Late Pleistocene climate change and its impact on palaeogeography of the southern Baltic Sea region

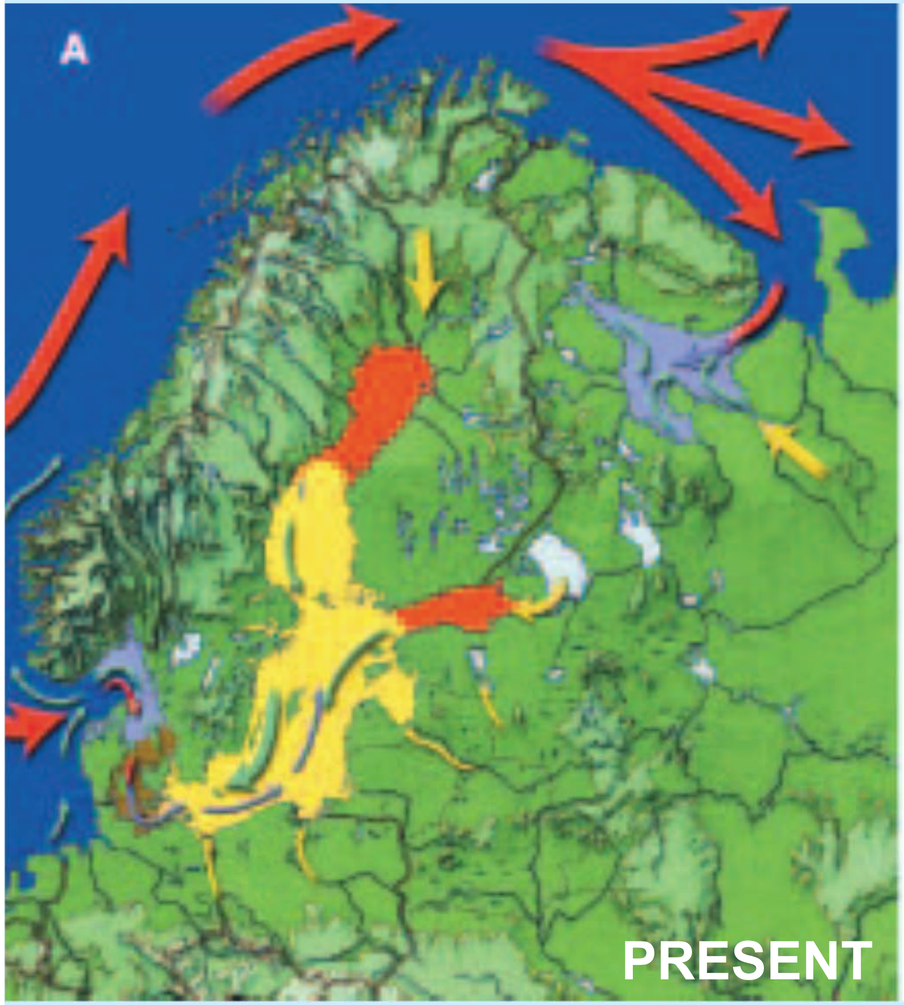
Leszek Marks

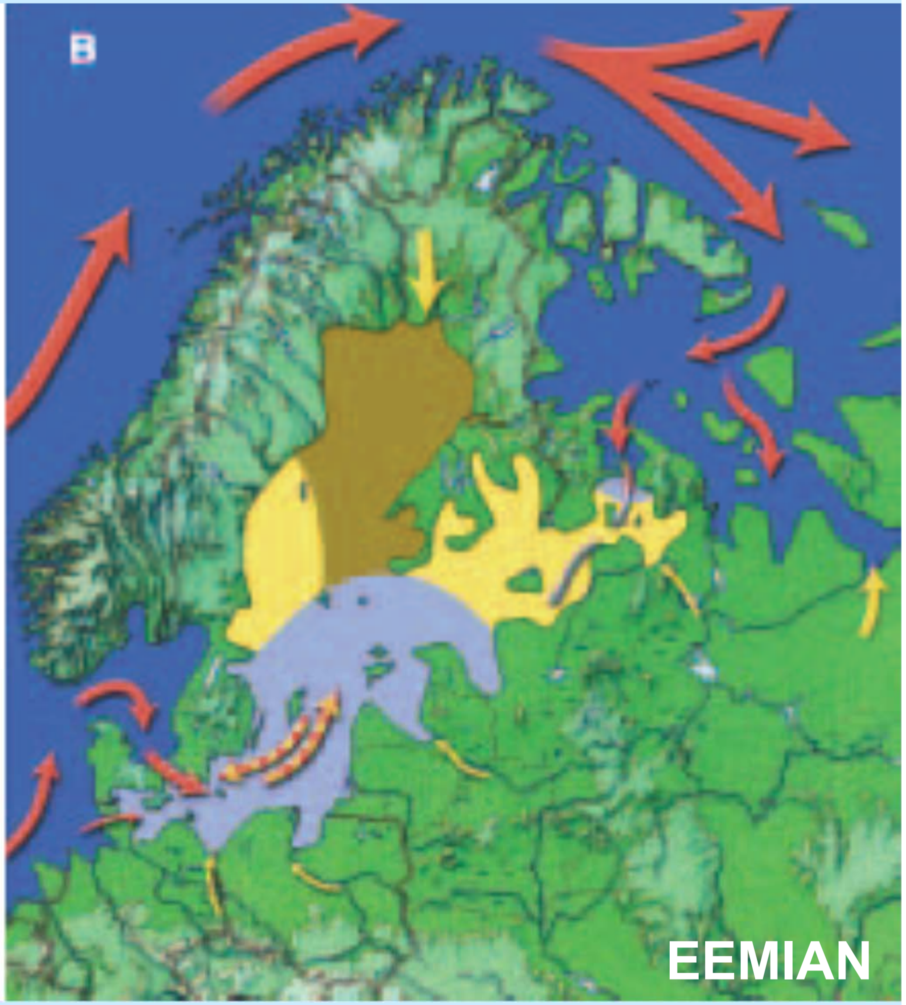
Polish Geological Institute–National Research Institute, Warsaw, Poland
Department of Climate Geology, University of Warsaw, Warsaw, Poland

Main items

- Regional bakground for climatic impact of the Eemian sea
- Outline of Eemian climate changes in the adjoining terrestrial area
- Principles of Central European climate during the last glacial stage
- Climate change at the turn of Pleistocene and Holocene

Surface hydrography of the Baltic Sea

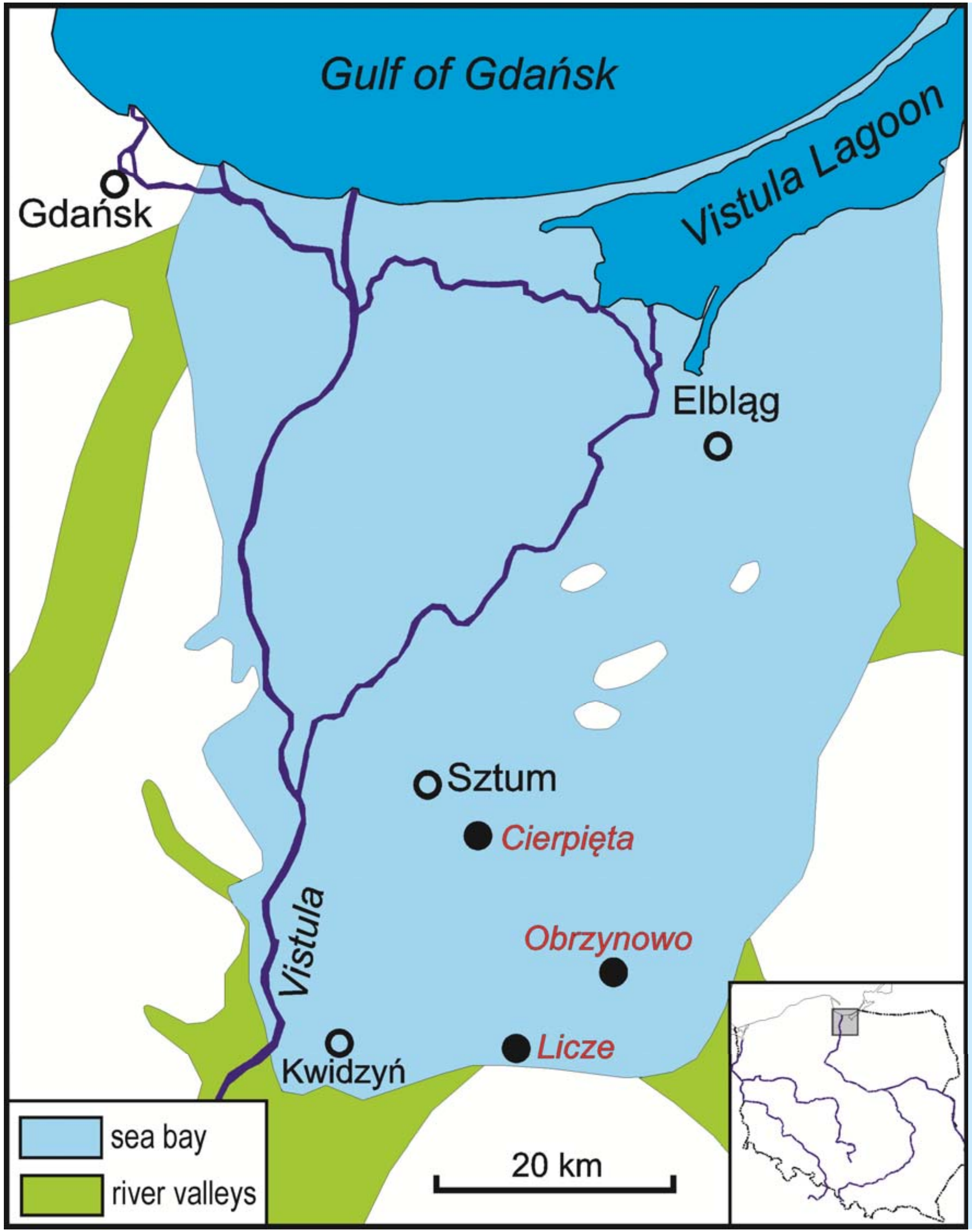




SALINITY OF SURFACE WATER: **dark blue – >30‰**, **light blue – 25-30‰**, **brown – 15-25‰**, **yellow – 5-15‰**, **red – <5‰**

CURRENTS INDICATED BY ARROWS: red – warm surface current, **blue – cold bottom current**, **green – brackish surface current (≈10‰)**, **stripped red/yellow – coastal water surface current (>15‰)**, **yellow – major source of river runoff** *Funder 2002*)

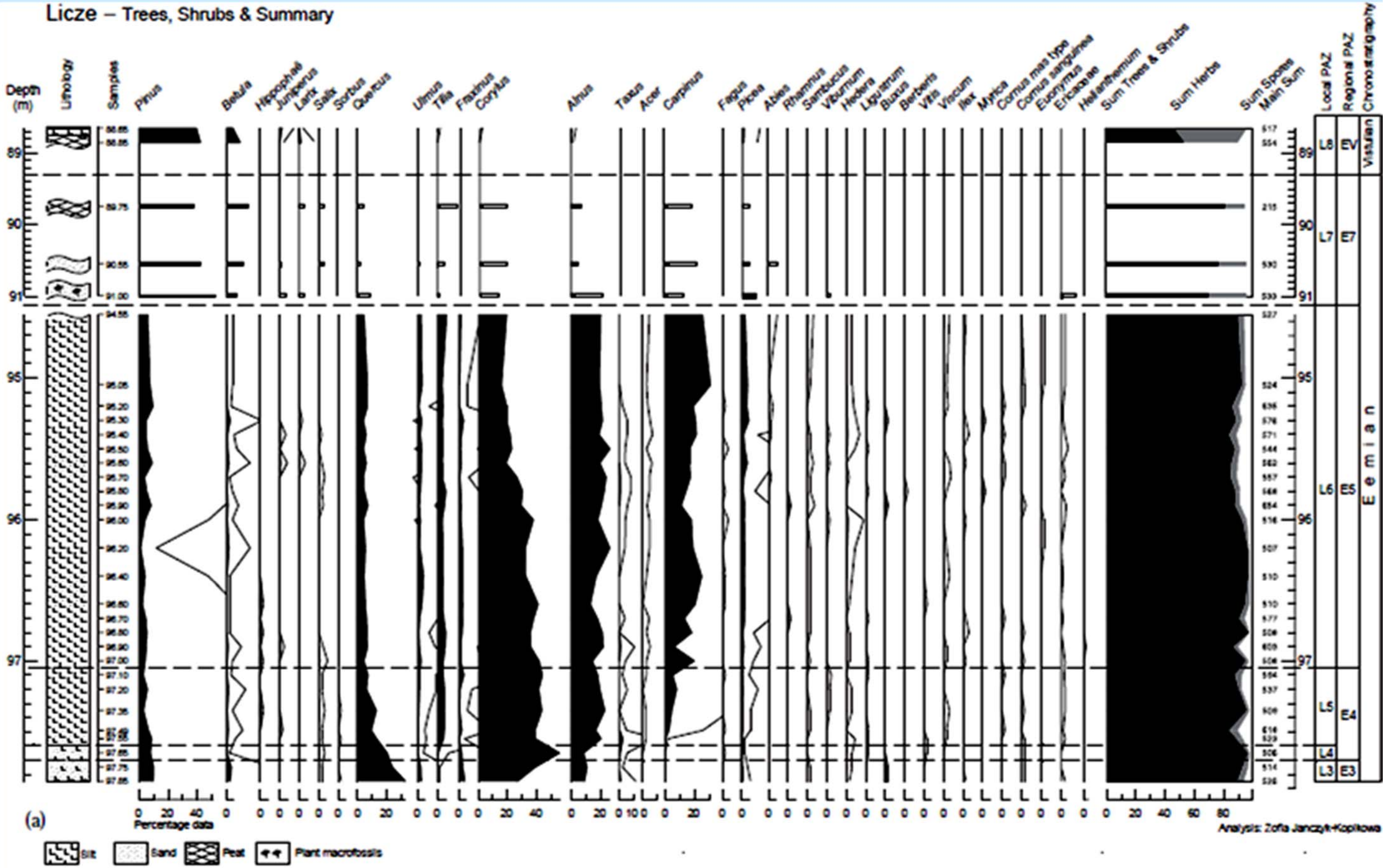
Eemian sea in the Lower Vistula Valley Region



● *Cierpięta* research borehole

Makowska (1986), modified

Chronology of Eemian based on pollen stratigraphy



RPAZ after Mamakowa (1988, 1989)

Head et al. (2005)

Correlation of Eemian LPAZ with RPAZ in southern Baltic region

	DENMARK Andersen (1961,1975)		N. GERMANY Müller (1974)	Time (years)	POLAND Mamakowa (1988,1989)		LICZE Head *et al.* (2005)	OBRZYNOWO (this study)
Early Weichselian	EW1	Poaceae-Ericales			EV1	Gramineae-*Artemisia*-*Betula nana*	L8	
EEMIAN	E7	*Pinus*-*Picea*-*Betula*	VI	11 000	E7	*Pinus*	L7	
	E6	*Picea*-*Pinus*-*Alnus*	V	8500	E6	*Picea*-*Abies*-*Alnus*	not sampled	OB5
	E5	*Picea*-*Carpinus*-*Alnus*	IV	7000	E5	*Carpinus*-*Corylus*-*Alnus*	L6	OB4
	E4	*Quercus*-*Tilia*-*Corylus*-*Alnus*	IIIc, IIIb, IIIa	3000	E4	*Corylus*-*Quercus*-*Tilia*	L5, L4	OB3
	E3	*Quercus*-*Fraxinus*	IIb	750	E3	*Quercus*-*Fraxinus*-*Ulmus*	L3, L2	OB2
	E2	*Betula*-*Pinus*-*Ulmus*	IIa	300	E2	*Pinus*-*Betula*-*Ulmus*	L1	OB1
	E1	*Betula*	I		E1	*Pinus*-*Betula*	L1	

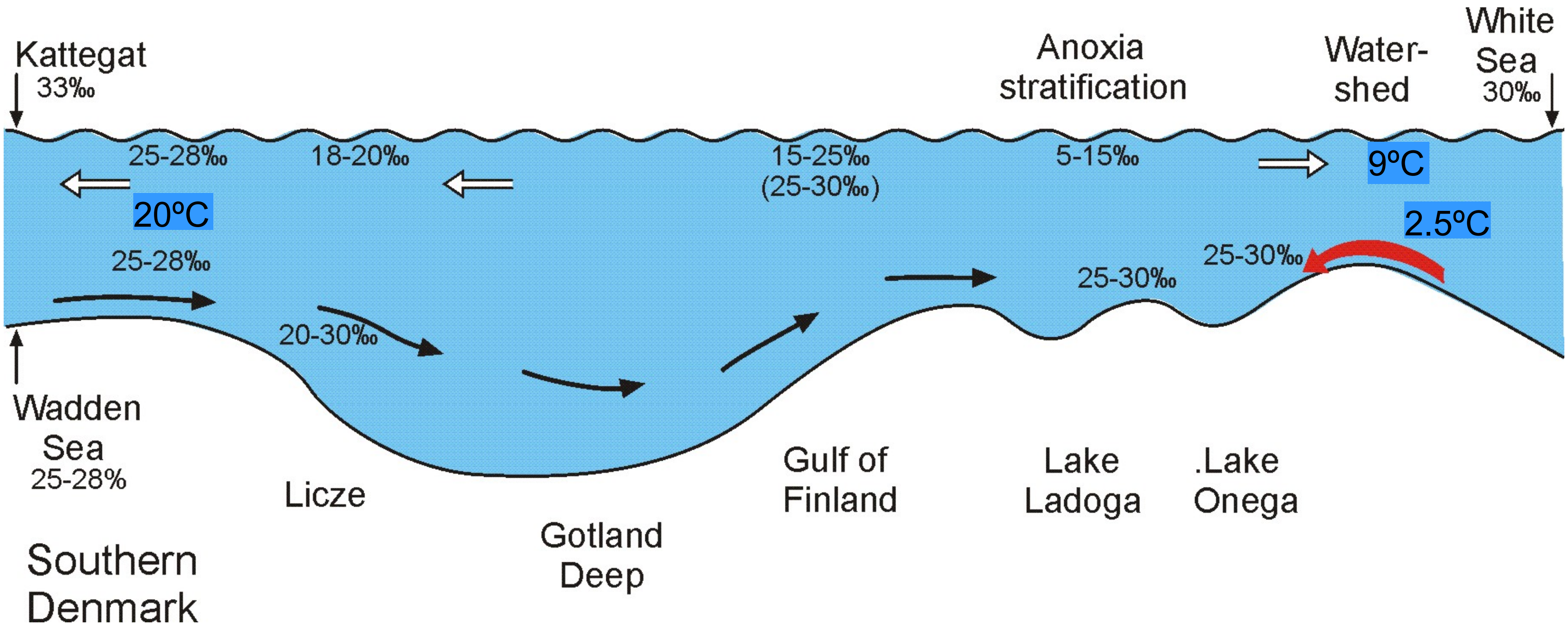
Knudsen et al. (2012)

