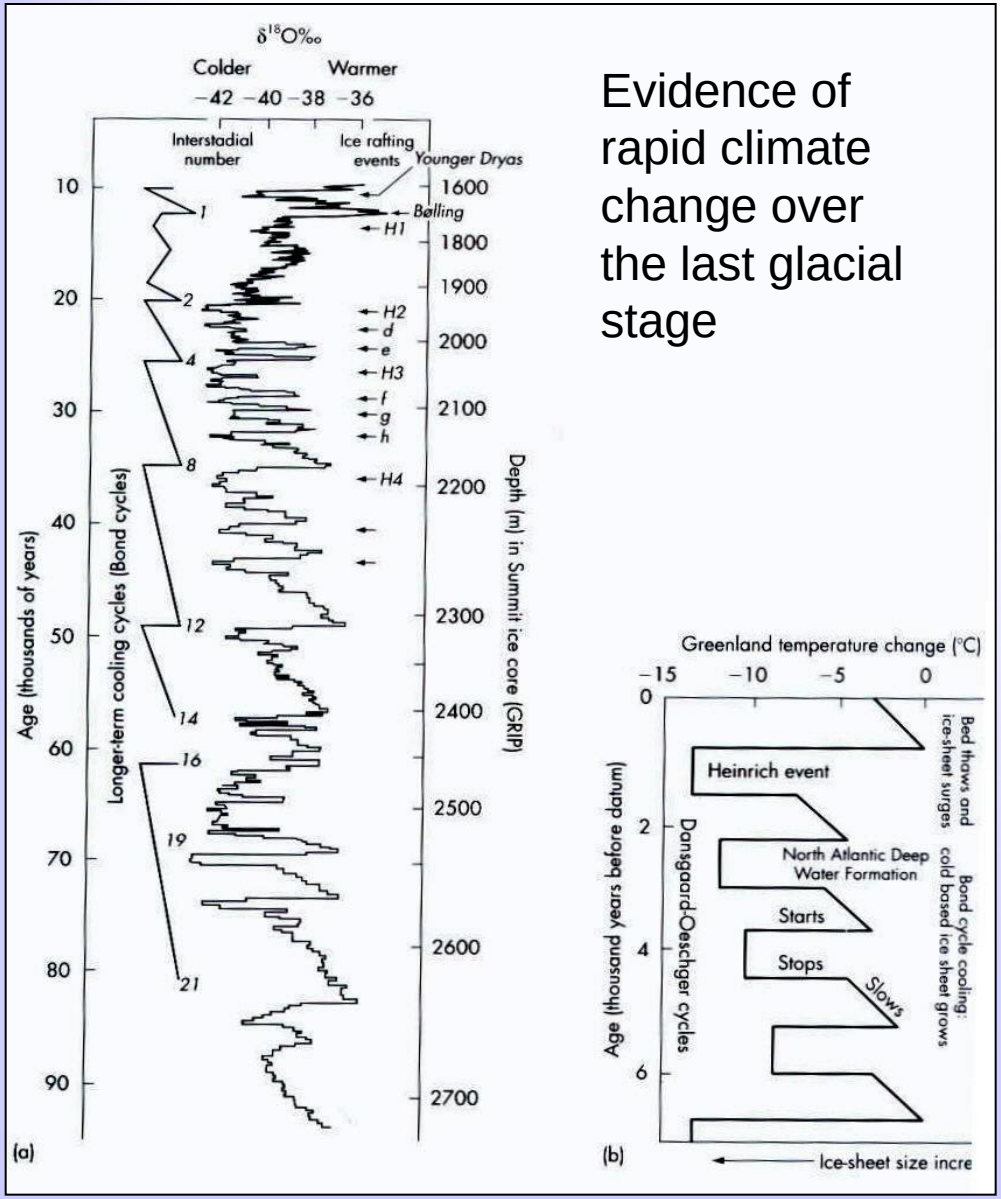
Comparing the Marine and the Ice core record

Low resolution archive

High resolution archive



Late Pleistocene-Holocene



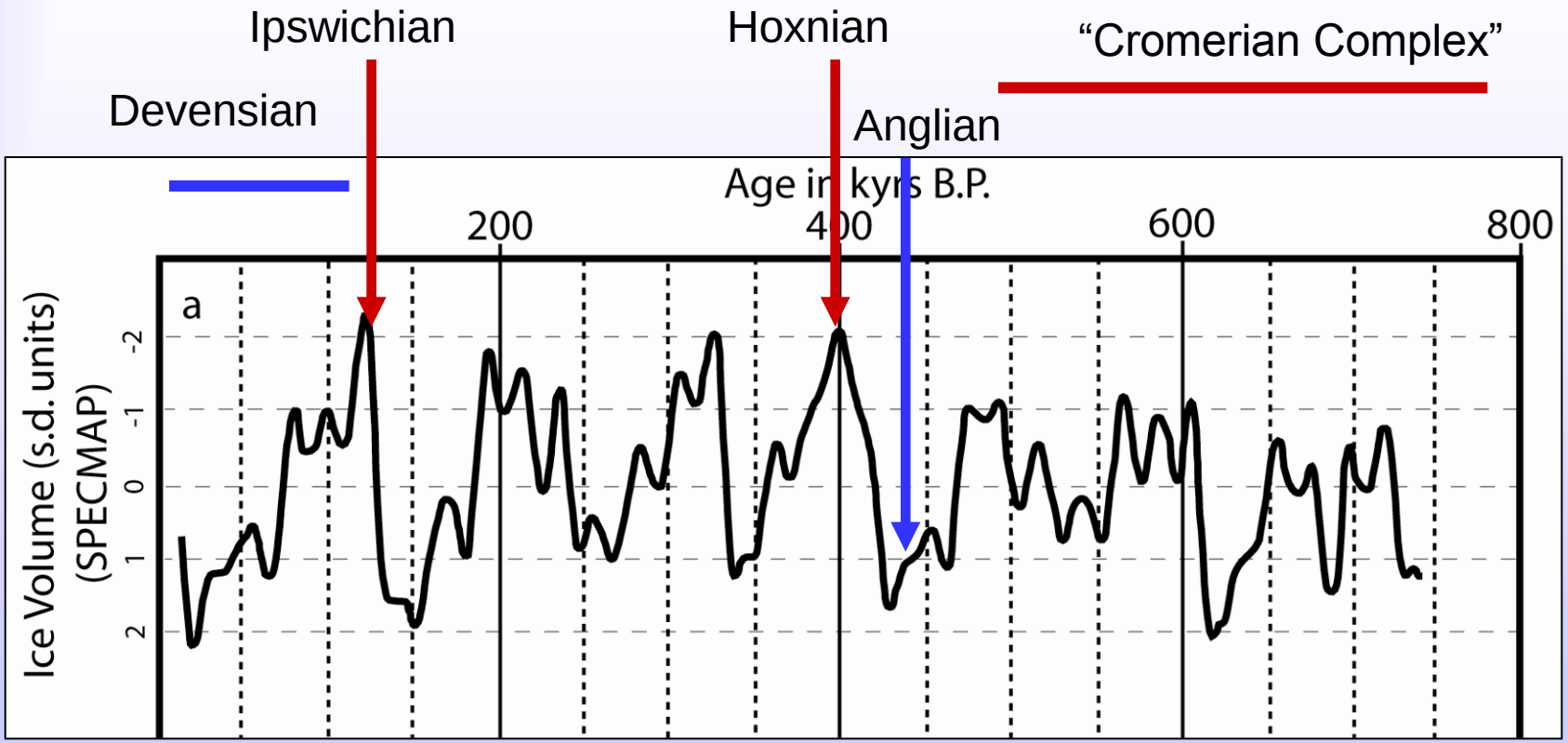
Evidence of rapid climate change over the last glacial stage

- Key goal to correlate terrestrial sequence to climatic framework of ice cores
- Possible through application of multiple dating techniques
- Also through better preservation potential of sediments from this time period

Towards a resolution

- Previous conflation of deposits of different interglacials into one – common problem
- Many more interglacials/glacials than previously thought
- Now attempts to correlate warm & cold stage deposits with marine/ice core record
- Based on multi-proxy approach:
  - Biostratigraphy (esp. mammals, molluscs)
  - Lithostratigraphy
  - Morphostratigraphy
  - Geochronology

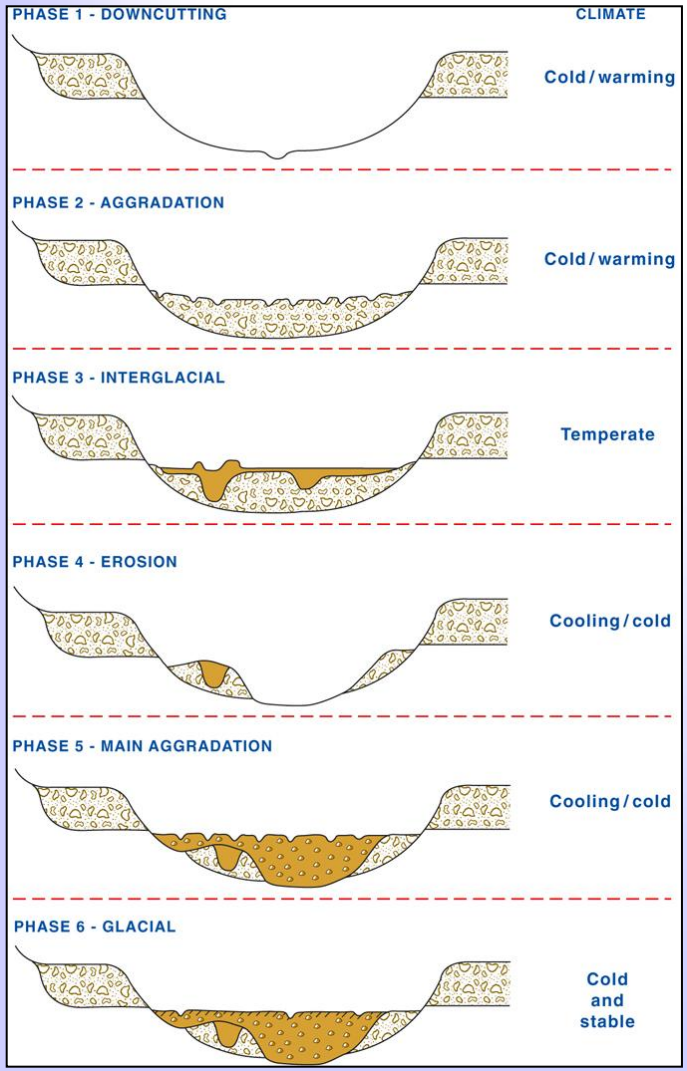
- Many British IG/G stages now confidently correlated with MIS record back to 500ka, plus new ‘unnamed’ stages
- Resolution remains poor prior to 0.78Ma – more work being done



