BOREAS COMMENT
Boreas, Vol. 35, pp. Oslo 2006 (August)

‘Cosmogenic ^{10}Be ages on the Pomeranian Moraine, Poland’: Comments

MICHAEL HOUMARK-NIELSEN, SVANTE BJÖRCK AND BARBARA WOHLFARTH

^{10}Be cosmogenic nuclide dating of the Pomeranian end moraine system is taken as an indication of a ‘Bølling age’ for the last major glacial invasion into the western Baltic basin and the northern Polish lowland (Rinterknecht *et al.* 2005). This reasoning is incompatible with other well-established chronologies on Late Weichselian ice-marginal stages and the migration of Lateglacial biota. Rinterknecht *et al.* (2005) set up a scenario where an ice stream moving through the Baltic reached 200–300 m above the present sea level to give the Pomeranian end moraines in northern Poland and Germany their final shape at *c.* 14.8 thousand years (kyr) ago. This would imply a glacier thickness in the western Baltic basin of at least this magnitude at onset of the Bølling. Despite published evidence indicating that the deglaciation in southern Scandinavia had been proceeding for several millennia, the Pomeranian ice advance should accordingly have commenced retreat, while subarctic shrub tundra and open birch forests existed in larger parts of the southern circum-Baltic region and active glacier ice was confined to the south Swedish uplands. Because the focus of the article aims solely at introducing ‘the first direct dating of the southern margin of the Scandinavian Ice Sheet in Poland’, we find ourselves compelled to expose a regional perspective on the authors’ conclusions.

Cosmogenic nuclide dating has been applied to boulders from the surface of the Pomeranian End Moraines in northern Poland. Eight dates from sites in the Odra–Oder Lobe in western Poland (Fig. 1) yielded ages ranging from 18 to 11 ^{10}Be kyr, with a mean of *c.* 14.3 ± 0.8 ^{10}Be kyr, while 19 dates from the Mazury and Suwalki lobes in northeastern Poland taken together give 15.0 ± 0.5 ^{10}Be kyr. The average age of 14.8 ± 0.4 ^{10}Be kyr is used as evidence to imply that the entire western Baltic basin was occupied by an ice stream at the onset of the Lateglacial warming that characterizes the Bølling period. This climatostratigraphic zone (Iversen 1954, 1973) is referred to as the Bølling Chronozone ($<$13.0–12.0 ^{14}C kyr; Mangerud *et al.* 1974), and corresponds to the GI-1e event in the Greenland ice cores 14.7–14.0 cal. kyr ago (Björck *et al.* 1998). Interpretation of these young cosmogenic exposure ages has wide implications for the understanding of the glacial and biogeographic development during the deglaciation of the last Scandinavian Ice Sheet in the Baltic Basin. However, we find it distressing that the authors neglect affluent evidence which is out of line with their conclusions. For example, Iversen (1954, 1973), Berglund (1979), Usinger (1985) and Stankowska & Stankowski (1988) have long since shown that pioneer biota had migrated into the region during the Oldest Dryas and that subarctic shrub tundra was established during the subsequent climatic amelioration of the Bølling period.

The application of a new and promising dating method, the strengths and weaknesses of which are not fully acknowledged (Walker 2005), needs careful handling, and conclusions on for example the age of glacial morphological features must be tested against other independent dating methods. We therefore find it surprising that Rinterknecht *et al.* (2005) avoid discussing their results and conclusions in the light of previous works on the age of moraine formation and deglaciation dynamics in the southern Baltic region. The authors disregard the consequences such a new age estimate has for reconstructing the biotic and palaeogeographic setting during the Lateglacial period in the region. In addition, they fail to discuss a possible subsequent revision of the already established timing of the Lateglacial development. The latter is based on numerous radiocarbon-dated plant remains, pollen-stratigraphic correlations, the Swedish varve-chronology and palaeomagnetic records; data that are readily available from the scientific literature published in recent decades. With this note, we take the liberty of providing readers of *Boreas* with input to such a discussion.

End moraines in the western Baltic region

Taking the cosmogenic ages at face value, Rinterknecht *et al.* (2005) conclude that the margin of the Scandinavian Ice Sheet was near its maximum later than previously inferred. The Pomeranian End Moraines as outlined by Woldstedt (1925) are situated south of the Baltic coast in northwestern Poland and northeast Germany (Fig. 1). The moraines are distinguished morphologically from older moraines of the Frankfurt–Poznan and Brandenburg–Leszno stages. Moraine formation younger than the Pomeranian