Chronology of Eemian sea in southern Baltic region

Top of Eemian deposits	***ca*. 8500–11 000 yrs**
Boundary E5/E6	**7000 lat**
<u>Top of marine Eemian deposits</u>	
Boundary E4/E5	**3000 yrs**
Boundary E3/E4	**750 yrs**
Boundary E2/E3	**300 yrs**
E1 or E2	**<300 yrs**
<u>Bottom of marine Eemian deposits</u>	
Boundary Saalian/Eemian	**0 (126 ka BP)**

Based on correlation with regional pollen assemblage zones (RPAZ) from northern Poland (*Mamakowa, 1989*), Bispingen in northern Germany (*Müller, 1974; Field et al., 1994*) and Danish subdivision (*Andersen, 1961, 1965, 1975)*

Circulation, temperature and salinity in the Eemian sea at the end of RPAZ E4 (*Corylus*) ~ 123.5-123 ka BP



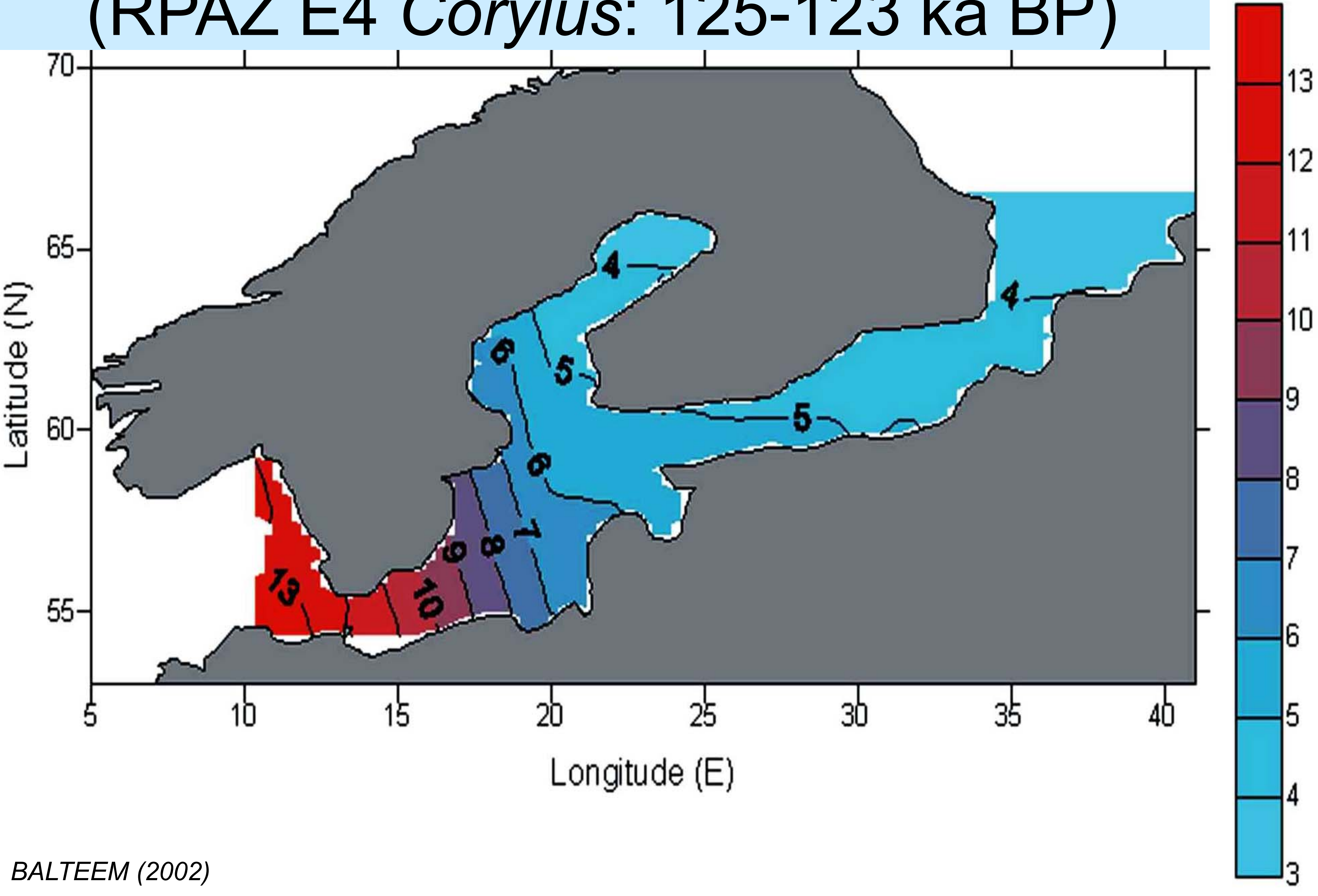
inflow of warm and high salinity water from the Kattegat

outflow of low salinity surface water from the Baltic region

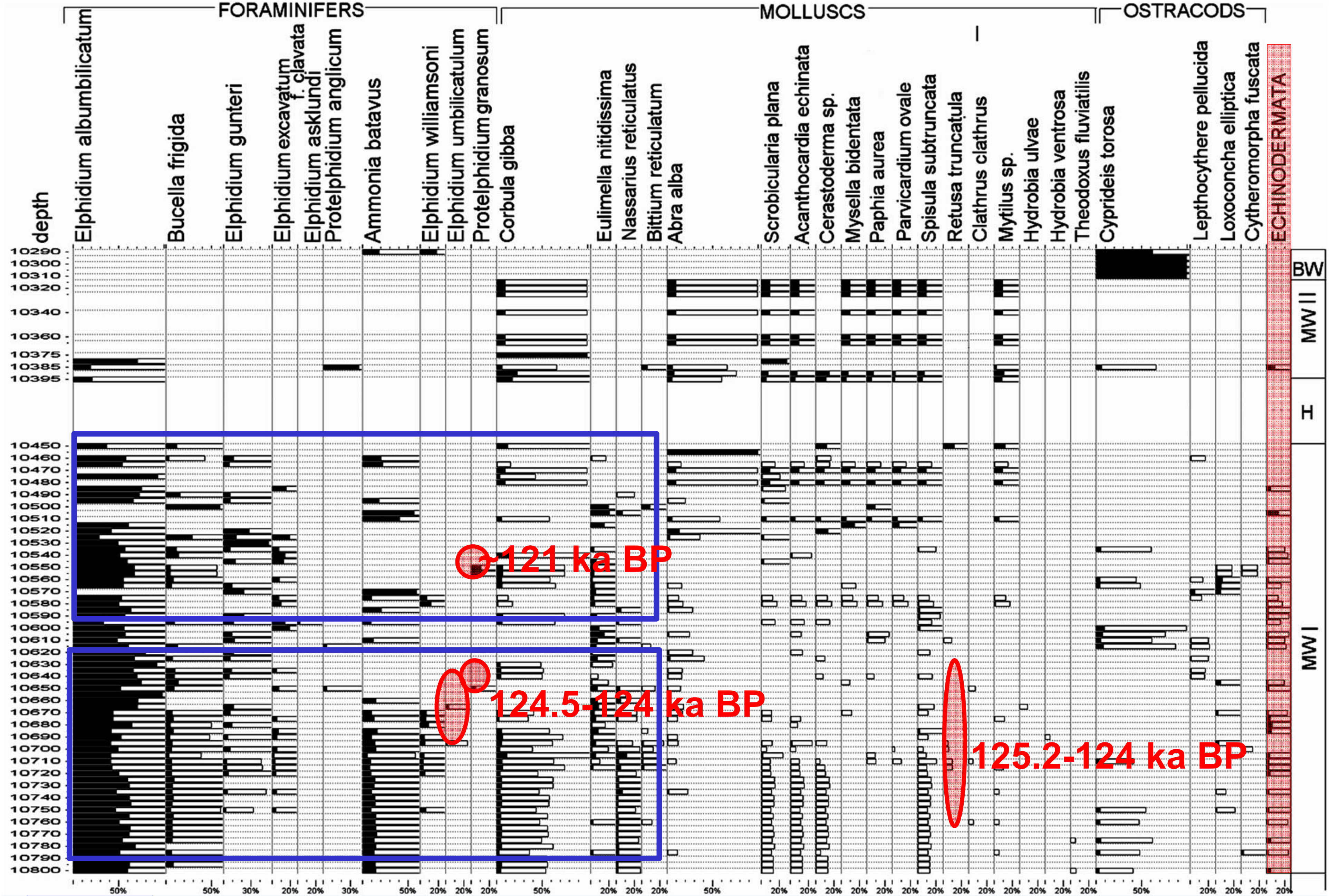
inflow of cold and high salinity bottom water from the White Sea

BALTEEM (2002)

Mean annual sea-surface temperature (RPAZ E4 *Corylus*: 125-123 ka BP)



BALTEEM (2002)



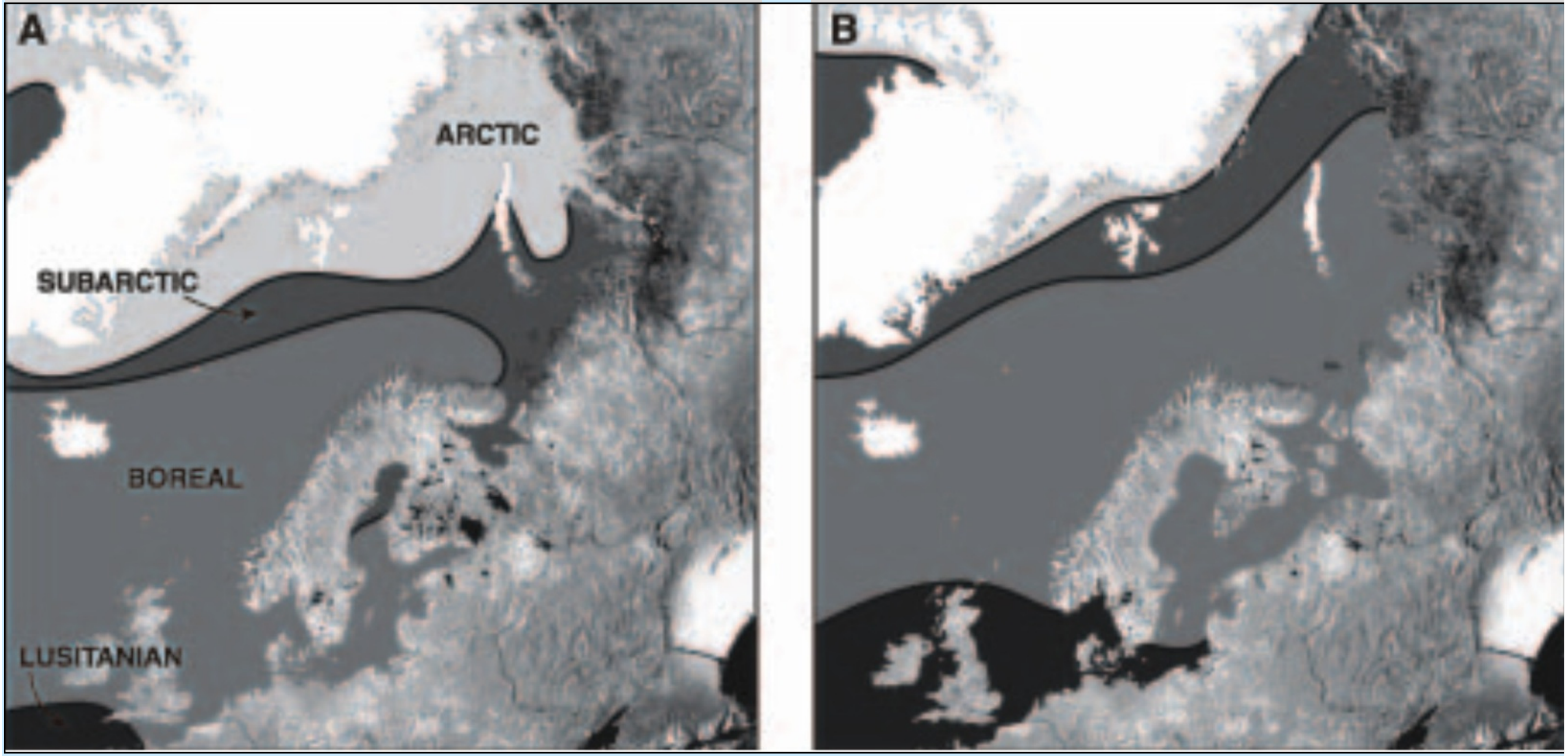
highest salinity

Lusitanian species

BW – brackish,
MW – marine, **H** – hiatus

Distribution of marine biogeographical zones in North Atlantic

PRESENT | EEMIAN

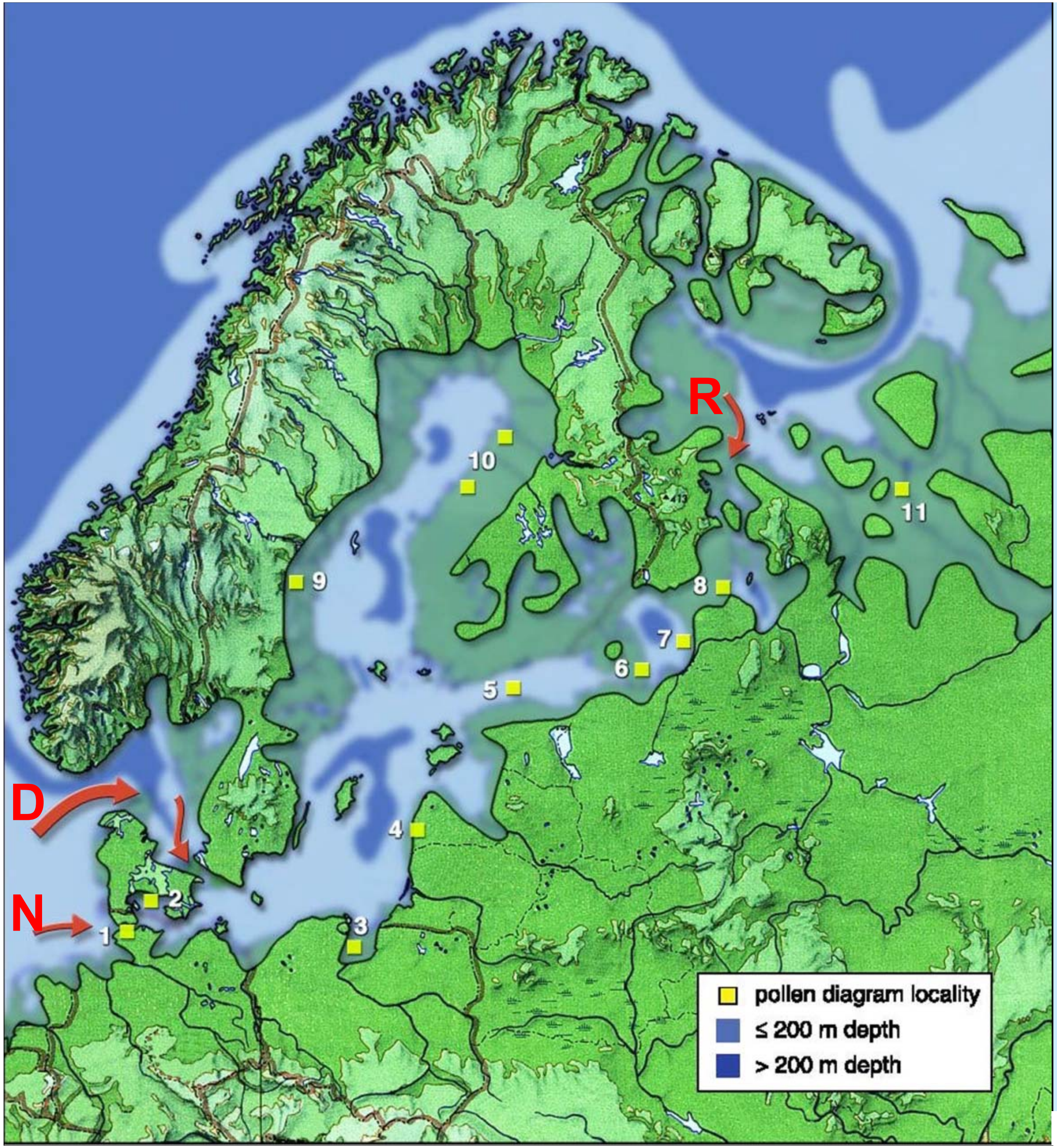


Funder et al. (2002)

Entranceways into the Eemian Baltic Sea

There were 3-4 passages that enabled water exchange with the ocean during in the Eemian:

- Through Kattegat across Sjælland and through the buried Alnarp-Esrum valley in southern Sweden
- Through northern Germany in the area of the Kiel Canal, but due to a winding pattern of broads and narrowings it could play a limited role only
- From a much-enlarged White Sea across Russian Karelia, passing the major watershed north of Lake Onega
- A shallow side entrance from the Severnaya Dvina basin into Karelia may also have existed along the river Vodla