Morphostratigraphy

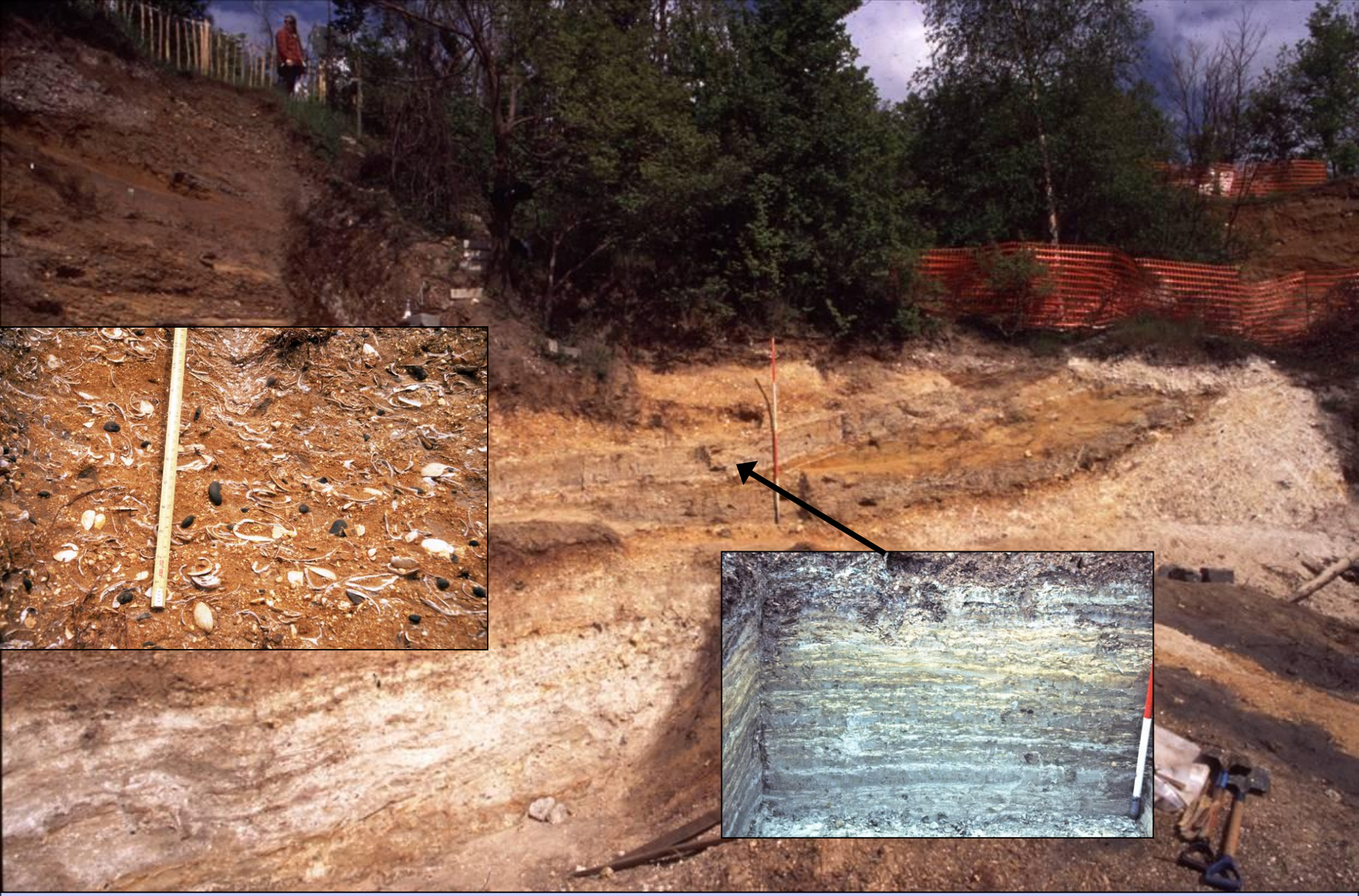
- Placing of sediments associated with landforms into a relative order (chronology), eg. river terraces, raised beaches, glacial landforms
- Can be used to test stratigraphic conclusions from faunal assemblages
- Faunal assemblages in lower raised beach/terrace must (normally!) be younger than those in high landforms
- Can then be applied to regions where morphostratigraphy is absent

River terraces

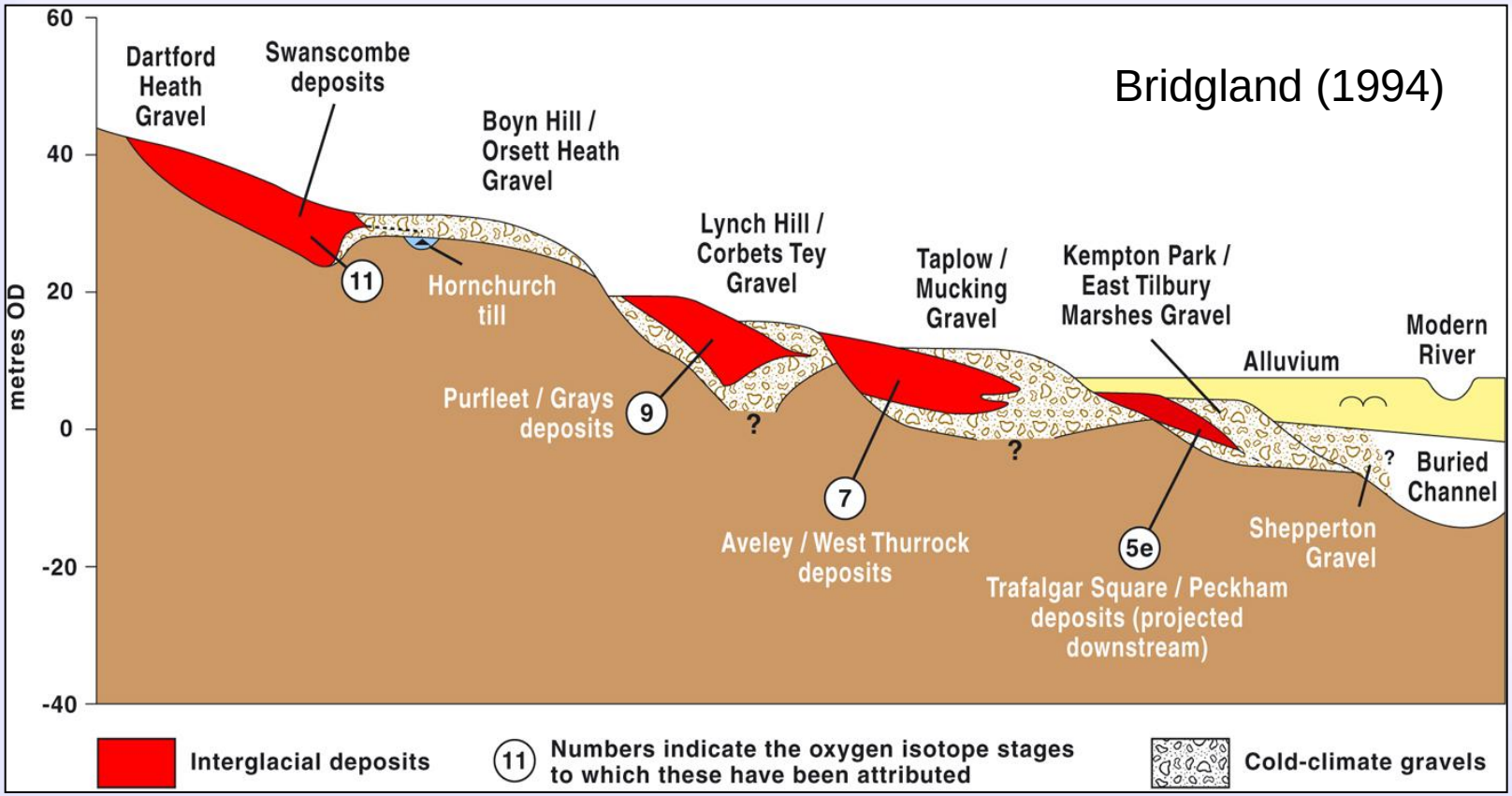


After Bridgland & Allen (1996)

- Major river systems in NW Europe contain series of terrace landforms in valleys
- Old floodplain deposits uplifted into the landscape by neotectonics
- Long-term archives of environmental change
- Each terrace has fully interglacial deposit, sandwiched between two gravel bodies



Purfleet, Lower Thames (Schreve *et al*., 2002)



Terrace deposits of the Lower Thames

- Four major terrace aggradations above modern river
- According to Bridgland 1994 model, each contains a different interglacial

Raised beaches

- Just as river systems have “staircases” of terraces, coastal regions have “staircases” of raised beaches
- Raised beaches form during interglacial highstands
- Separated vertically by uplift

Upper Jurassic Portland Stone at Portland Bill under attack by storm waves. Seawater is forced into bedding planes and joints. The Red Crane is on an Ipswichian Interglacial raised beach platform. (photo from 70s or 80s) *Ian West (c) 2004*

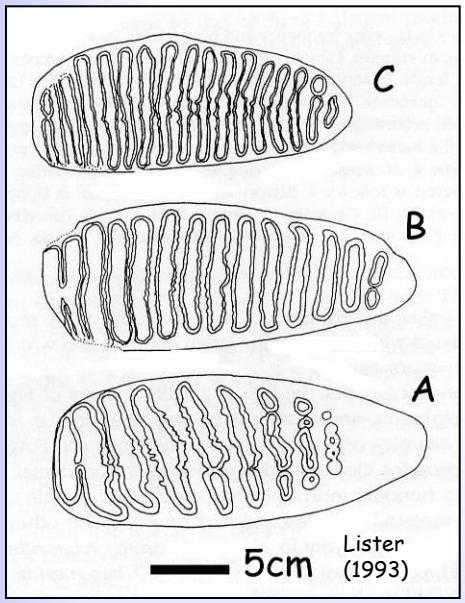
Portland raised beach, Dorset, 15m above modern SL