Taylor & Francis
Taylor & Francis Group
DOI 10.1080/03009480600781966

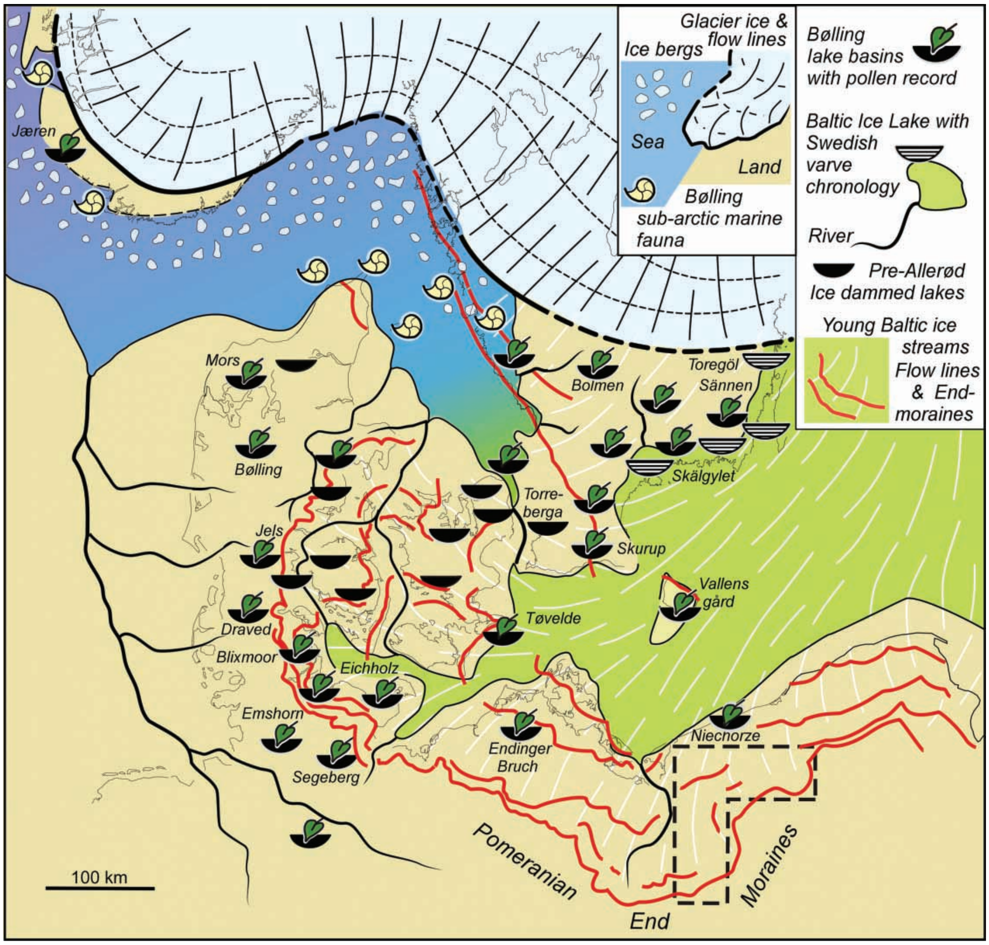

Fig. 1. Palaeogeographic reconstruction of the western Baltic region 14.7–14.0 kyr ago. Inferred distribution of active glacier ice, arctic sea and the Baltic Ice Lake during the Bølling Chronozone is shown. Type and reference sites with marine, lacustrine and terrestrial floral and faunal remains are indicated. Red lines depict prominent Late Weichselian ice-marginal moraines and their suggested connections with the Pomeranian Moraine. Compiled from Iversen (1973), Ehlers (1996), Usinger (1985), Lundqvist & Wohlfharth (2001), Smed (2002), De Klerk (2002) and Houmark-Nielsen & Kjær (2003). Dashed box indicates area of cosmogenic nuclide dating by Rinterknecht *et al*. (2005).

includes the Rosentahl and Velgast stages (Ehlers 1996) and the Gardno phase (Kozarski & Kasprzak 1987). The age of the Pomeranian stage, as well as that of older and younger stages, has been estimated by radiocarbon dating on plant macrofossils (Kozarski 1988; Marks 2002). Dated material obtained from inside and outside the moraines gives ages close to 22 kyr (18.4 ^{14}C kyr) for the Poznan moraines. The age of the Pomeranian moraines has been estimated to *c.* 18.6 kyr (15.2 ^{14}C kyr). The subsequent Gardno phase has been given ages around 15.6–17.0 kyr (13.2–14.3 ^{14}C kyr), while its western extension linked to the end moraine stages of the Odra Bank is dated to around 16.7 kyr (14.06 ^{14}C kyr). In spite of dating uncertainties in the order of $\pm$1 kyr for the calibrated radiocarbon ages, the mean cosmogenic age of *c.* 14.8$\pm$0.4 ^{10}Be kyr for the Pomeranian moraine published by Rinterknecht *et al.* (2005) is at least 3–4 kyr younger than those obtained by radiocarbon.