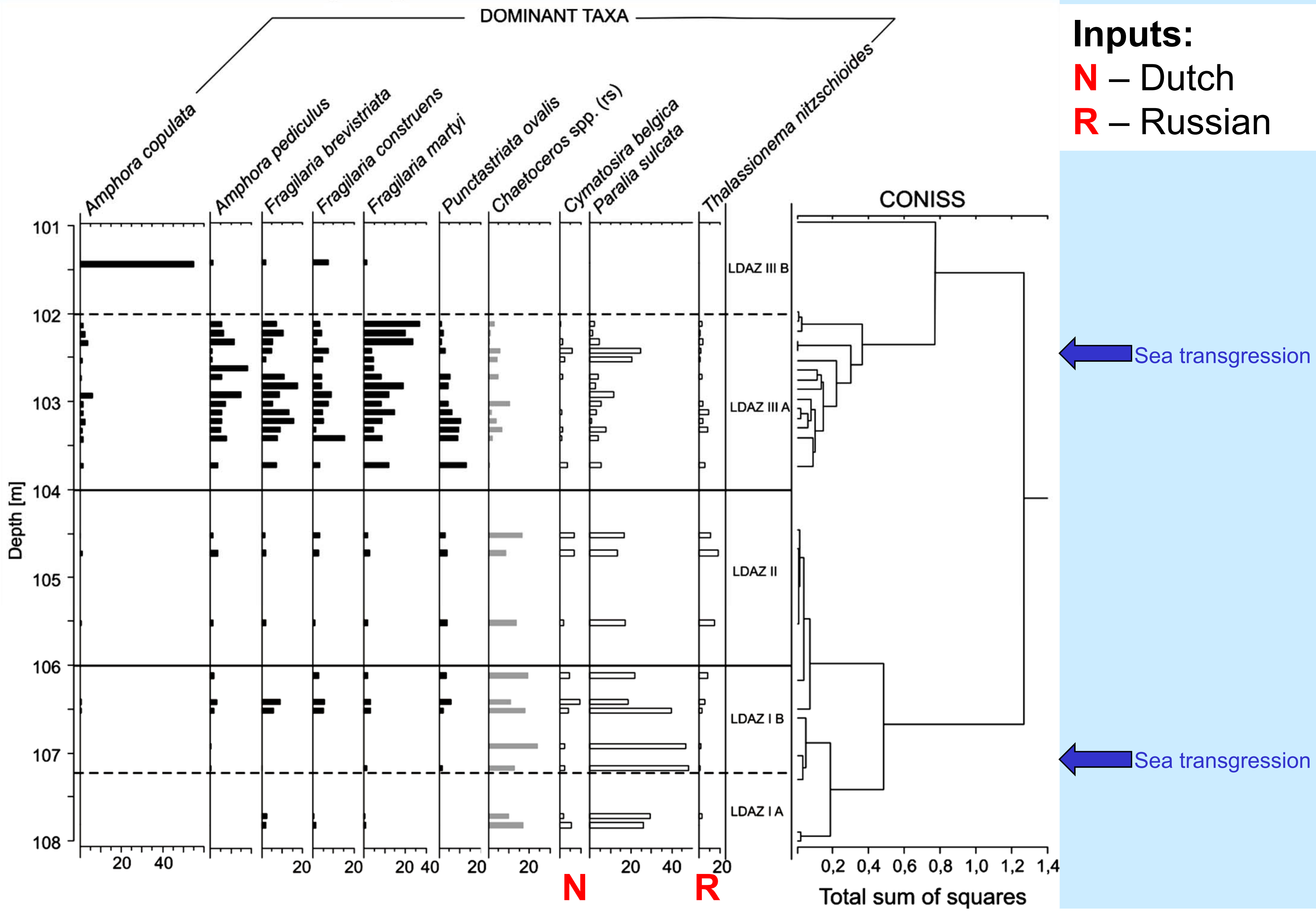


Sea water input to the Baltic Basin during Eemian

D – Danish input
N – Dutch input
R – Russian input

Funder et al. (2002), supplemented

Site Cierpięta: dominant taxa of diatoms

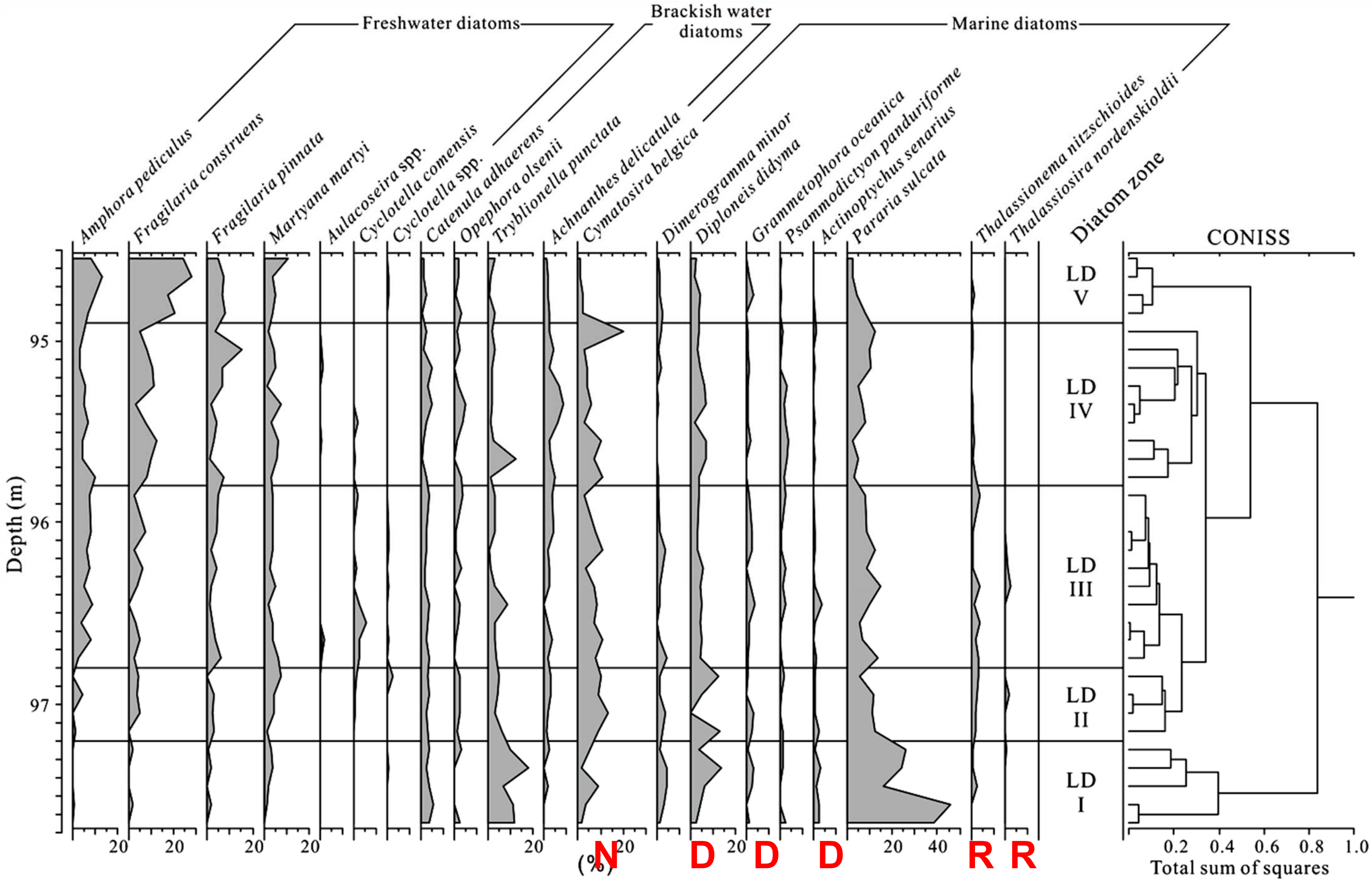


Inputs:

N – Dutch

R – Russian

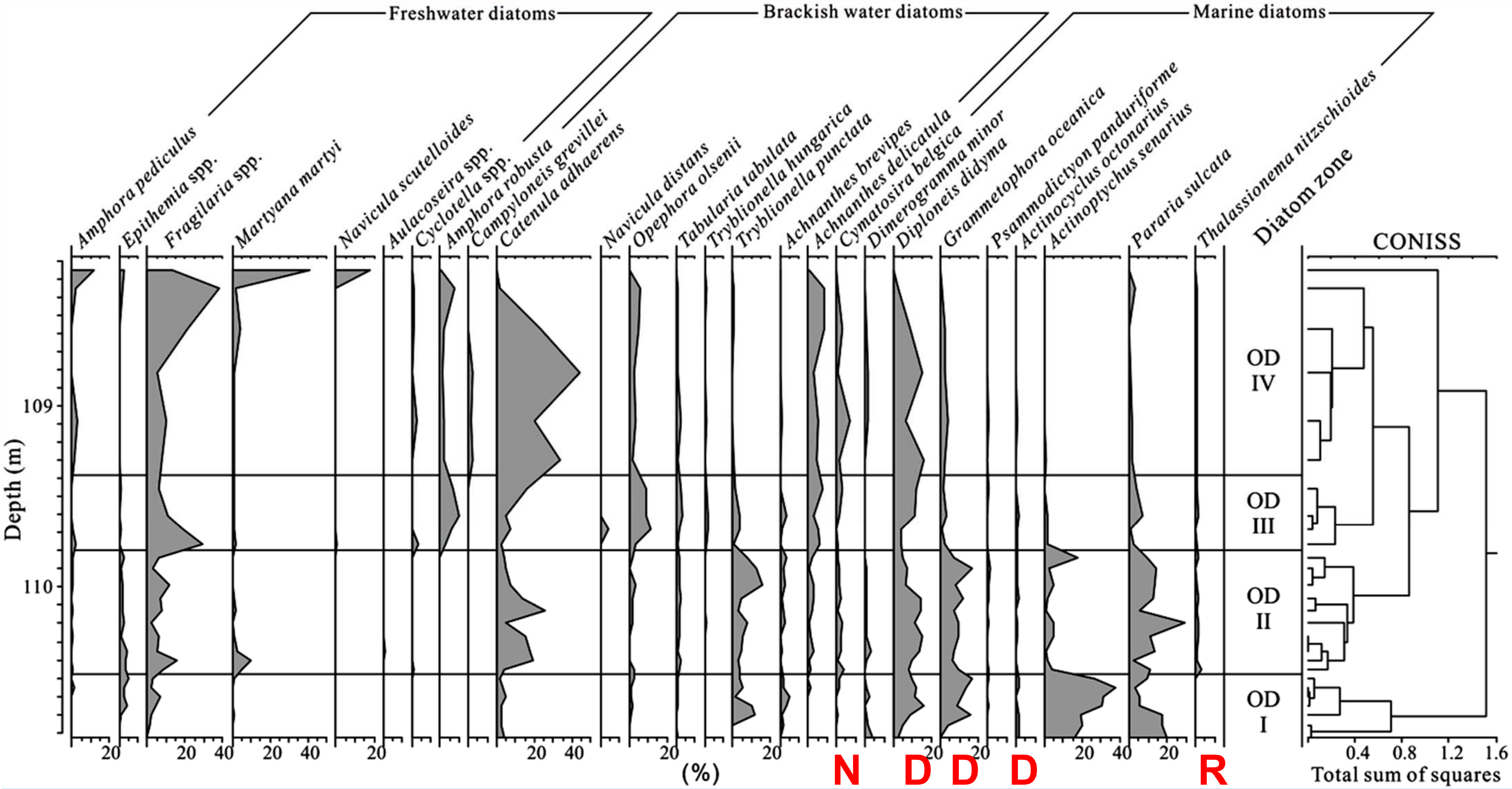
Site Licze: dominant taxa of diatoms



Inputs: D – Danish, N – Dutch, R – Russian

Knudsen et al. (2012), supplemented

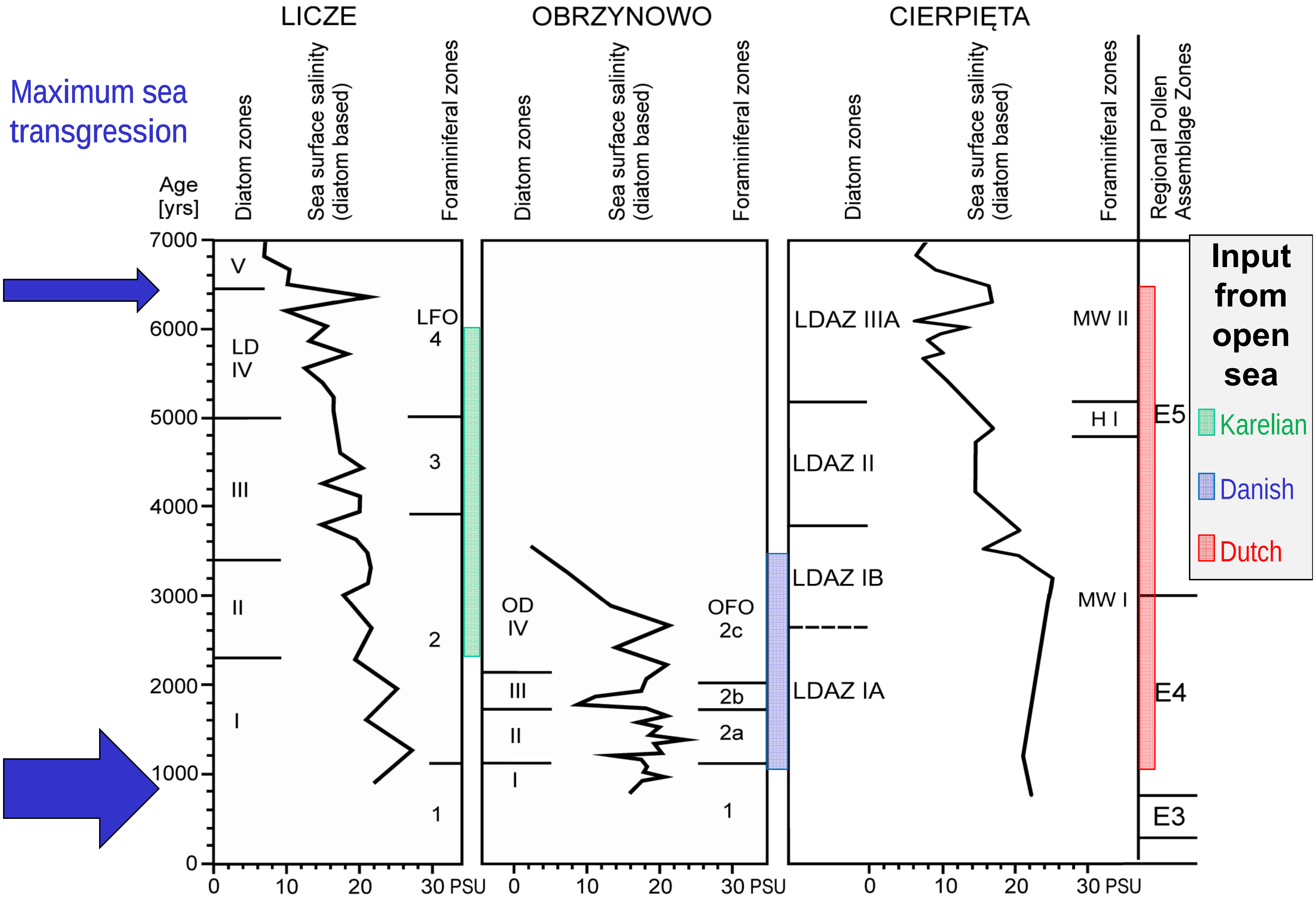
Site Obrzynowo: dominant taxa of diatoms