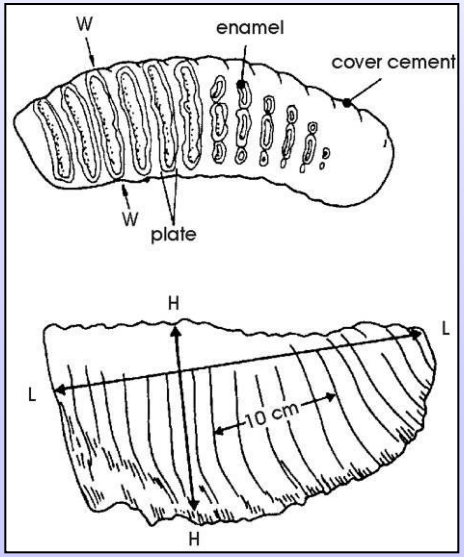
Biostratigraphy

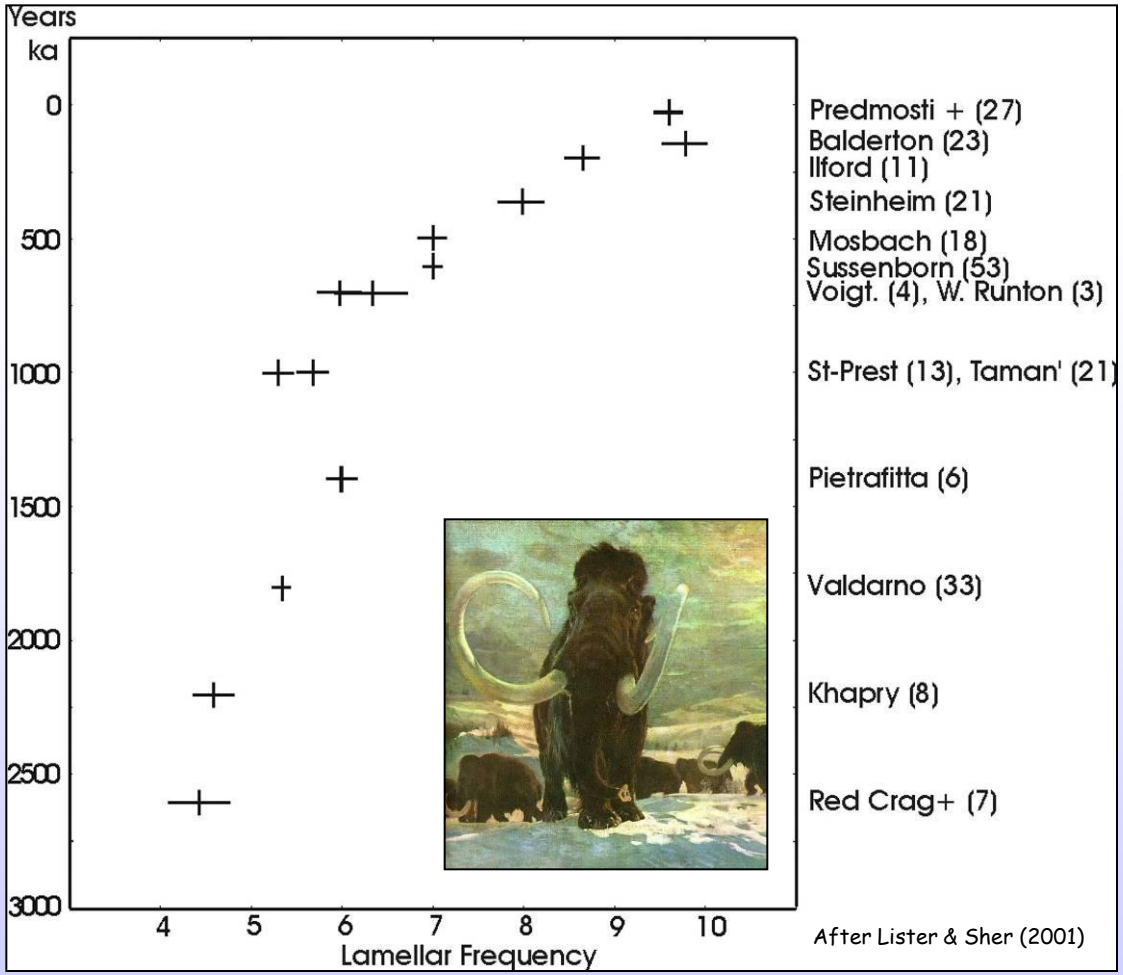
- Powerful tool for recognition & correlation of different time periods (now down to MIS substages)
- More suitable than any other biological group as (1) rapid turnover (origination & extinction) & (2) quantifiable evolutionary trends
- Presence/absence of particular species & FAD/LAD
- Evolutionary stage & morphological change
- Assemblage composition

Evolutionary trends in mammoth

A: *Mammuthus meridionalis*, 2.6-0.7Ma
B: *Mammuthus trogontherii*, 0.7-0.2Ma
C: *Mammuthus primigenius*, 0.2-0.01Ma



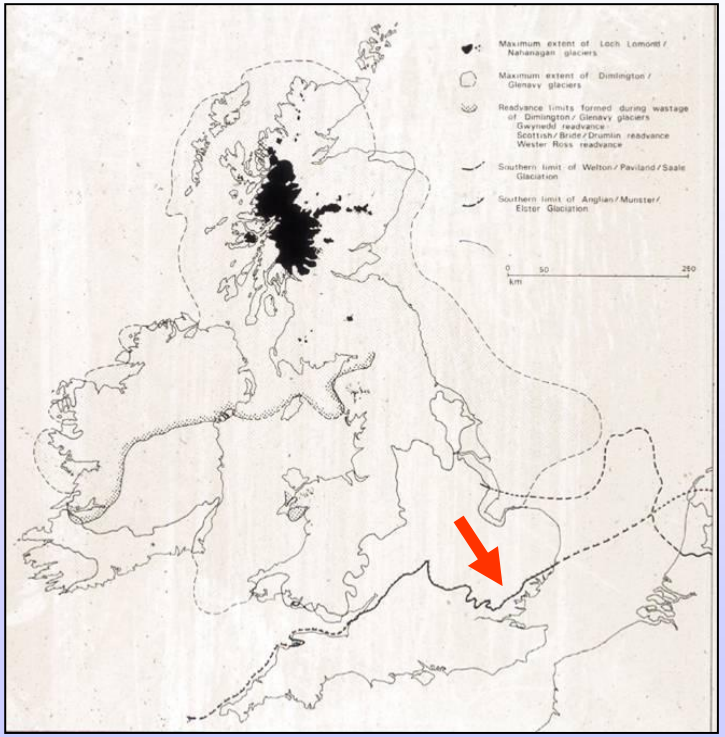


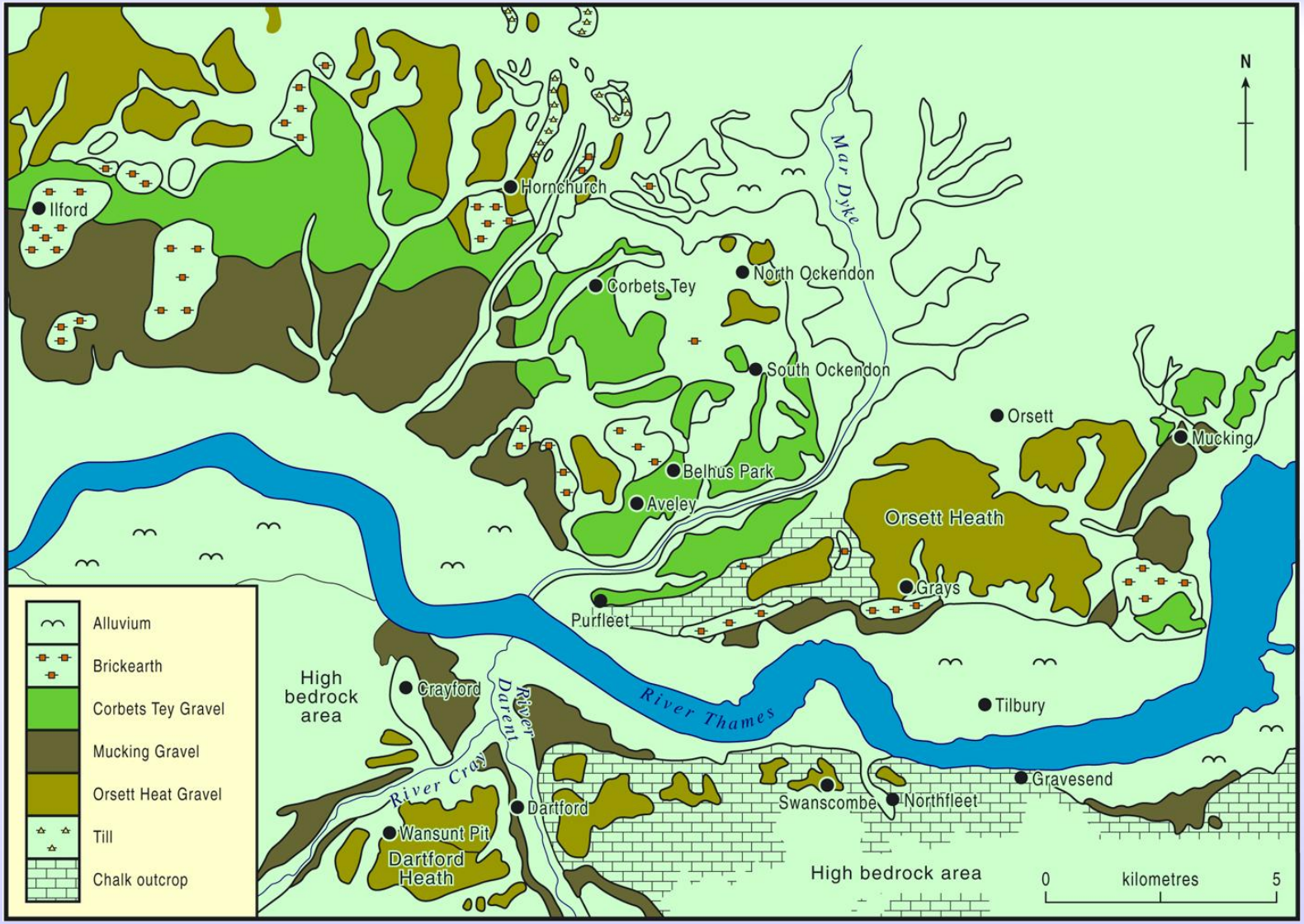


Lithostratigraphy

- Certain sedimentary units are important age markers & can be used to correlate a diverse range of deposits across a wide area, eg. palaeosols, glacial tills

Chalk rich Lowestoft till, deposited during Anglian glacial (MIS 12)





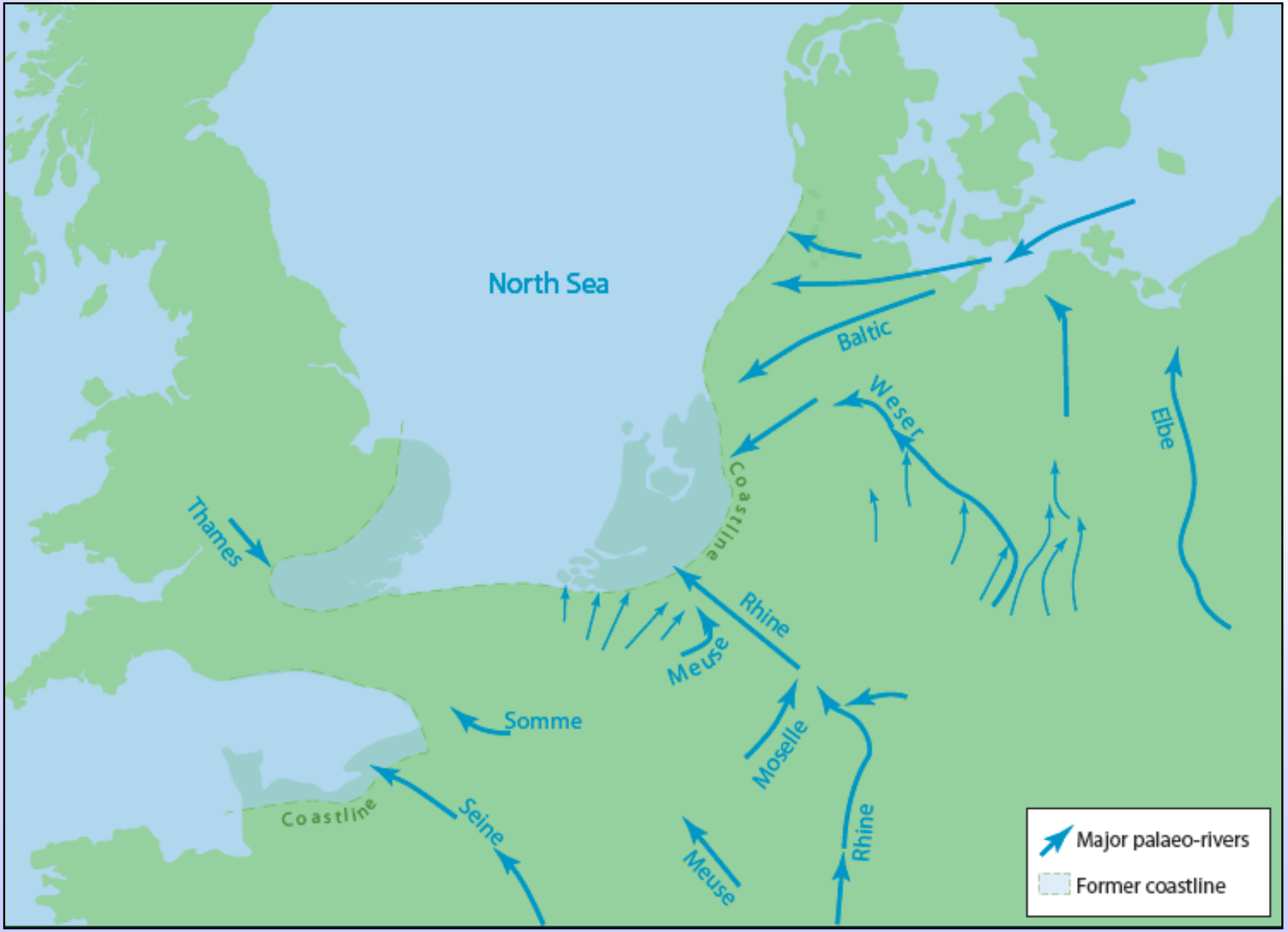
- As well as morpho- features, river terraces are regionally-correlateable lithological units

Chronostratigraphy

- Not many dating techniques can be applied to terrestrial sequences in Britain
- Techniques applied:
  - Radiocarbon
  - U-series
  - Optically Stimulated Luminescence
  - Amino Acid Racemisation
  - Orbital Tuning

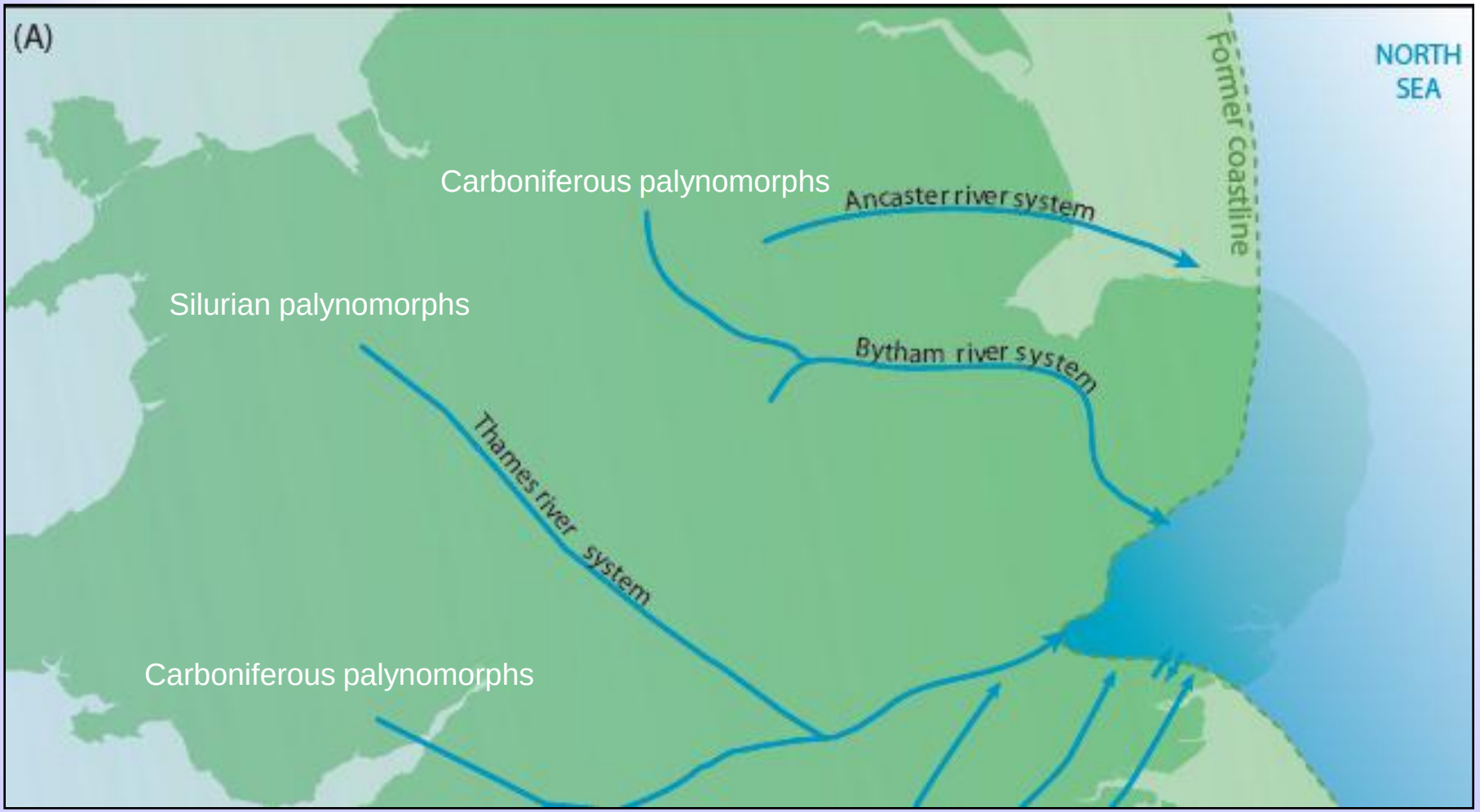
The Early Pleistocene

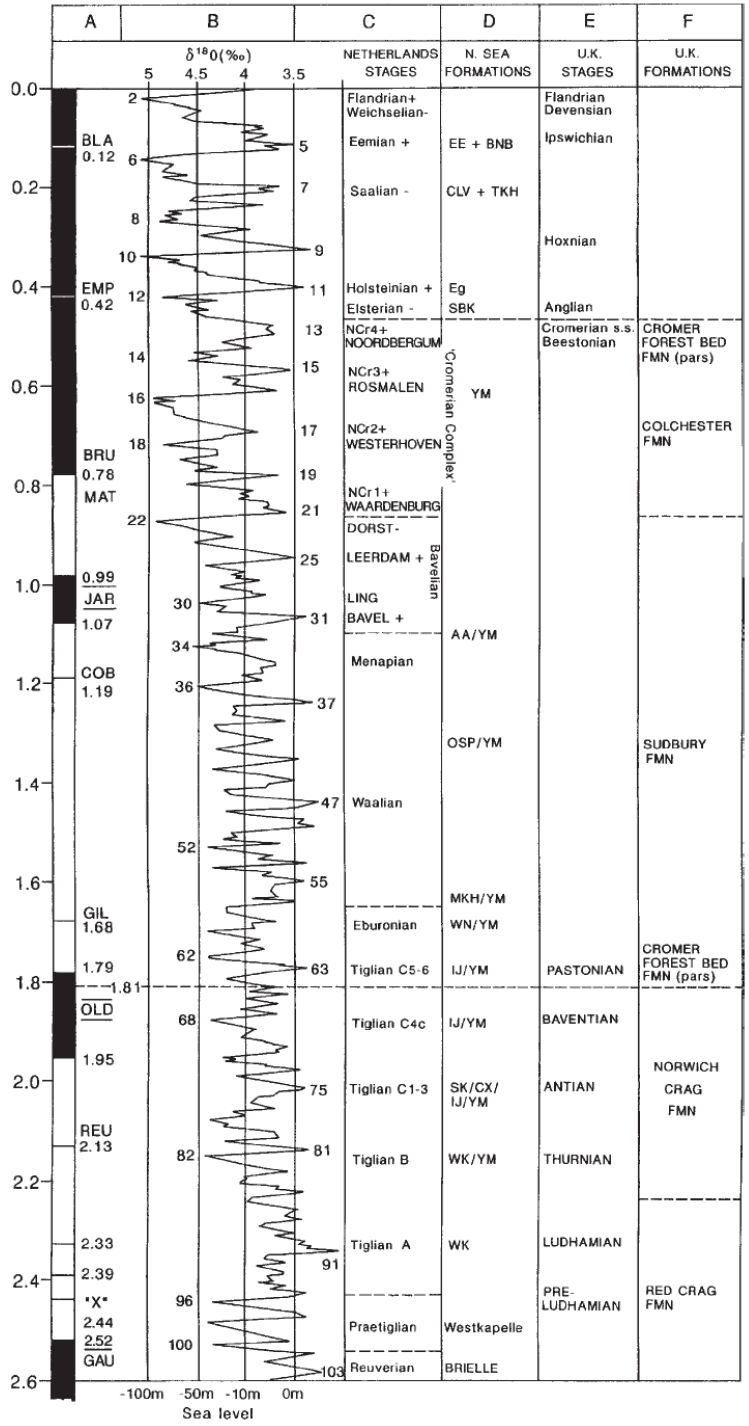
- Onset of Quaternary marks major change in climate systems, from 22 kyrs low magnitude change (prior) to 40 kyrs high magnitude change
- Evidence limited but records both stable landscapes & deep chemical weathering (clay-with-flints & silcretes)
- Reflects negligible tectonics & warm humid climates
- Climate changes from stable warm conditions to regular cooling cycles


North Sea
Baltic
Weser
Elbe
Thames
Coastline
Rhine
Meuse
Somme
Moselle
Coastline
Seine
Meuse
Rhine
Major palaeo-rivers
Former coastline

Stratigraphy of the Crag Basin

- Marine sediments of this basin are termed ‘Crags’: local term referring to shelly sands
- Can be divided into four main units on stratigraphic criteria (from oldest to youngest)
  - Coralline Crag – Pliocene age
  - Red Crag – Pliocene/Pleistocene boundary
  - Norwich Crag – Early Pleistocene
  - Wroxham Crag – Early to early Middle Pleistocene


(A)
NORTH SEA
Former coastline
Carboniferous palynomorphs
Ancaster river system
Silurian palynomorphs
Bytham river system
Thames river system
Carboniferous palynomorphs