Inputs: D – Danish, **N** – Dutch, **R** – Russian

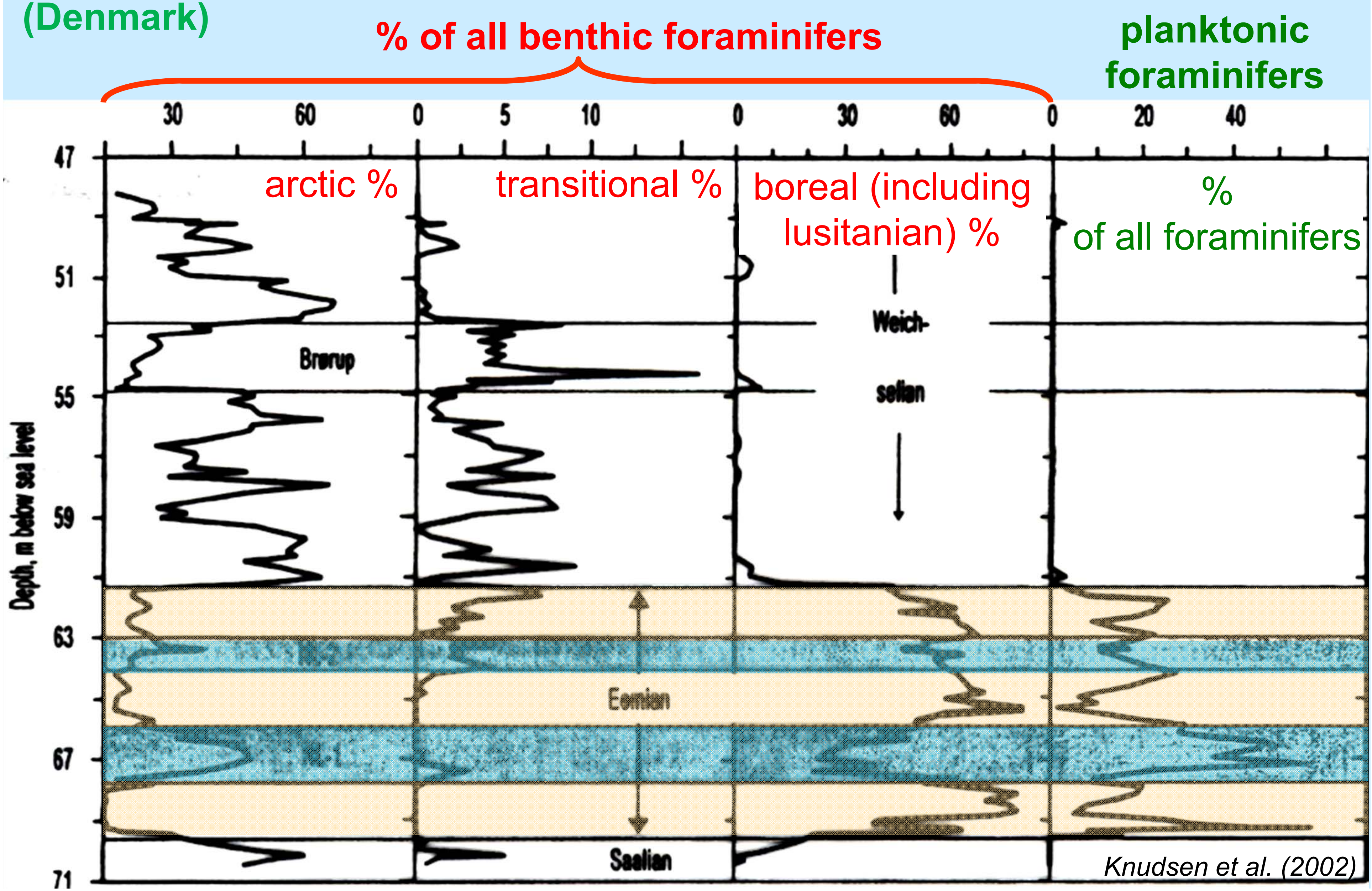
Knudsen et al. (2012), supplemented

Salinity of the Eemian sea in the Polish area



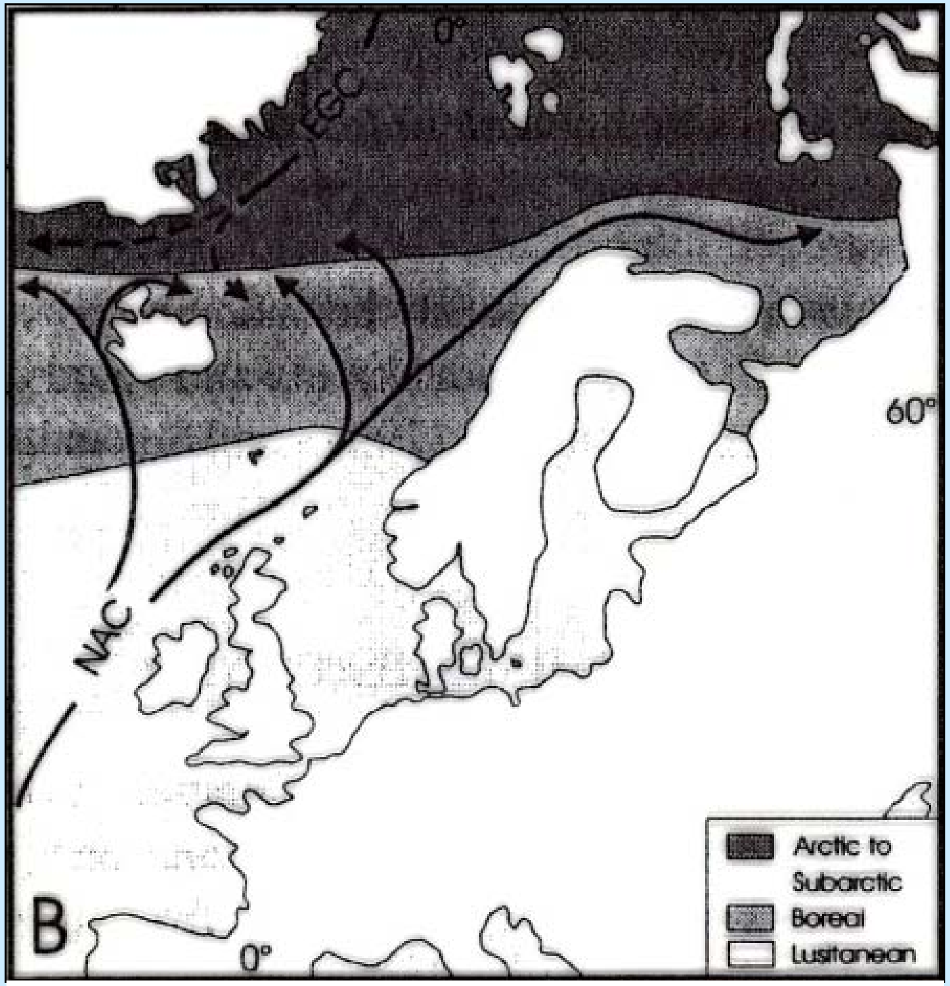
Cold events during Eemian

Site Nørre Lyngby (Denmark)

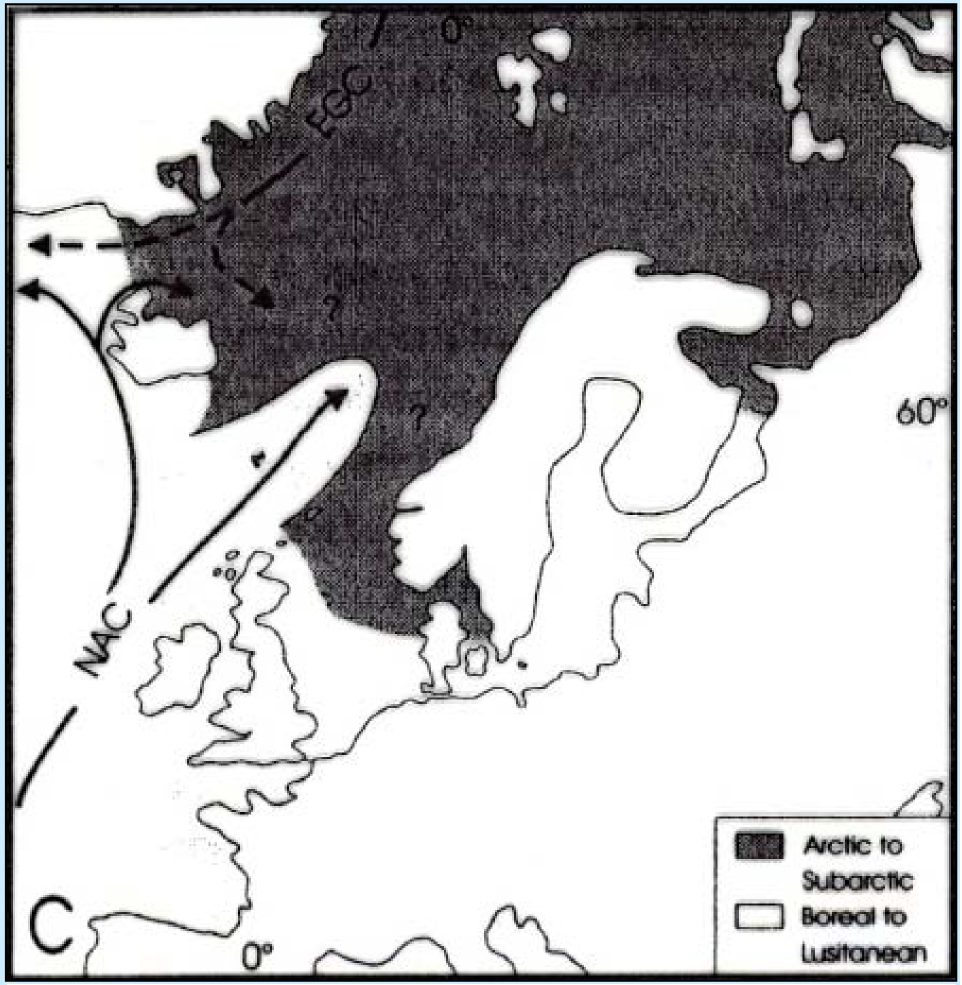


Knudsen et al. (2002)

Surface water circulation and faunal provinces in North Atlantic during Eemian



Warm phases of Eemian



Cold events in Eemian

NAC – North Atlantic Current, **EGC** – East Greenland Current

Knudsen et al. (2002)

Plant climate indicator species

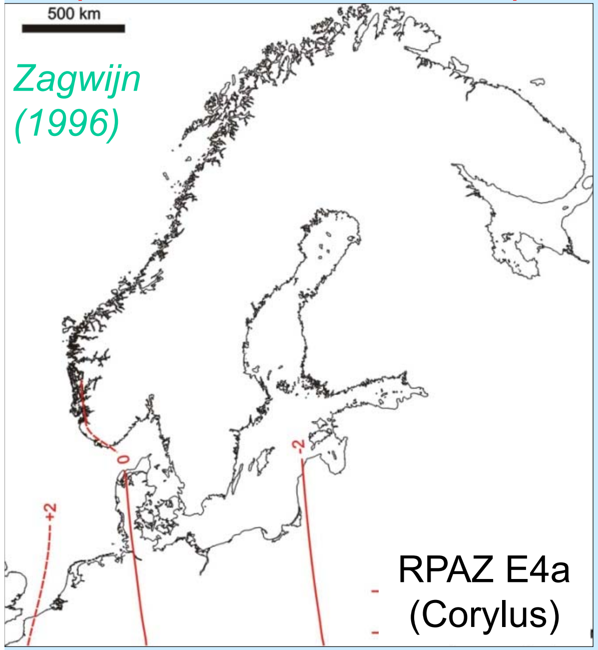
Taxon	Mean July temperature		Mean January temperature	
	Minimum	Maximum	Minimum	Maximum
Abies alba			-4.0	
Acer tataricum	19.0			
Aldrovanda vesiculosa	18.0			
Armeria maritima			-8.0	
Betula nana	7.0			
Buxus sempervirens	18.0		1.0	
Calluna vulgaris	8.0			
Caltha palustris	8.0			
Carex pseudocyperus	13.0			
Carex rostrata	8.0			
Ceratophyllum demersum	15.0			
Ceratophyllum submersum	16.0			
Cladium mariscus	15.5		-15.0	
co-occurrence Calluna + Larix			-13.0	
Cyperus glomeratus	20.0			
Eleocharis palustris	10.0			
Eriophorum vaginatum	7.0			
Filipendula	10.0			
Filipendula ulmaria	8.0			
Frangula alnus	13.0			
Hedera helix	15.0		-2.0	
Hippoph aë rhamnoıdes	11.5			
Hydrocotyle vulgaris	11.5		-6.0	
Ilex aquifolium	12.5		0.0	
Jasione montana	11.5			
Juniperus communis	10.0			
Linum perenne	12.0			
Menyanthes trifoliata	8.0			
Myrica gale	10.0			
Myriophyllum alterniflorum	7.5			
Myriophyllum spicatum	10.0			
Myriophyllum verticillatum	10.0			
Najas flexilis	15.0			
Najas marina	15.0			
Najas minor	18.0			
Nuphar sp.	13.0			
Nymphaea alba	12.0			
Nymphaea candida	12.0			
Parnassia palustris	7.0			
Polygonum viviparum	5.0	20.0		
Potamogeton filiformis	8.0			
Potentilla palustris	8.0			
Ranunculus flammula	8.5			
Ranunculus sect. Batrachium	10.0			
Sanguisorba minor	12.0		-12.0	
Sanguisorba officinalis	9.5			

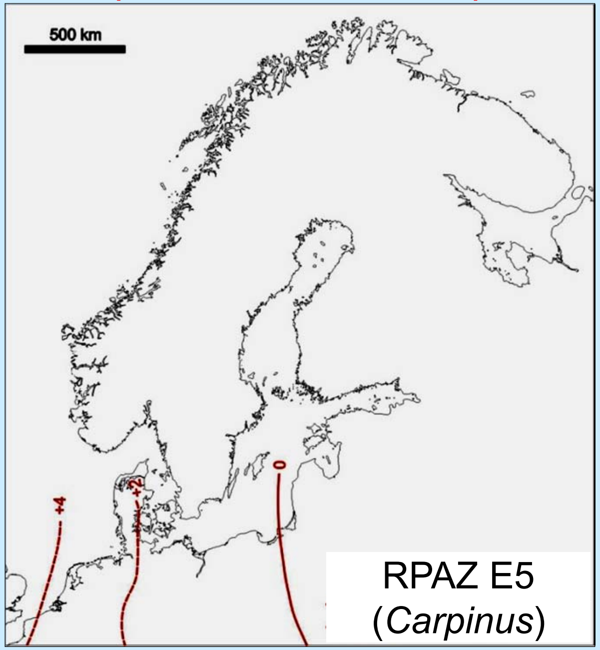
Aalbersberg & Litt (1998)

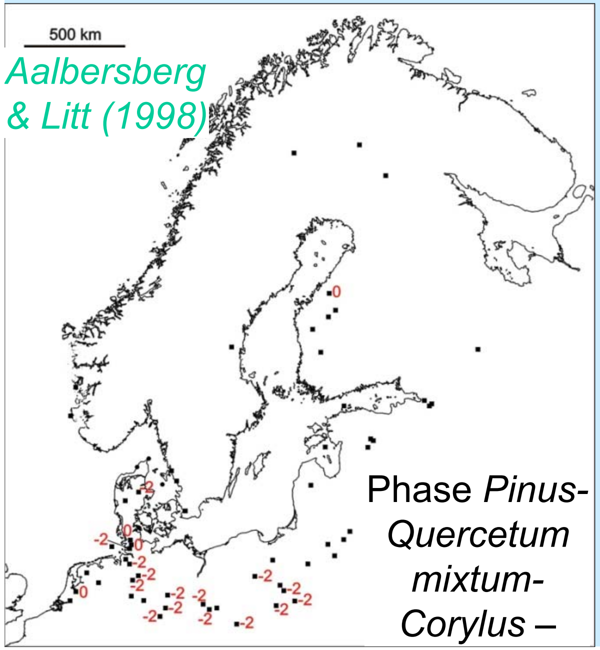
Eemian January temperature

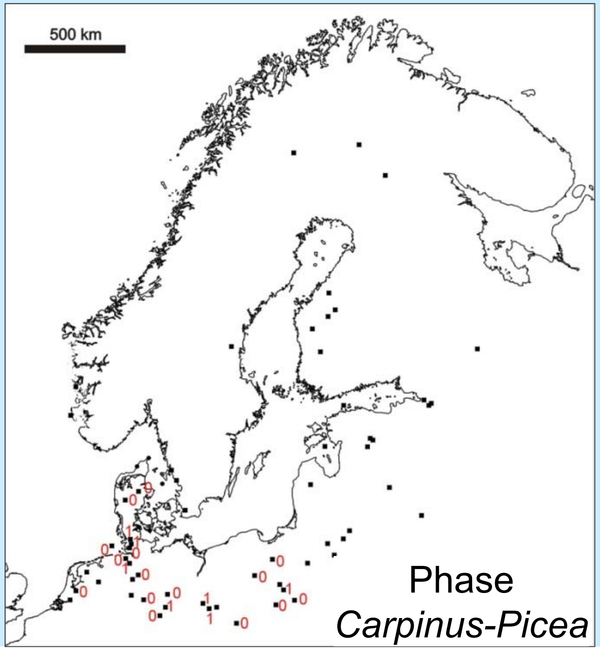
750-3000 yrs
(125.25-123 ka BP)

3000-7000 yrs
(123-119 ka BP)









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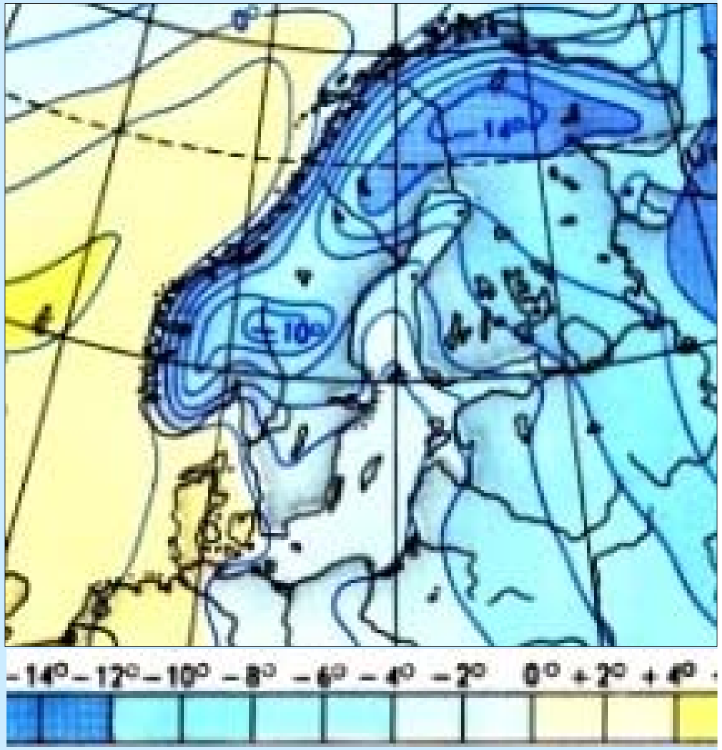

Eemian
July temperature

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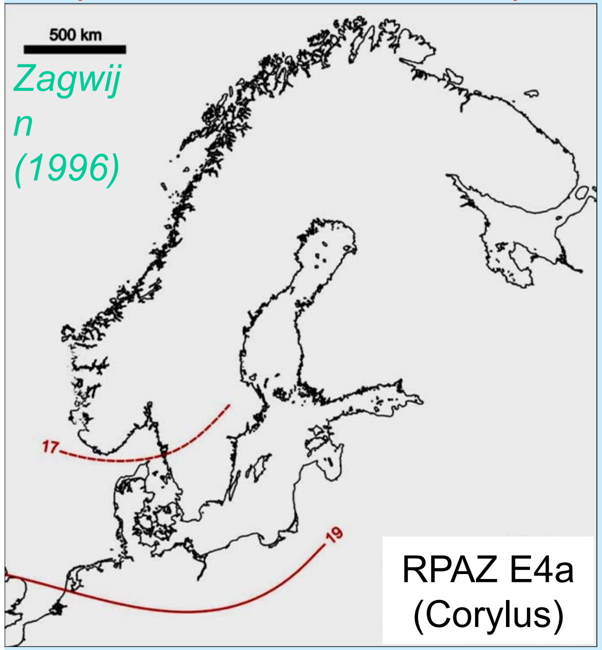