Palaeomagnetism – A more robust timescale for the Crags

Red Crag boreholes show Normal-Reversed pattern (correlated with Gauss – Reunion Chron)

Norwich Crag generally Normalised (Olduvai Chron)

Wroxham Crag:
early = Reversed (Matuyama)
later = Normalised (Brunhes)

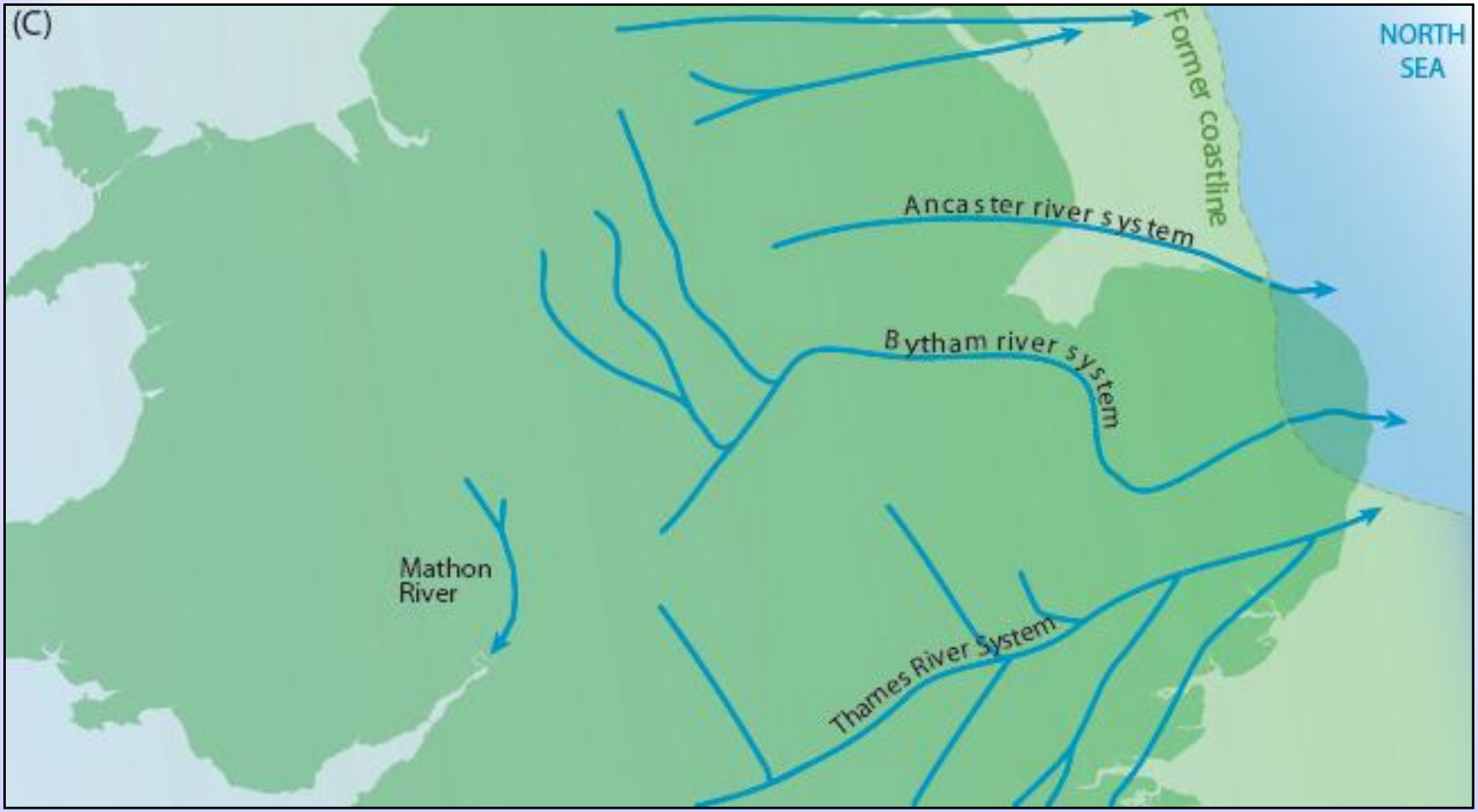
Red Crag

- Mixture of biological sediments (molluscs & forams) & inwashed sediments (sands & fine gravel)
- Gravel is composed almost completely of locally derived rock types (c. 95% flint from local Cretaceous bedrock); rivers transporting coarse-grained material but only local sources

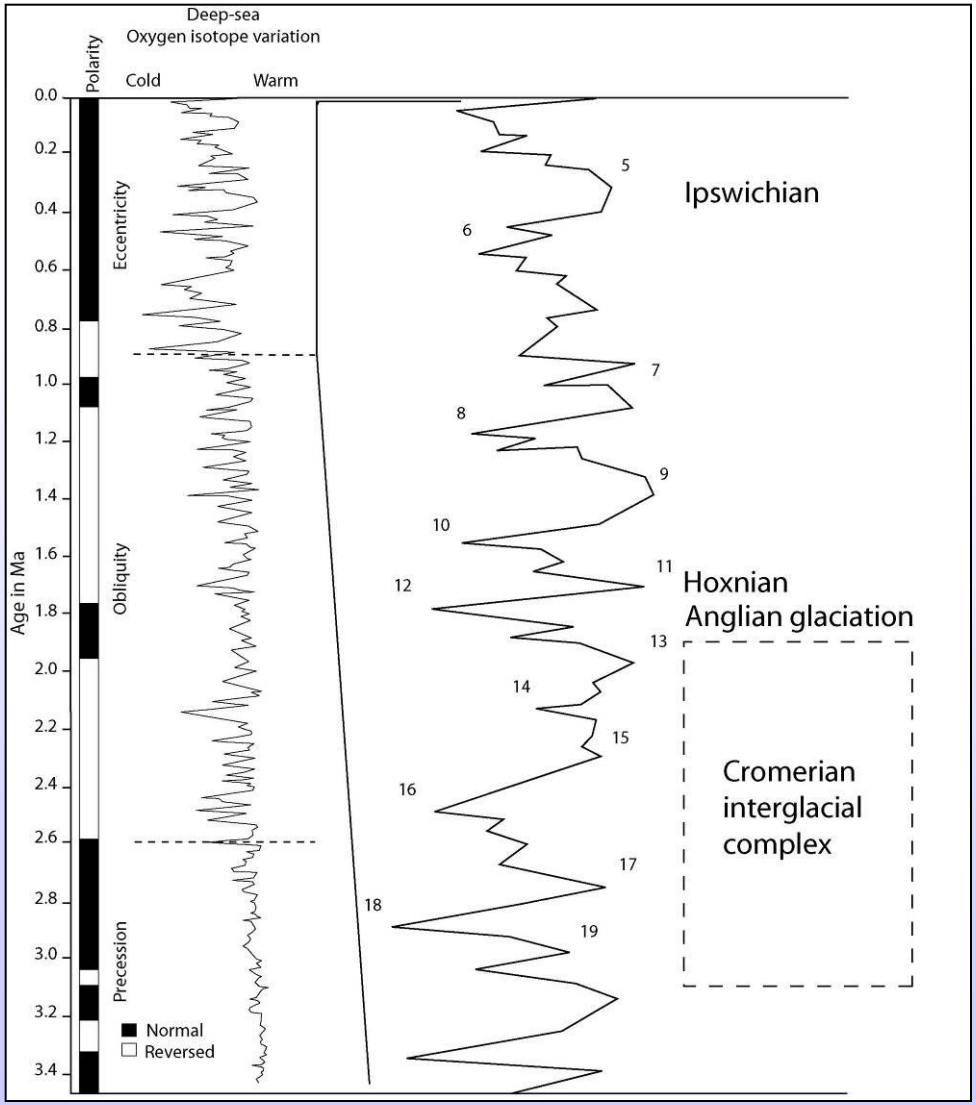
Wroxham Crag

- Shallow marine deposits dominated by coarse gravels
- Wroxham Crag contains 50% flint (locally derived) & 50% far-travelled (from N., S. Wales, Pennines, Midlands)
- Implies intense weathering of landscape to generate coarse-grained sediment; high energy rivers

Far-travelled igneous rocks & cherts


(C)
NORTH SEA
Former coastline
Ancaster river system
Bytham river system
Mathon River
Thames River System