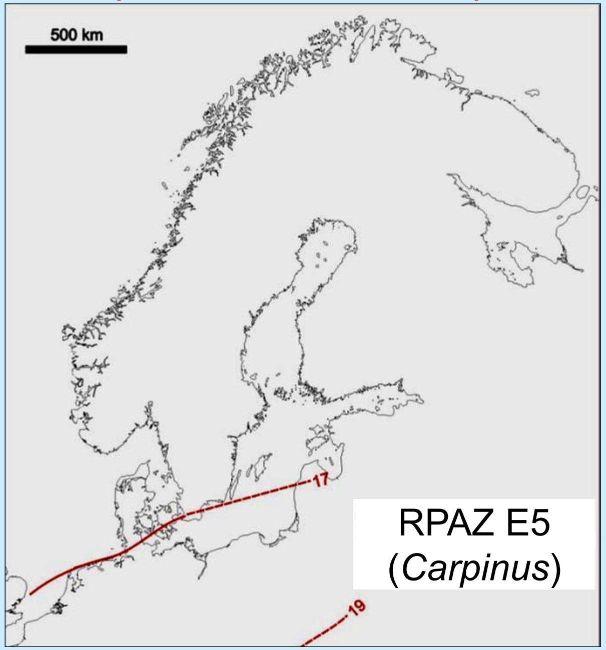

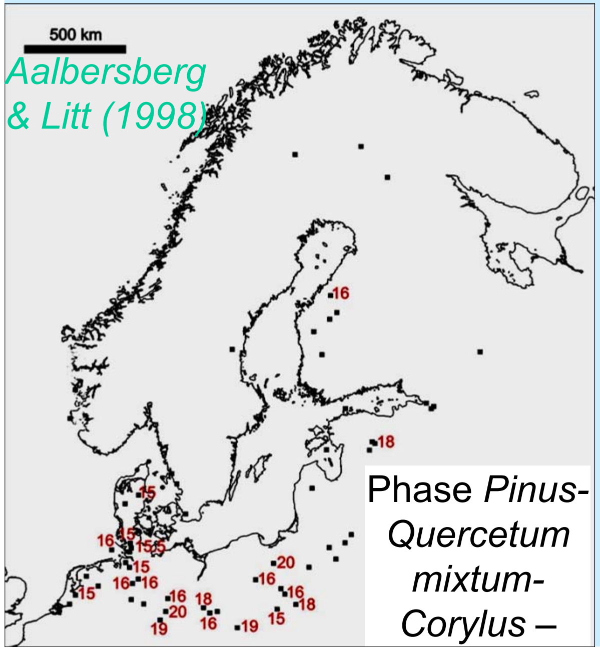

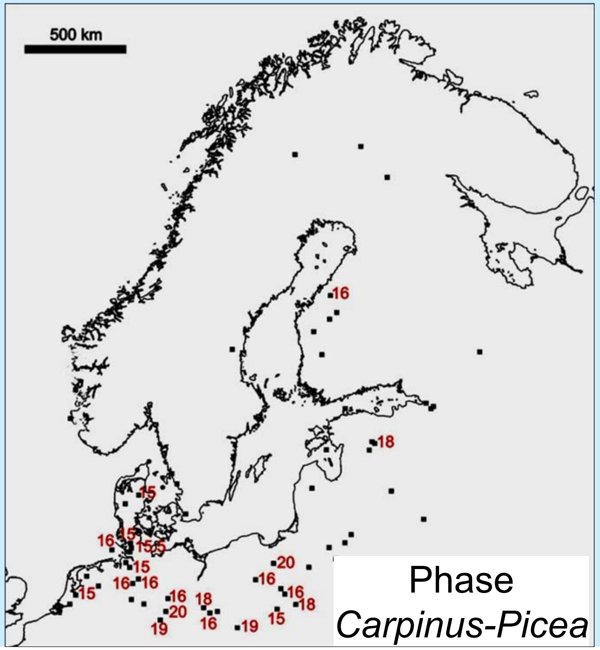

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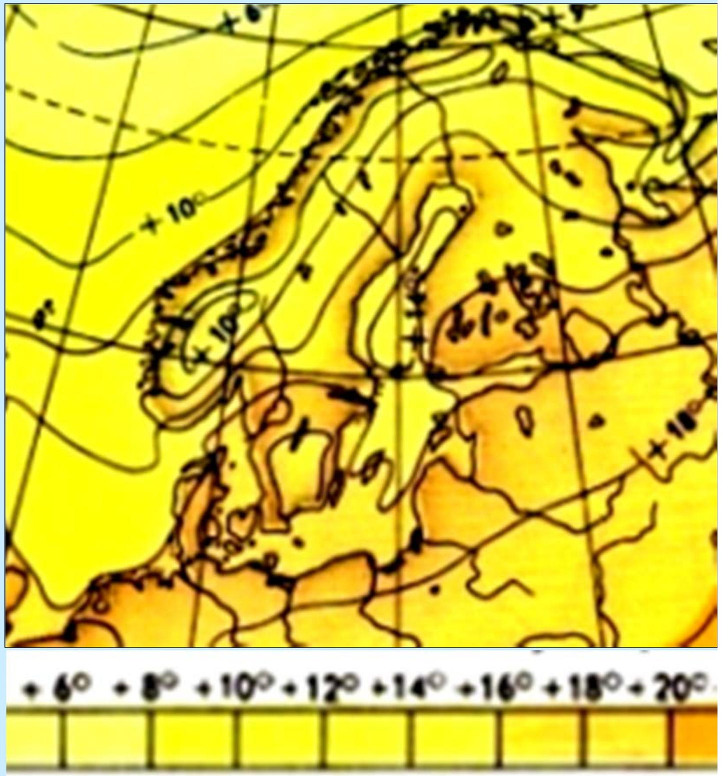
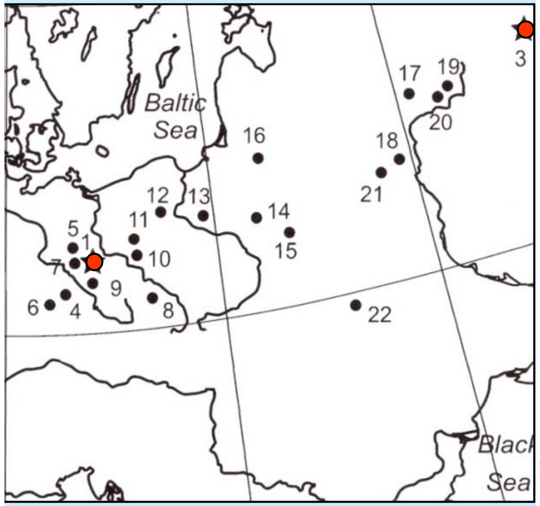
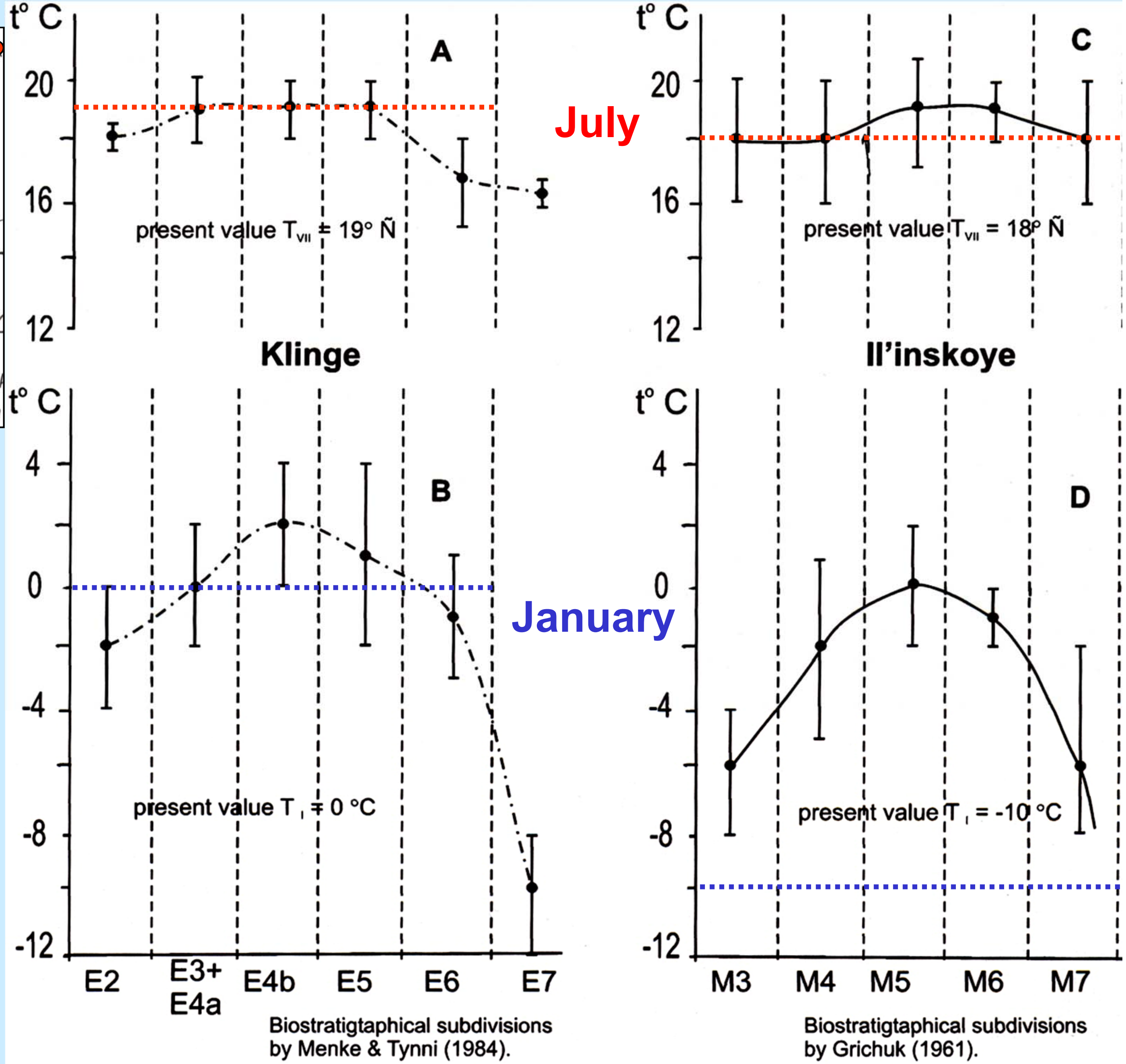


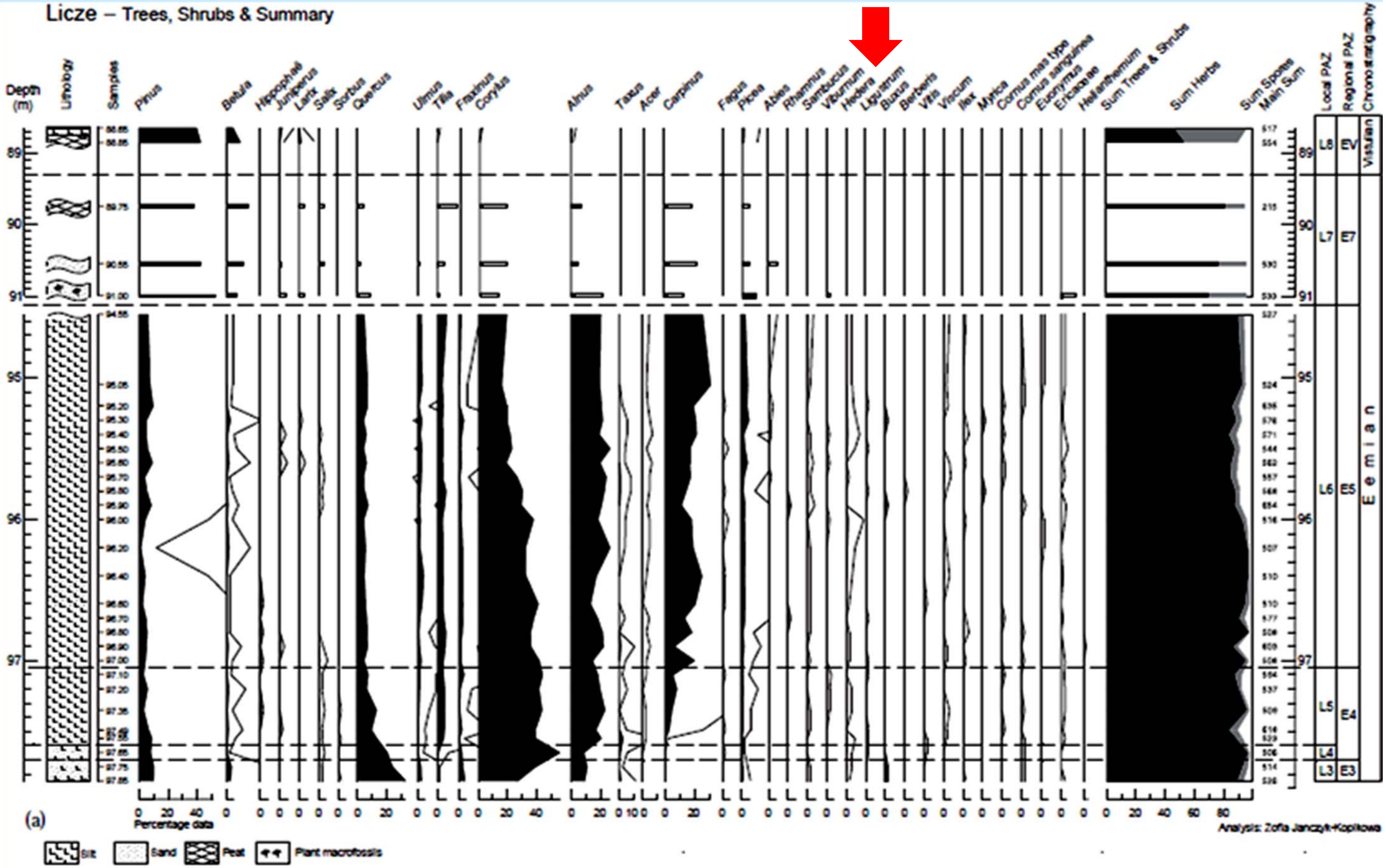
Eemian temperatures in central and eastern Europe





Velichko et al. (2005)

Site Licze: Heddera in the pollen spectrum



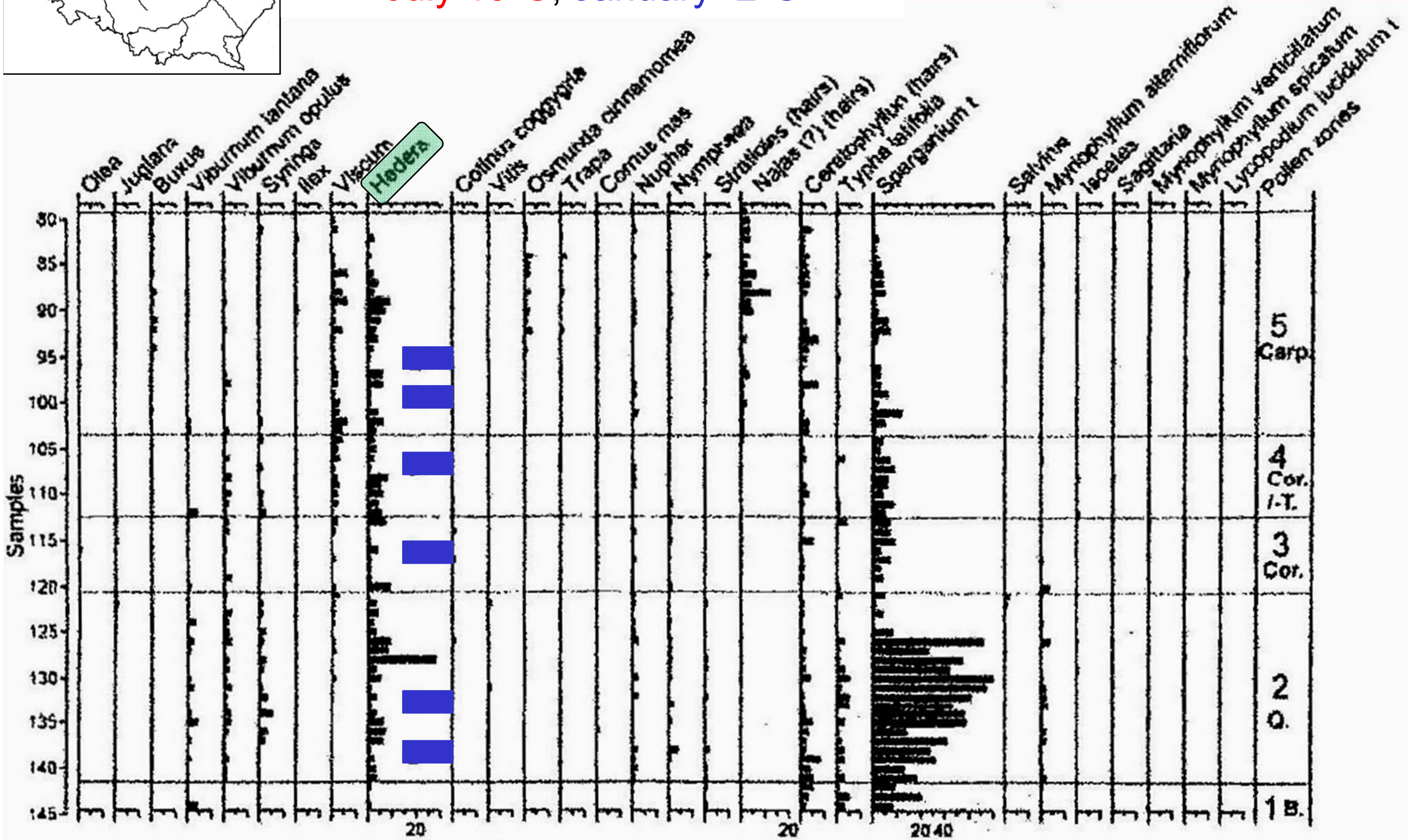
RPAZ after Mamakowa (1988, 1989)

Head et al. (2005)

Cyclicity of Eemian climate

Hedera **minimum temperatures:**

July 15ºC, January -2ºC

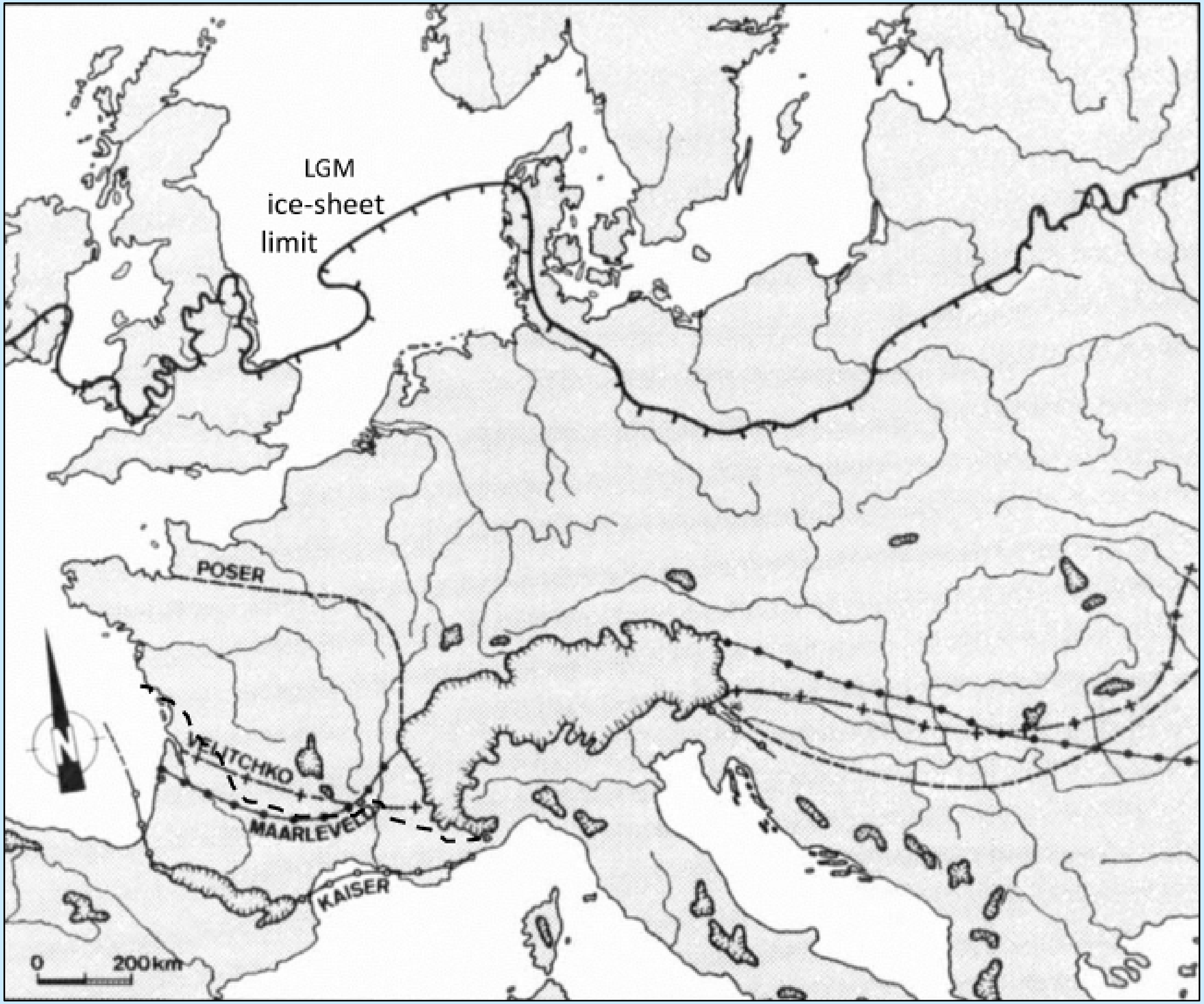


Bińka & Nitychoruk (2011)

Characteristics of Eemian terrestrial climate

- Climatic reconstructions of Zagwijn (1996) and Aalbersberg & Litt (1998) for the region reveal the climate consistently warmer than in the Holocene
- Mean temperature of the warmest month during the Eemian in western Europe was as much as 2^{o}C higher than at present in RPAZ E3b-E4a, and remained higher than at present until the middle of RPAZ E6b
- Mean temperature of the coldest month in western Europe was up to 3^{o}C higher than at present and closely parallels the sea-level curve for this period
- The warmest month thermal maximum was earlier (RPAZ E4a) than that of the coldest month (RPAZ E5), while precipitation estimates suggest an increase from relatively low values prior to RPAZ E4b to greater than 800 mm in the subsequent zones
- Eemian climate appears to have moved from relatively continental conditions prior to RPAZ E4b to a more oceanic type

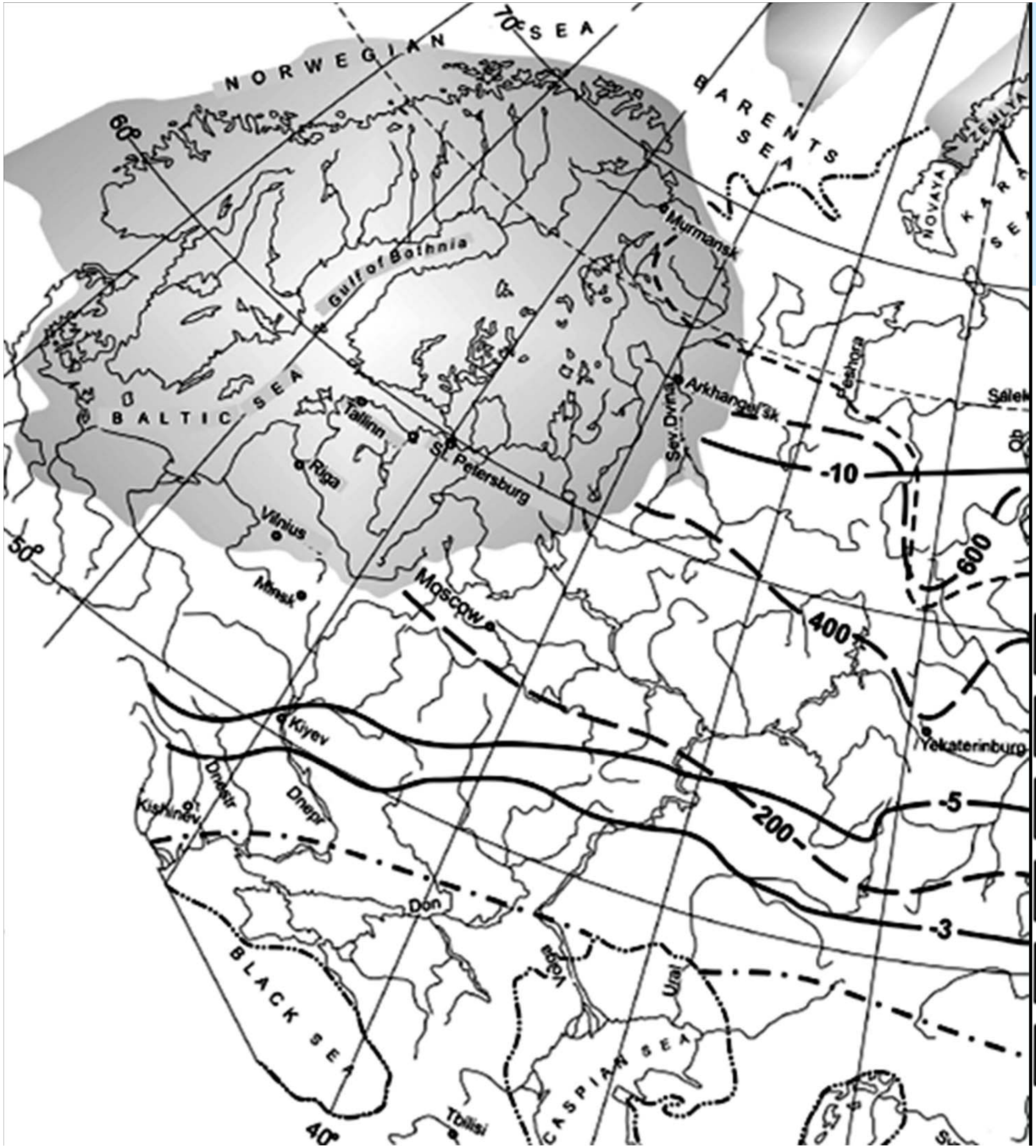
LGM permafrost boundaries in western and central Europe



Vanderberghe et al. (2014)

Permafrost in Eastern Europe at 20–18 ka BP

Permafrost is stable at -5.5º to -8ºC



Mean annual temperatures of permafrost [in °C]

Thickness of permafrost [in m]

LGM limit of permafrost

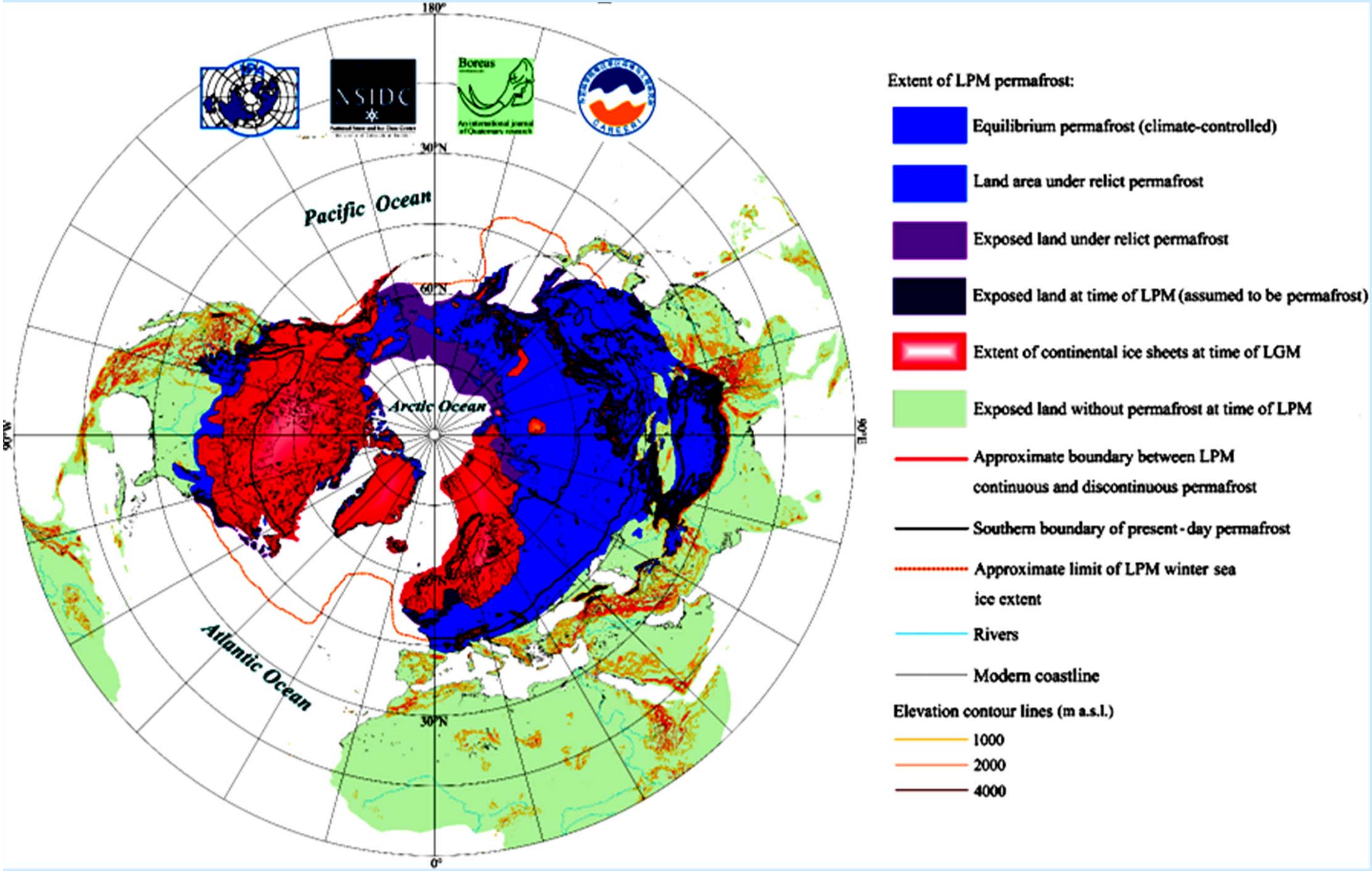
Present limit of permafrost

LGM coastline

Ice-sheet

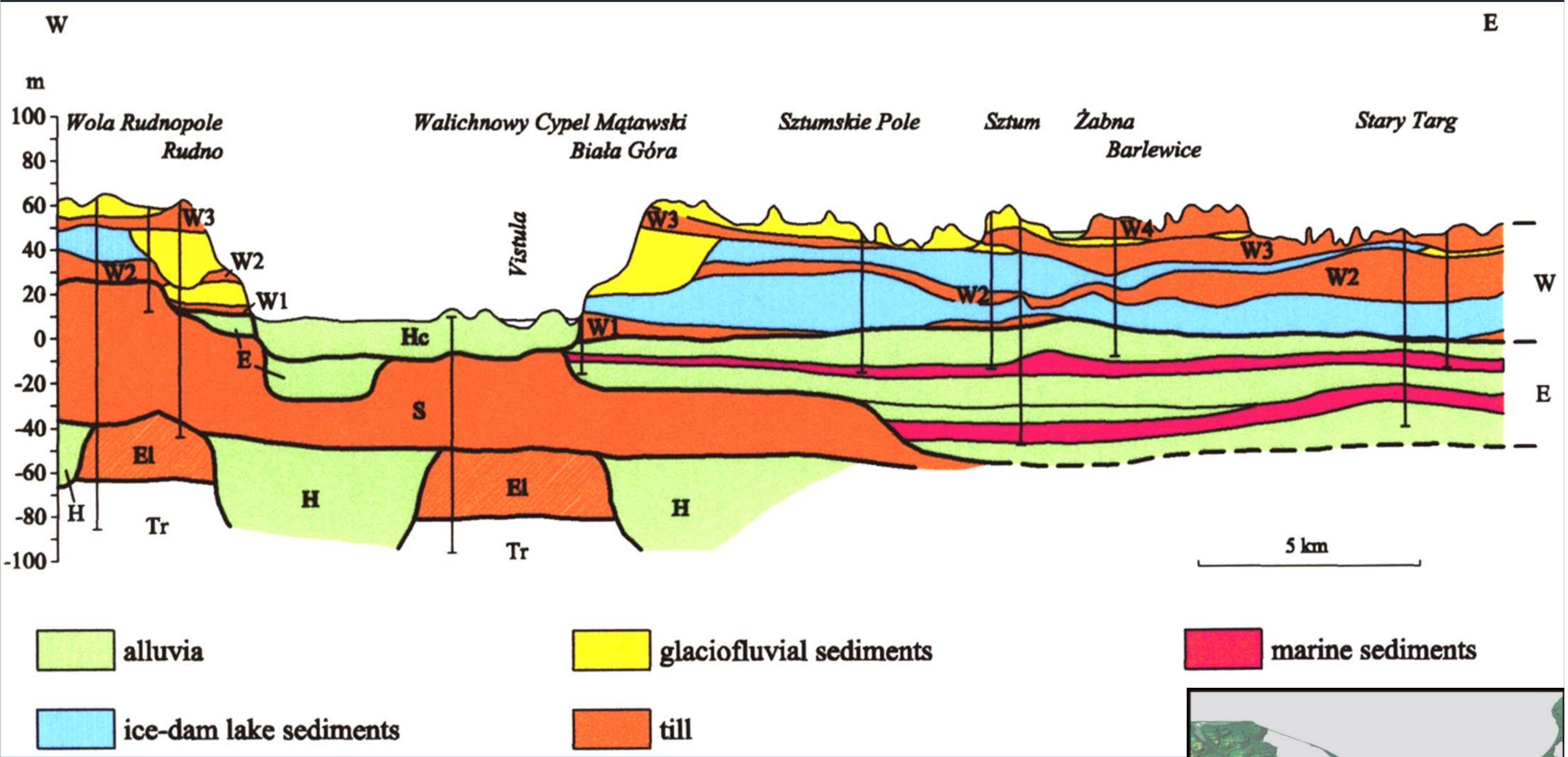
Vanderberghe et al. (2014)

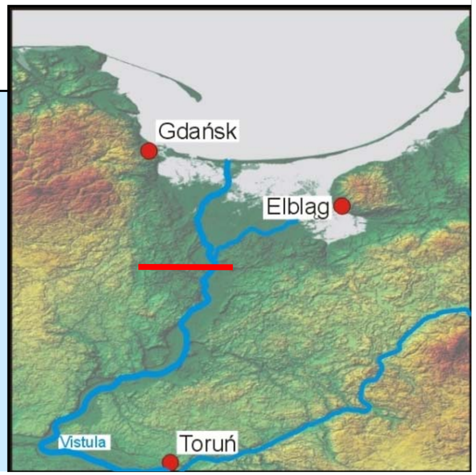
Extent of permafrost 25–17 ka BP in northern hemisphere



Vanderberghe et al. (2014)