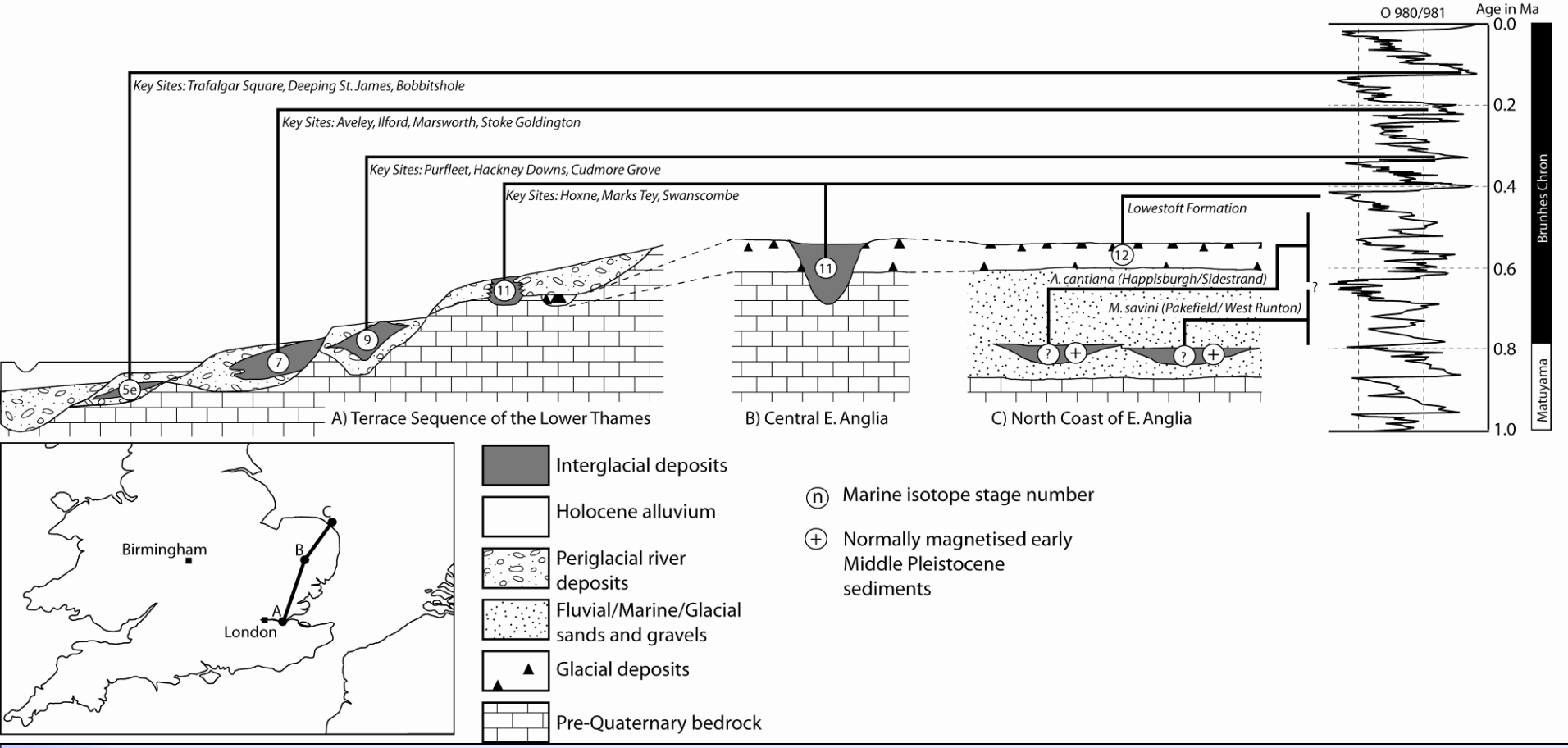
The Early Middle Pleistocene



early Middle Pleistocene

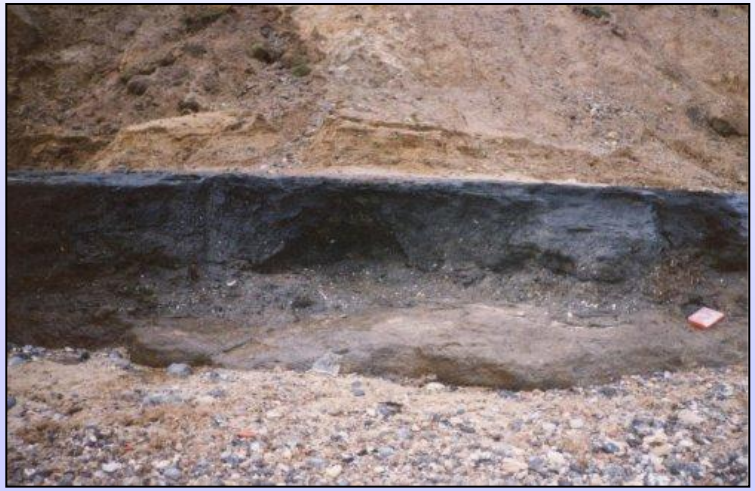
The ‘Cromerian Complex’

- Typically represented by terrestrial interglacial deposits found below glacial sequences on Norfolk/Suffolk coast
- Referred to as Cromer Forest-bed Series
- Interbed with Wroxham Crag



- How do we know that Cromerian Complex deposits belong to the early Middle Pleistocene?
  - Lie below Anglian Lowestoft Till (MIS 12, c. 450ka) – important marker horizon

- Range of depositional environments:
- Raised beach (Boxgrove)
- Cave (Westbury-sub-Mendip)
- Fluvial/freshwater (West Runton)



Early Middle Pleistocene

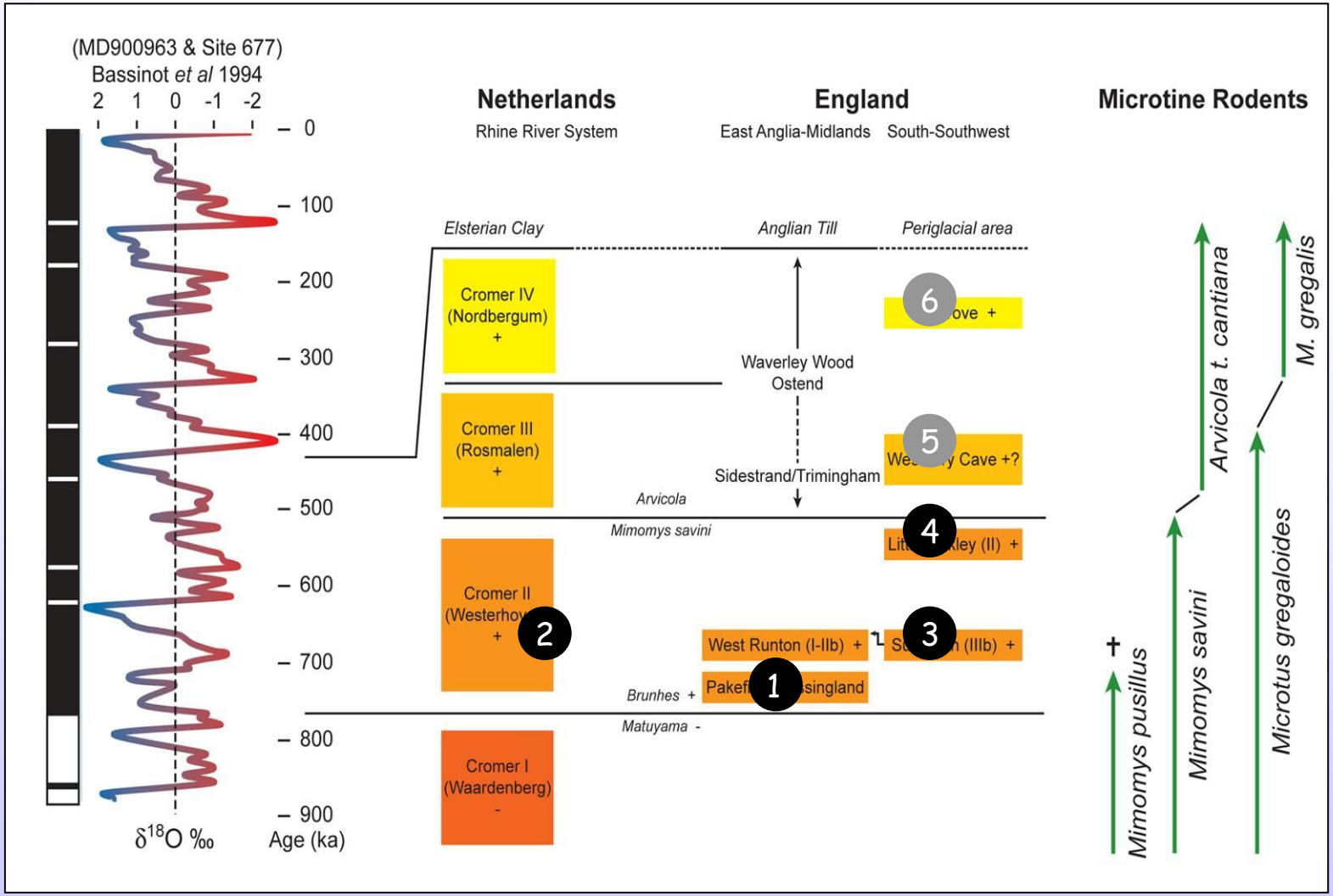


Chart modified from Preece & Parfitt (2000)

- Frequently reflect channel fills, overbank deposits & small ponds that can fill up with sediments after 100 years
- Channel filling during climatic optimum = lots of warm proxies; during end of climatic optimum = cooler climate proxies

Pakefield, Suffolk

Beetles: Summer = 18 to 23°C, Winter = -6 to 4°C

Plant macrofossils: *Trapa natans*, *Salvinia natans* (>18°C)

Vertebrates: *Hippopotamus*

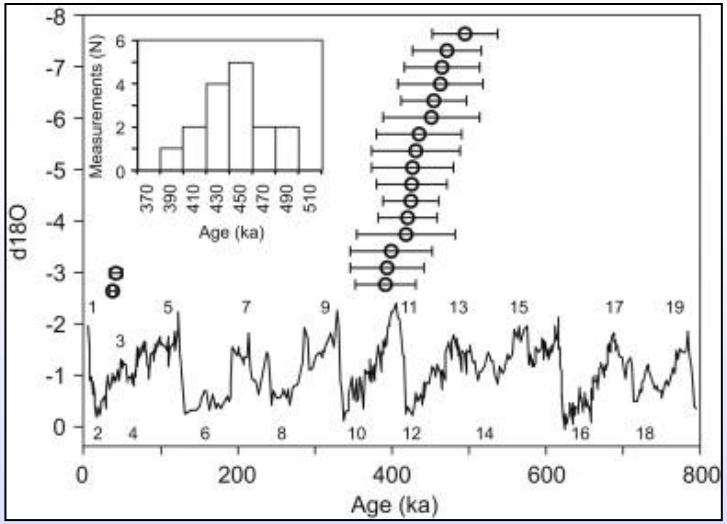
Sediments: Pedogenic carbonate, characteristic of seasonally dry sub-humid regions (Mediterranean)

Earliest humans in Britain

- Possible new site at Happisburgh III (Parfitt *et al*., 2010, *Nature*) may pre-date 780ka
- Earliest definitive evidence in UK at Pakefield (c. 780-600ka) – simple flake tools

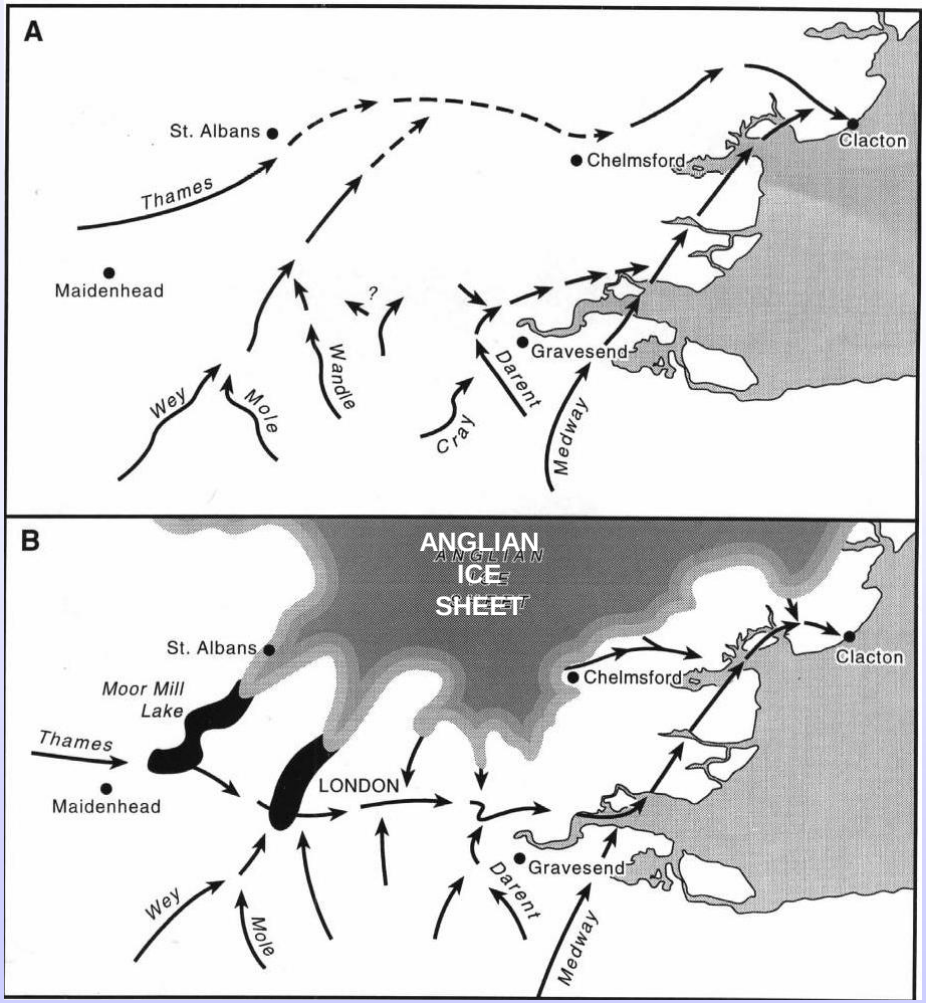
Anglian glaciation

- Single glacial event
- Most of E England covered by British Ice
- Scandinavian ice reaches NE tip of East Anglia & records three advance & retreat events
- Timing relatively well constrained (MIS 12, c. 450ka), based on marine record, radiometric dating, terrace correlations



Ages of Anglian outwash in North Norfolk (Pawley et al., 2008)

Diversion of the Thames



From Bridgland (1994)

Hornchurch Till

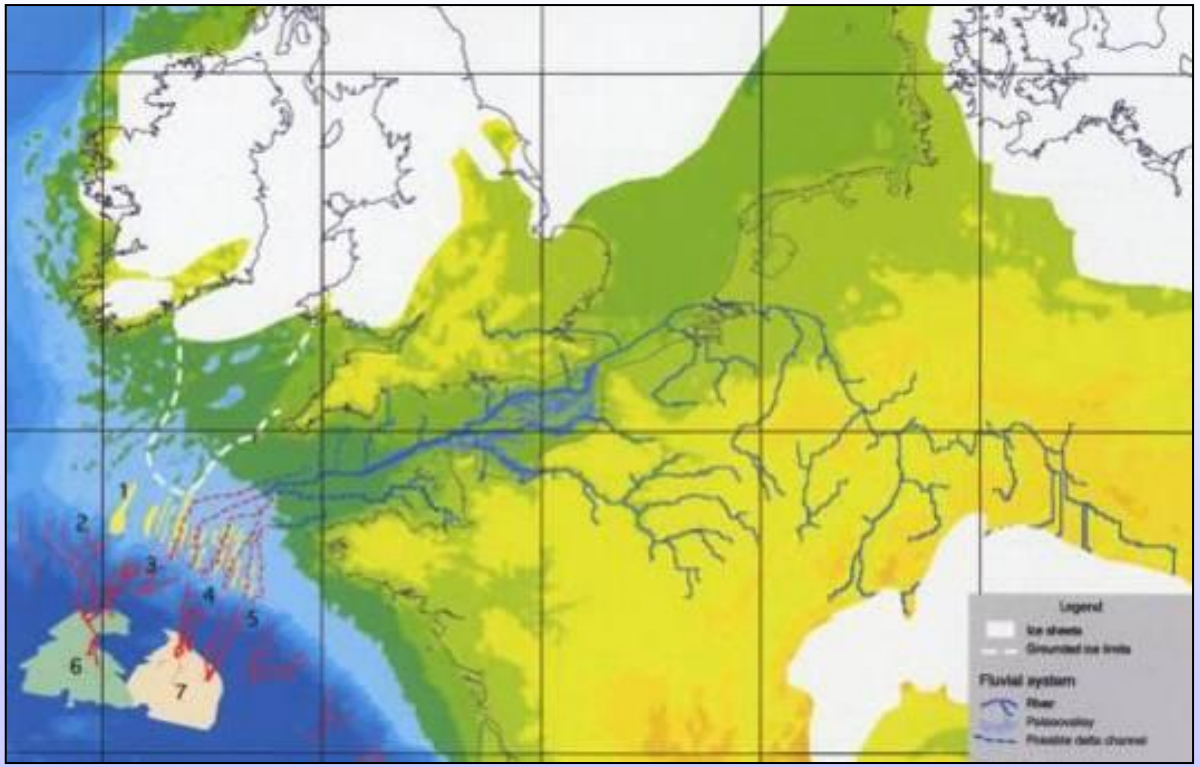
- Breaching of chalk ridge & creation of Strait of Dover
- Biogeographical barrier
- Island isolation

nature Vol 448 | 19 July 2007 | doi:10.1038/nature06018

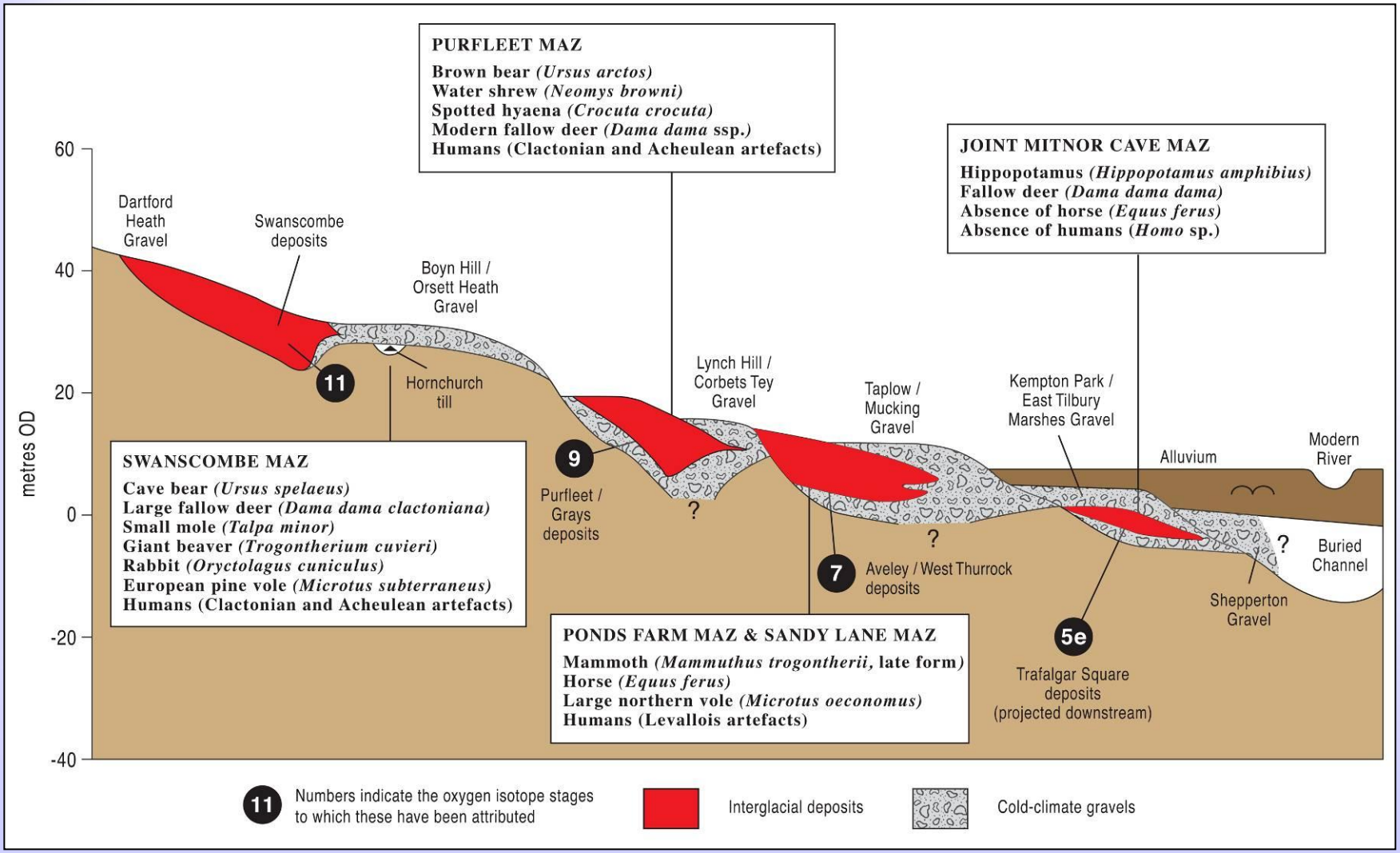
LETTERS

Catastrophic flooding origin of shelf valley systems in the English Channel

Sanjeev Gupta[1], Jenny S. Collier[1], Andy Palmer-Felgate[1] & Graeme Potter[2]



Mammalian Assemblage-Zones



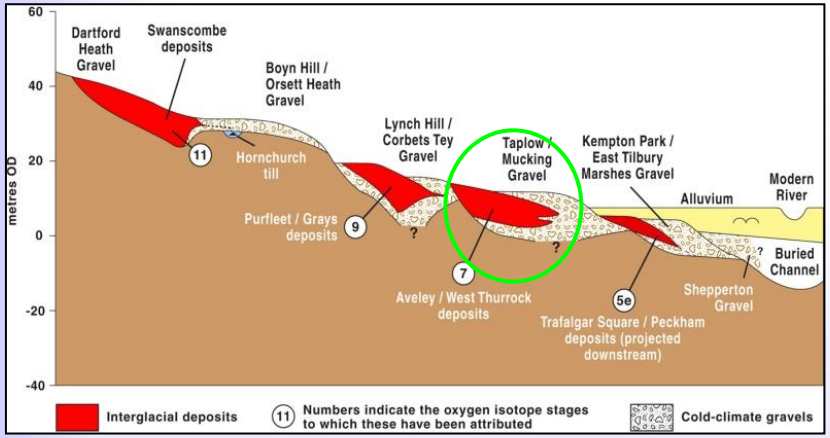
Adapted from Schreve (2001, 2004)

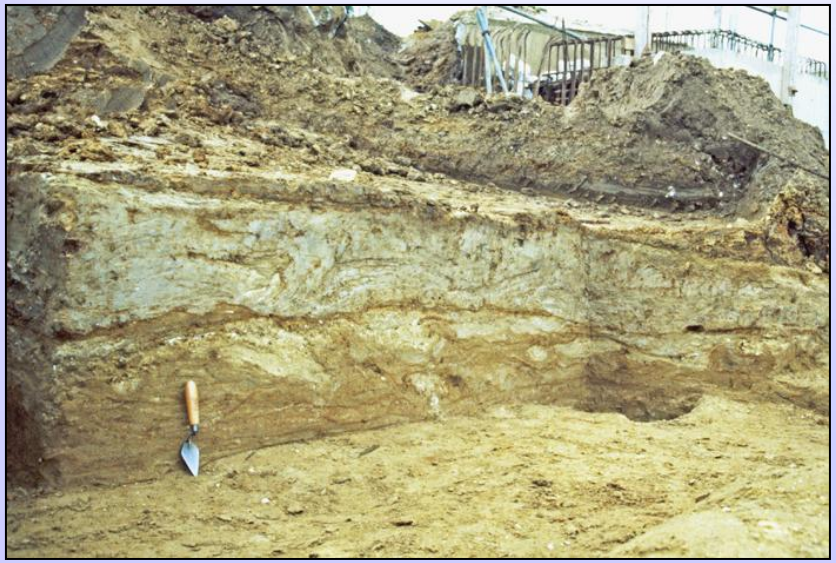

Theodoxus danubialis
Lyrodiscus (Retinella) skertchlyi
Corbicula fluminalis
Borysthenia (Valvata) naticina