Sequence of deposits of the last glacial stage

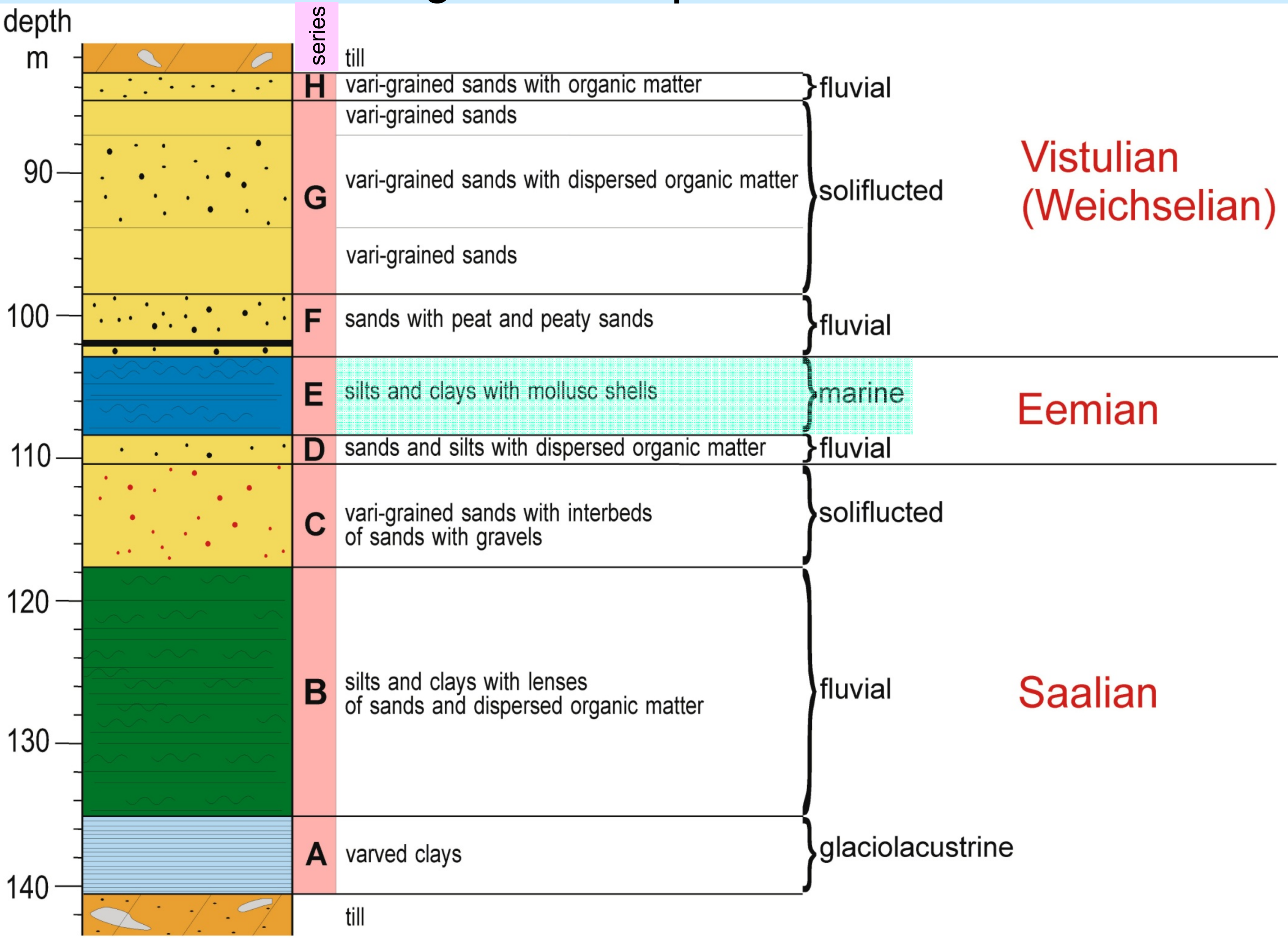




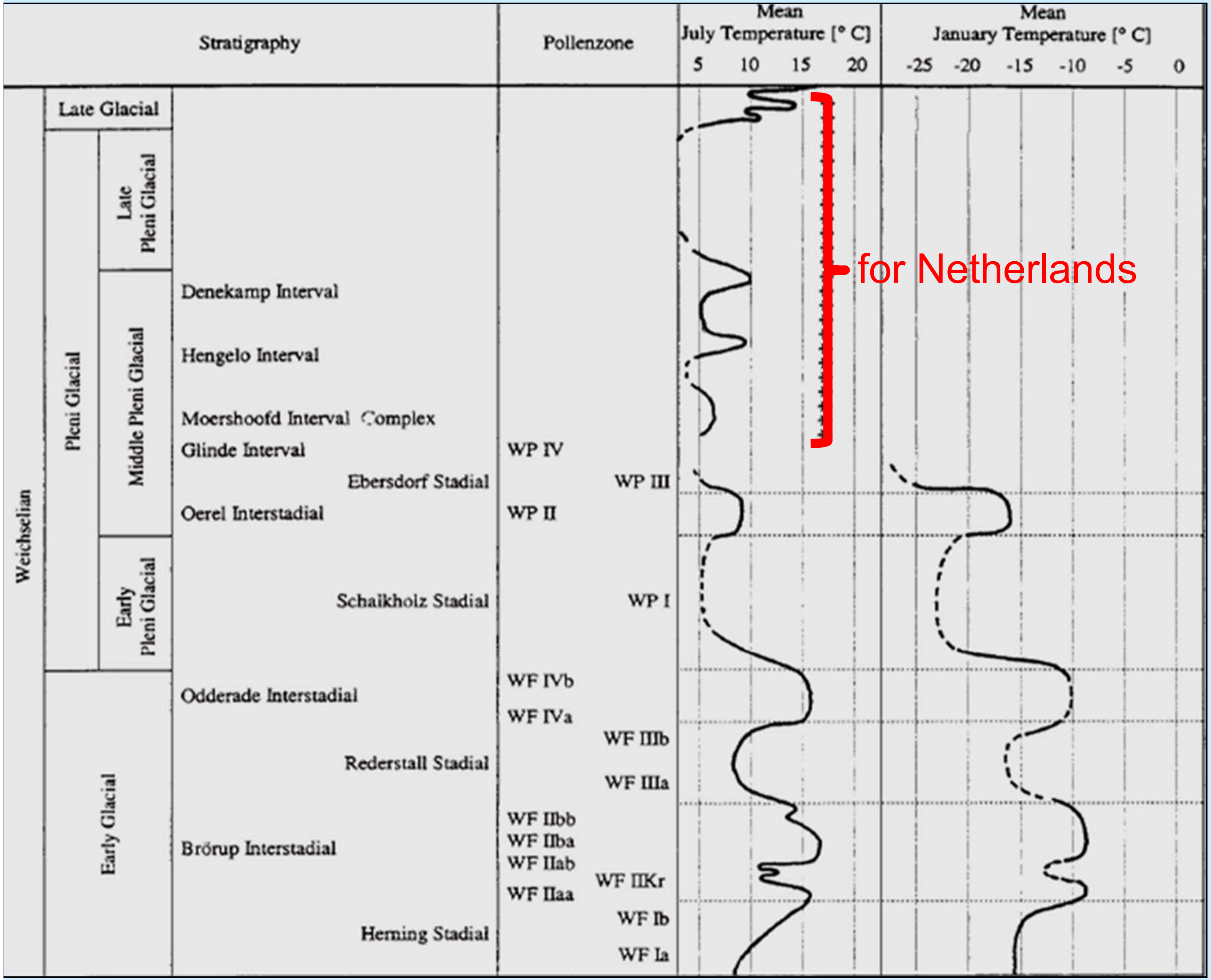
Geological cross-section in the vicinity of Sztum after Makowska (1984), modified

Tr – Tertiary; Quaternary: **El** – Elsterian, **H** – Holsteinian, **S** – Saalian, **E** – Eemian, **W** – Weichselian (glacial phases **W1-W4**), **Hc** – Holocene

Post-Eemian non-glacial sequence in northern Poland



Weichselian palaeotemperatures in northwestern Germany

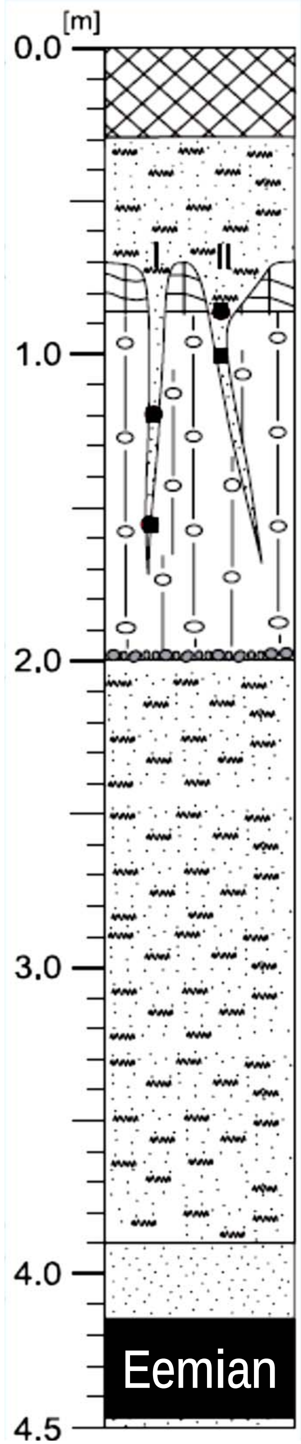


Based on palynological data, botanical macrofossils, and fossil *Coleoptera*

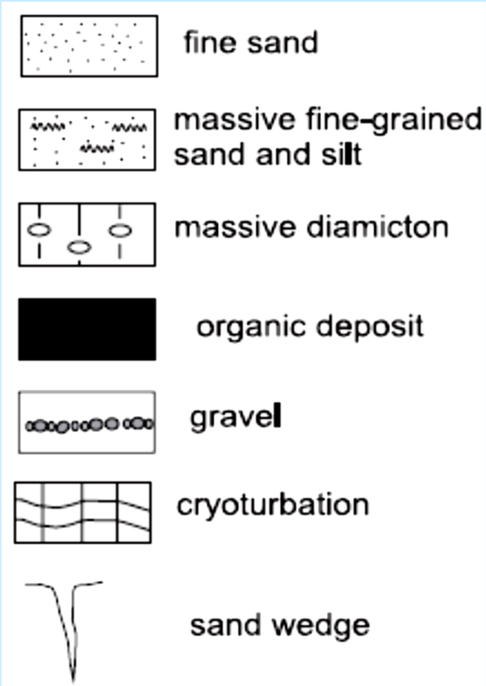
Caspers & Freund (2001)

Ice-wedges in north-eastern Poland

Active ice-wedge polygons develop in a coarse substrate at mean annual temperatures below -8 to 6ºC (*Péwé, 1966*)

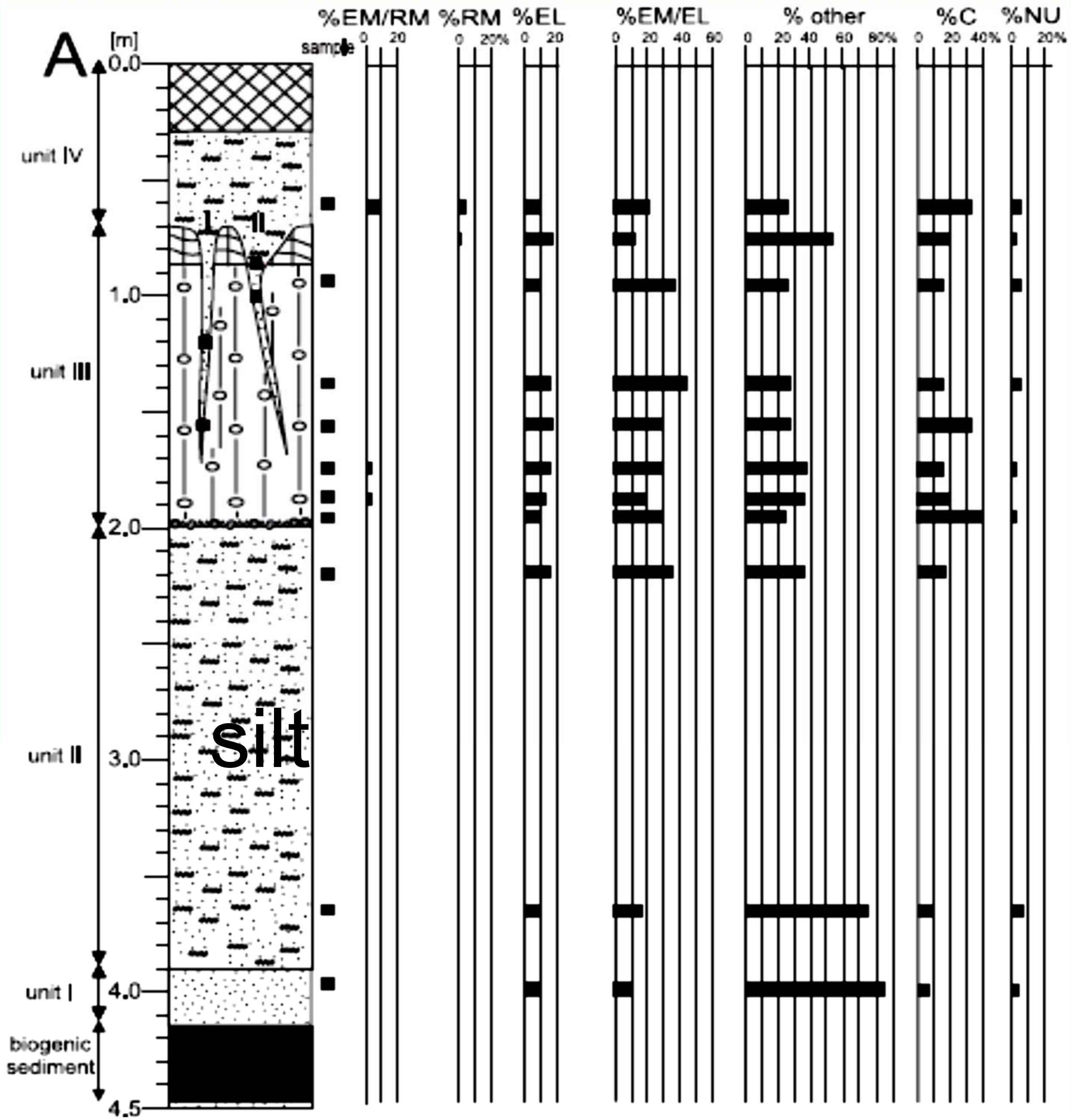


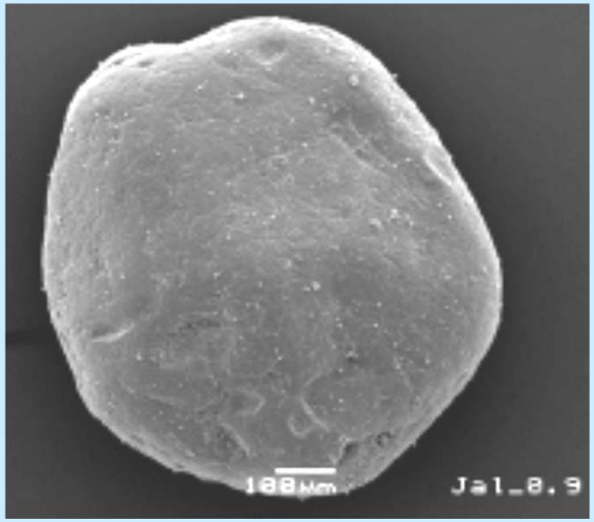
Jałówka site



Woronko et al. (2013)

Rounding and frosting of the quartz grains

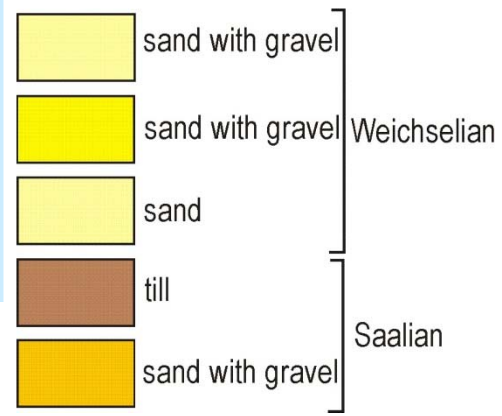


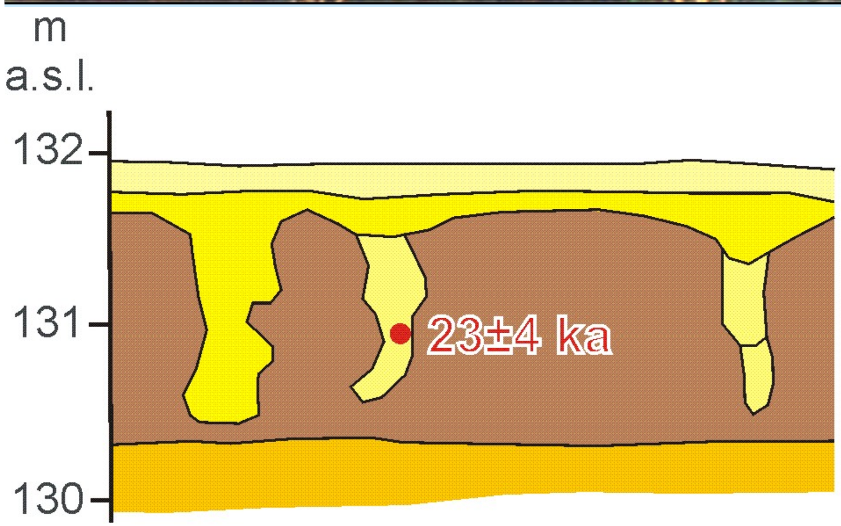


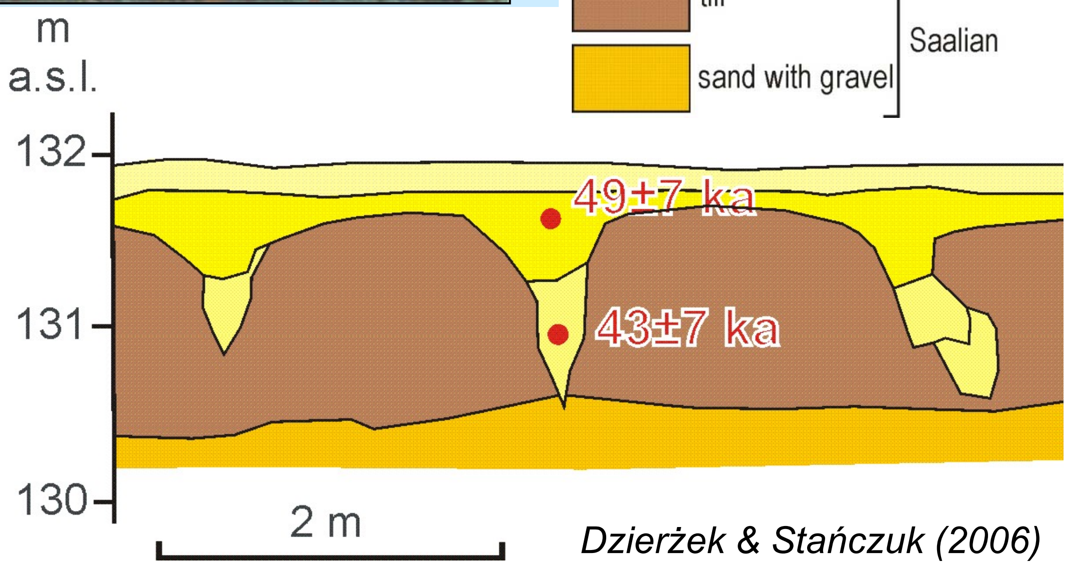
NU – fresh, angular
RM – rounded and mat
EL – rounded and shiny
EM/RM – moderately rounded and mat
EM/EL – moderately rounded and shiny
C – broken
Other – weathered *in situ*

Woronko et al. (2013)

Record of Weichselian ice wedges in eastern Poland

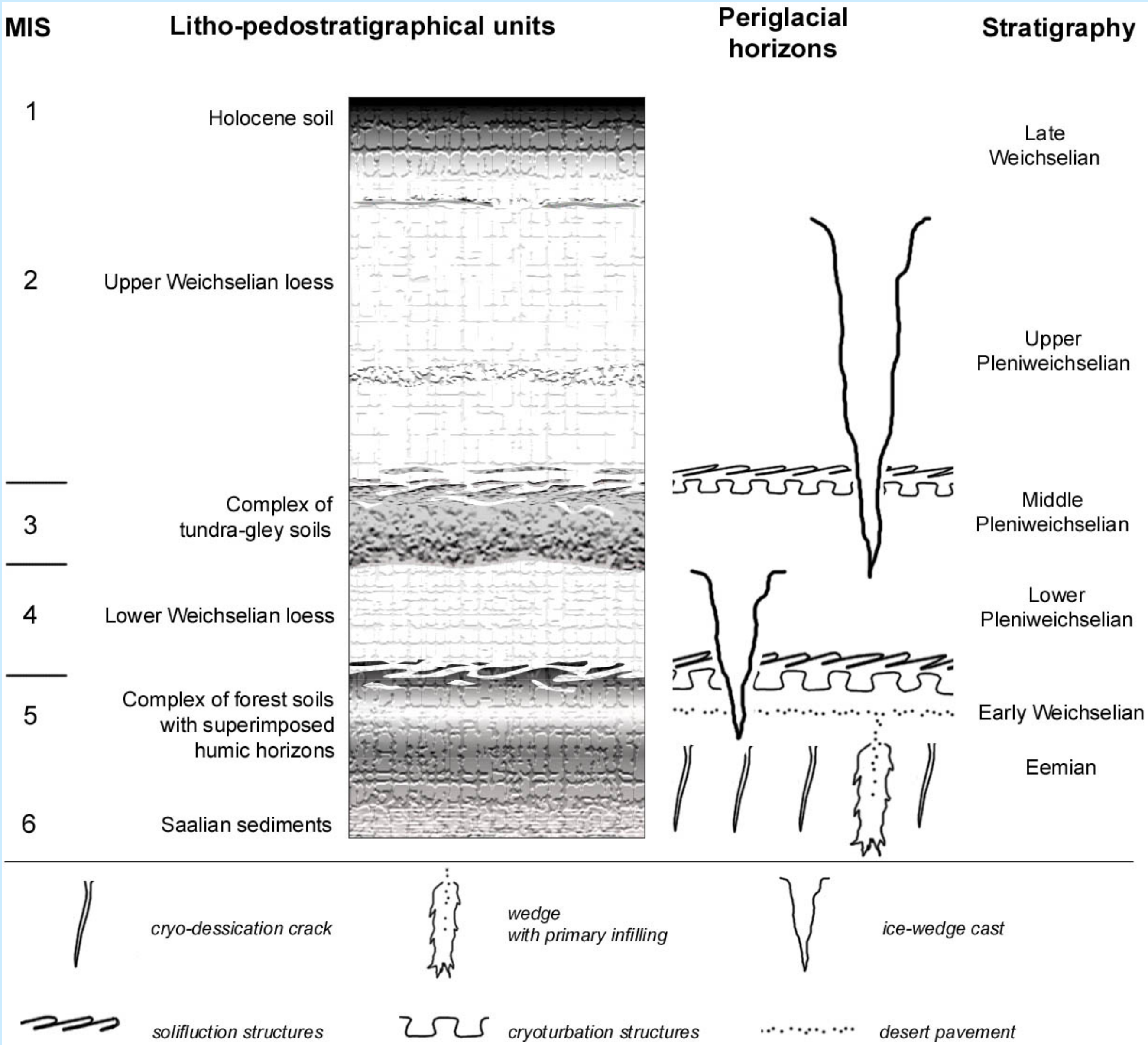






Dzierżek & Stańczuk (2006)

Record of Late Pleistocene climate change in loess-soil sequences (mid-eastern Europe)

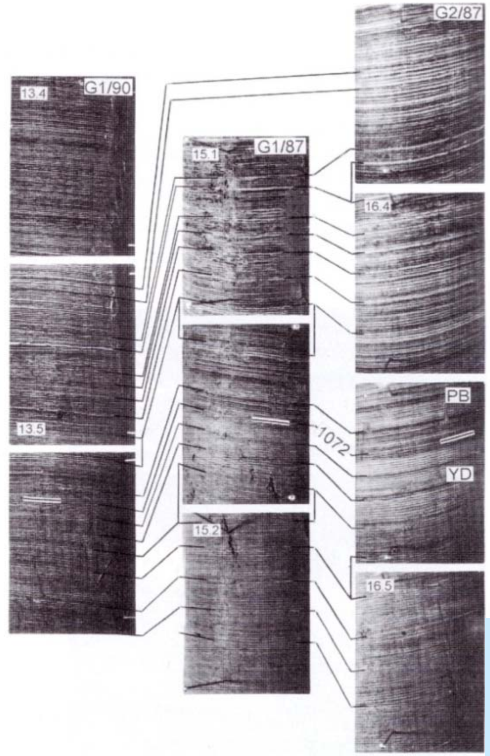


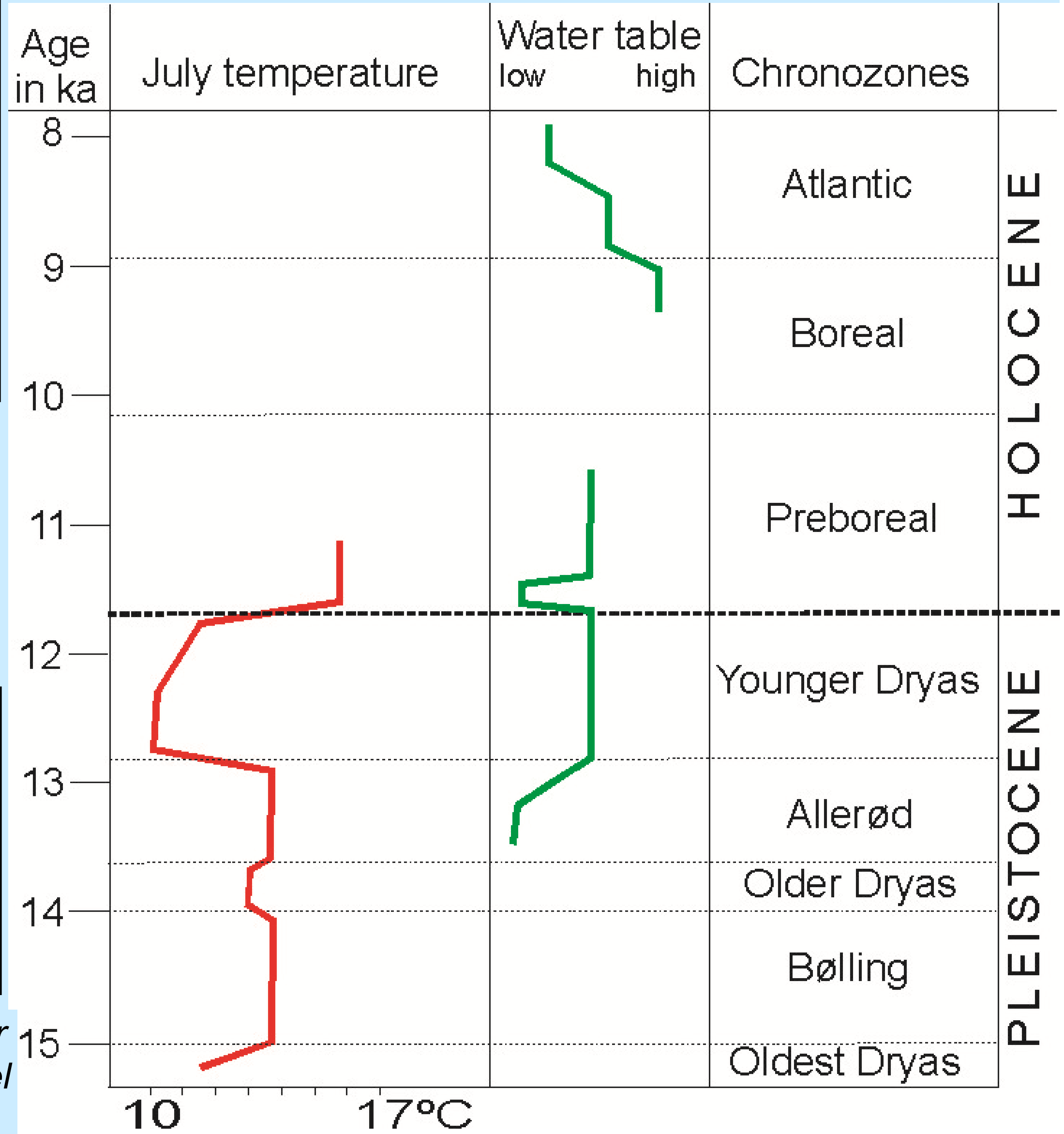
Jary (2004)

Recapitulation of the Weichselian terrestrial climate in southern Baltic region

- Early glacial has been indicated by fluvial activity characteristic for temperate climate and expressed by floodplain and ox-bow lake deposition
- Such temperate river activity could be interrupted occasionally by deposition of anastomosing rivers, active in a cool climate
- The following, more severe climatic conditions with low temperatures and decreased precipitation, most probably connected with aggraded permafrost, could initiate intensive aeolian processes
- They were interrupted by more wet episodes and seasonal development of an active layer in a ground when solifluction moved down-slope huge amounts of surficial deposits that had been transformed earlier in a periglacial environment

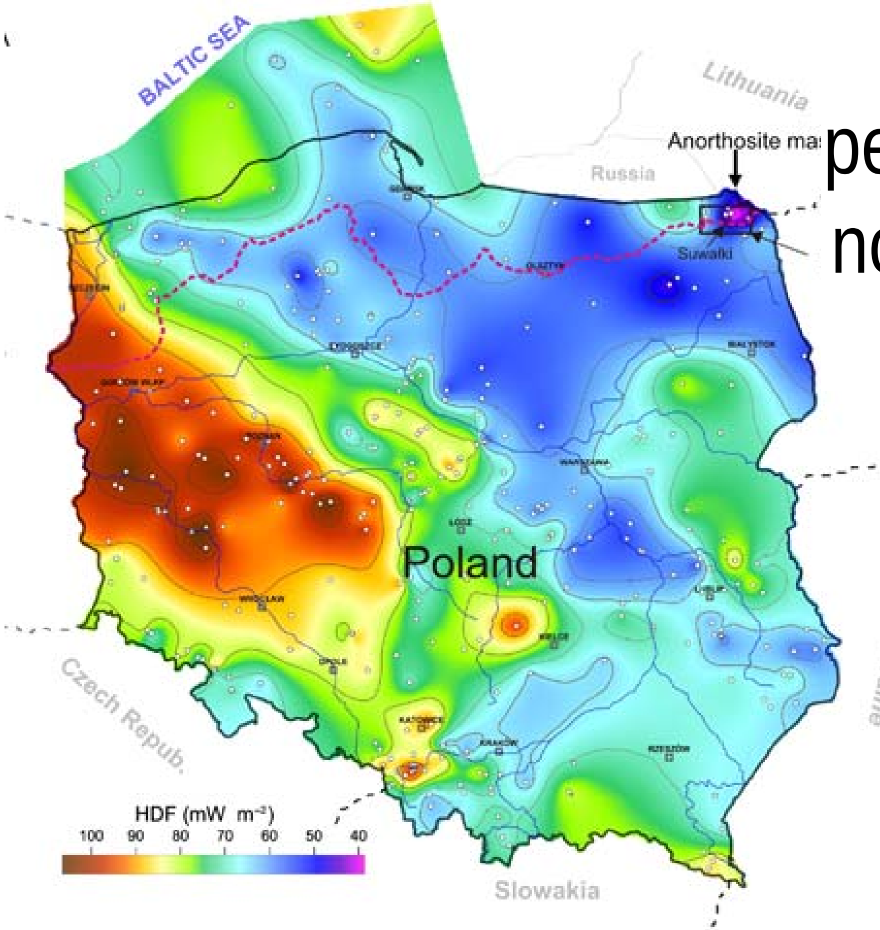
Climate at the turn of Pleistocene and Holocene

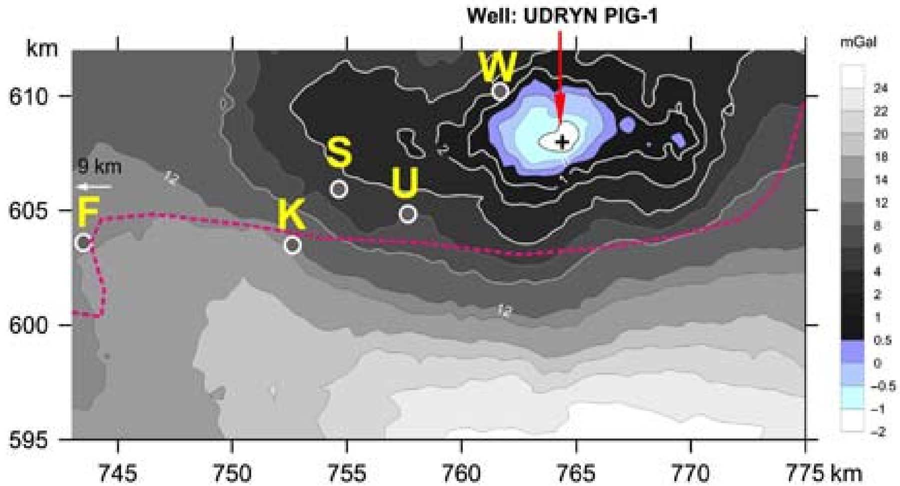


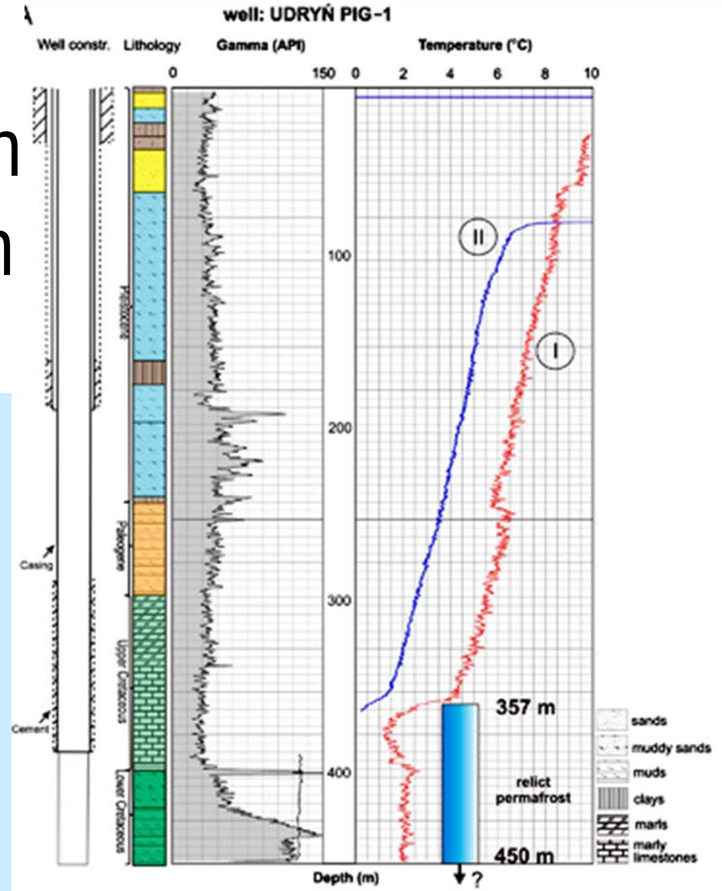


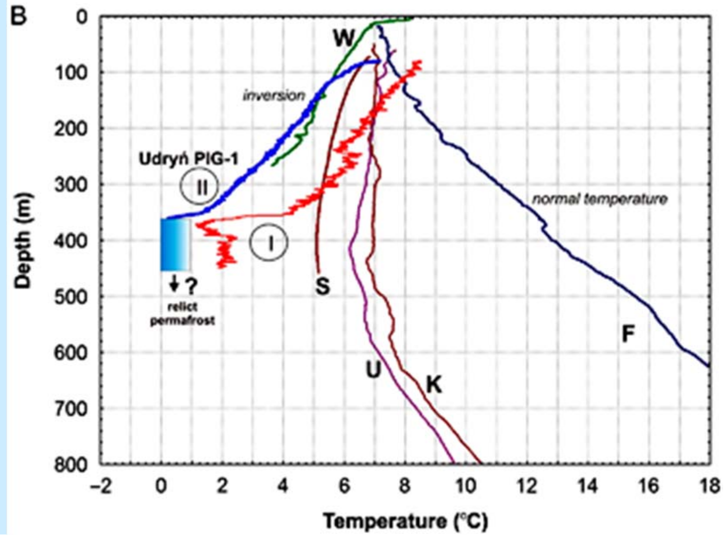
Record from Goslar et al. (1998); Starkel et al. (1998)

Relict permafrost in northeastern Poland









Szewczyk & Nawrocki (2011)

Conclusions

- Late Pleistocene climate change in the southern Baltic Sea region has been significantly influenced by the Eemian sea as well as development or decay of the Scandinavian ice sheet
- Distinct regional variation was common: the climate was more oceanic in the west and more continental in the east
- In general the climate was not stabile during Late Pleistocene and comprised numerous warmer and cooler episodes of varying magnitude

Acknowledgments

The presentation is based on data collected during realization of research projects funded by the Ministry of Science and Higher Education in Poland:

- ‚***Chronostratigraphy of deposits of Pleistocene seas in Poland, based on integrated geological investigations***’ [no. 1349/B/P01/2009/37]
- ‚***Geological and geomorphological mapping connected with palaeontological and sedimentological investigations in the Polish-Belarusian border area***’ [497/N-BIAŁORUŚ/2009/0]

Data on the Eemian sea come also from BALTEEM project ‘***Palaeoenvironmental and palaeoclimatic evolution of the Baltic Sea basin during the Last Interglacial (Eemian, Mikulino)***”, led by Phillip L. Gibbard (University of Cambridge), Karen-Luise Knudsen (University of Aarhus), Hans Petter Sejrup (University of Bergen) and Matti Eronen (University of Helsinki) [Contract no: ENV4-CT98-0809 BALTEEM]

Thank you for attention