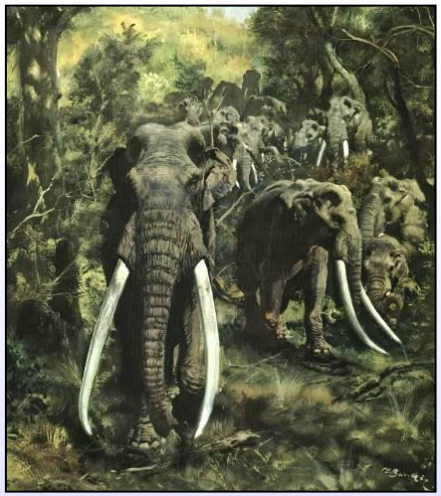
A new & testable framework

- Lower Thames terrace sequence is a globally important archive for this period
- Mammalian assemblage of each terrace allows age & palaeoecology of different interglacials to be established
- Five discrete Mammal Assemblage-Zones responding to 100ka cycle & sub-Milankovitch level
- Advantage of longer/more complex sequences & possibility to compare with river terrace models
- Support from absolute dating at every stage

Penultimate Interglacial (MIS 7) Ponds Farm MAZ







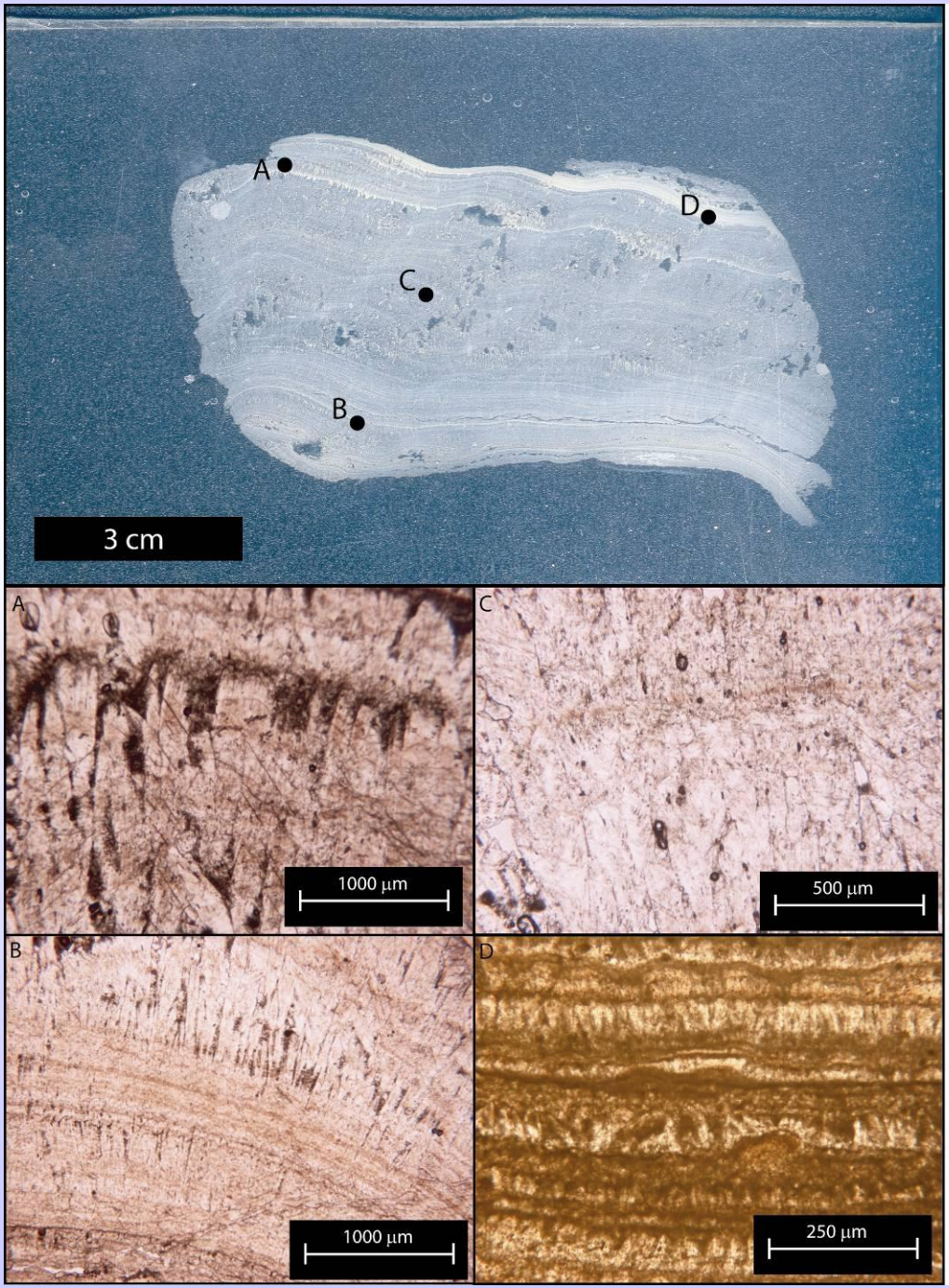
Straight-tusked elephant

White-toothed shrew

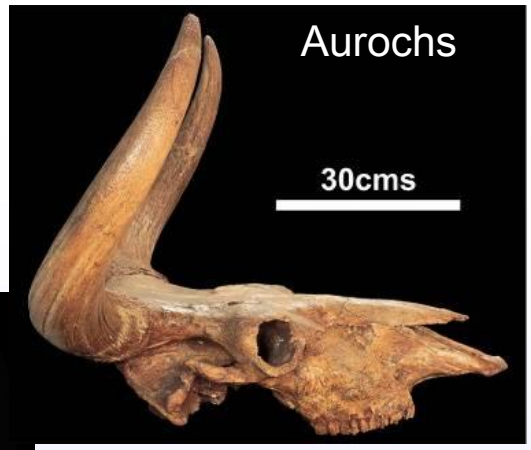
European pond terrapin

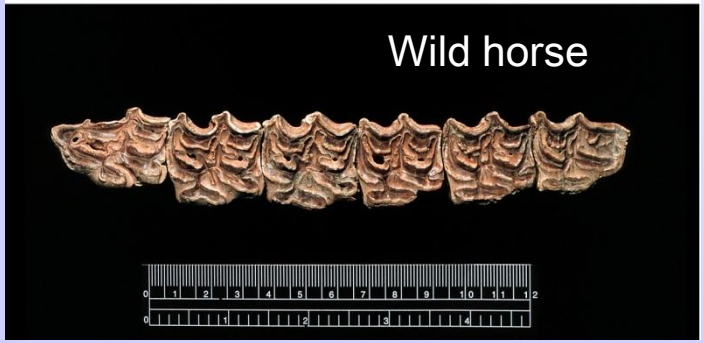
Tufa samples from the Marsworth sequence

Rich in woodland pollen types



Sandy Lane MAZ



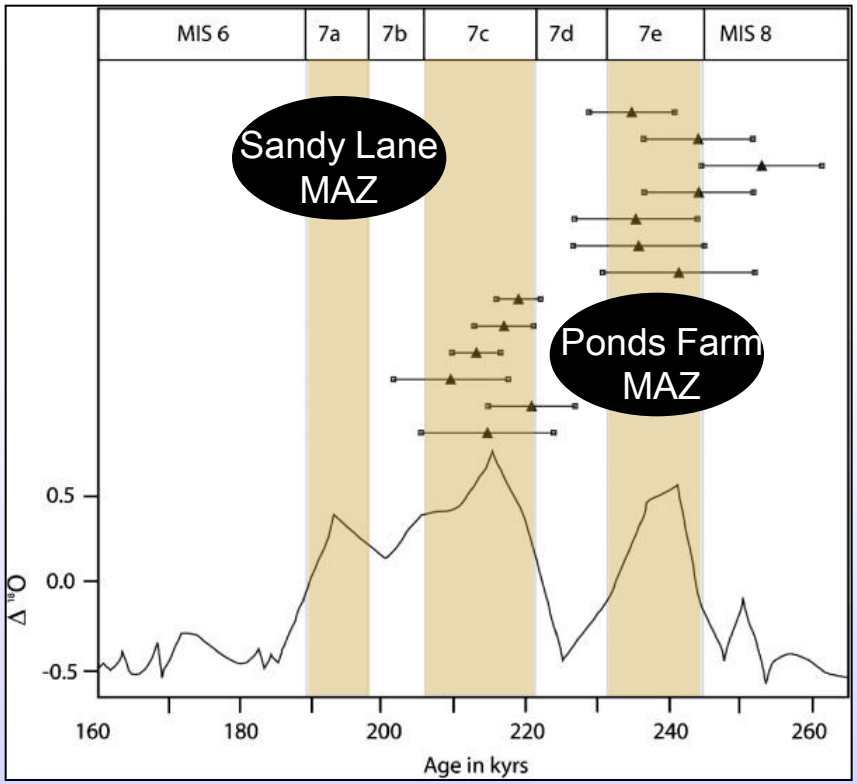


Steppe mammoth

Excavations on the A13, Aveley

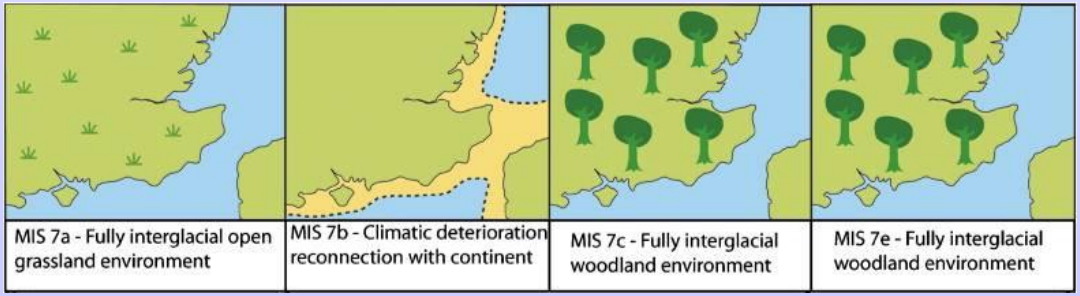
Geochronological support

U-series ages on Marsworth tufa, plotted against SPECMAP isotopic curve (from Candy & Schreve, 2007)



Sandy Lane MAZ = late interglacial, open grassland

Ponds Farm MAZ = early interglacial, woodland



Summary

- Many aspects of stratigraphy now well constrained & correlated with marine record
- Support from geochronology, other methods of relative dating
- Britain perfectly placed, with detailed archive of palaeoclimatic/palaeoenvironmental change
- Potential for understanding climatic events in a much clearer way than simply by marine and ice core records
- Context for human evolution & occupation