Overviews on the connection of end moraine systems belonging to Late Weichselian ice advances of Baltic provenance in Poland, Germany, Denmark and southernmost Sweden do not differ significantly from each other (Hurtig 1969; Lagerlund & Houmark-Nielsen 1993; Ehlers 1996; Stephan 2001; Smed 2002; Houmark-Nielsen & Kjær 2003; Ehlers *et al.* 2004). Based on these compilations, Fig. 1 illustrates our synthesis of the position and correlation of end moraines associated with the Young Baltic Ice Streams *sensu* Houmark-Nielsen & Kjær (2003) and Kjær *et al.* (2003). Consequently, end moraine systems in other parts of the western Baltic region, which are correlated with the Pomeranian stage, should be expected to be of almost equal age. Boulton *et al.* (2001) summarize, in accordance with Kozarski (1988), that ice advanced to the western Baltic between 20 and 15 kyr BP and that the terminal morphological features occupy the coastal region in a 100–200 km wide zone. The outlines by

Ehlers (1996) and Boulton *et al.* (2001) are used by Rinterknecht *et al.* (2005) to sketch the position and to frame the possible ^{10}Be ages of end moraines in Poland. However, an important difference in our knowledge today, compared to the situation in the 1980s when Kozarski published his dates, is that we now know there is a considerable difference between ^{14}C years and calendar years dating from the Lateglacial time period.

Palaeoenvironments in the western Baltic region

In a compilation of the position and ages of successive ice-marginal stages during the last deglaciation of southern Sweden, Lundqvist & Wohlfarth (2001) demonstrated that large areas must have been free of active glacier ice at the onset of the Bølling period, a concept already presented by Björck & Möller (1987). This has recently been confirmed in a high-resolution study in the southernmost part of Sweden giving clear evidence for the onset of lacustrine sedimentation >14.2 cal. kyr or ~12.5 ^{14}C kyr BP, i.e. during the period assigned to the Bølling warming (Davies *et al.* 2004). Moreover, Usinger (1978, 1985) and recently Noe-Nygaard & Heiberg (2001) and De Klerk (2002) indicate that lake basins existed along the Baltic coast of the Danish archipelago, northern Germany and Bornholm at the beginning of the Bølling period. These basins do not contain any evidence of subsequent glacier overriding. Supported by previously published pollen diagrams and radiocarbon ages from the western Baltic region and making extensive use of luminescence and new AMS radiocarbon dates, Houmark-Nielsen & Kjær (2003) drew the conclusion that the terminal moraines pictured in Fig. 1 clearly pre-date the Bølling period. Their palaeogeographical reconstruction shows that while calving occurred off the mouth of the Oslo Fjord, the active glacier ice had retreated to the south Swedish highland and the foothills of the Norwegian Mountains. If these reconstructions in the eyes of Rinterknecht *et al.* are proven invalid, the authors have an obligation to reveal alternative solutions.

Plant macrofossil and pollen-stratigraphic studies (Iversen 1954, 1973; Usinger 1985; Berglund 1979; Bennike *et al.* 2004) have identified a specific biotic signature for the Bølling period, i.e. the immigration of a subarctic bush and shrub tundra and open woodlands of *Betula pubescens.* In areas south of the Baltic, scattered stands of *Pinus sylvestris* were present. This biostratigraphic signal of a climatic amelioration indicates a significant rise in northwest European air temperatures (Coope *et al.* 1998), which is synchronous with a similar climatic event registered in the Greenland ice cores (Stuiver *et al.* 1995; Björck *et al.* 1998). The onset of abrupt warming at the boundary between GS-2 and GI-1e is dated to *c.* 14.7 kyr. Correlation of Lateglacial marine, terrestrial and ice core records tuned to the calendar-year time scale is given by Walker *et al.* (1995) and Björck *et al.* (1998), with a duration of the GI-1e event of 500–700 years. AMS-dating used in a reinvestigation of the classical Bølling sequence revealed ages between 12.59±0.08 ^{14}C kyr and 12.15±0.08 ^{14}C kyr (Bennike *et al.* 2004), which sets an age of *c.* 14.7–14.0 cal. kyr for the deposits of the Bølling period at the *Bølling* type section in Denmark.

Reconstructions for the entire Baltic region (Björck 1995) suggest that the Baltic Ice Lake covered larger parts of the southern Baltic basin during the Bølling period. This interpretation is supported by Sandgren *et al.* (1997), who used palaeomagnetic properties to correlate lake records across the Baltic Sea. They showed that lacustrine sedimentation in southernmost Sweden (Lake Torreberga) (Fig. 1) and in southwest Estonia began *c.* 14.4 cal. kyr ago. This implies that active glacier ice had outplayed its role before the Bølling period in the southern Baltic region. A scenario of general glacier withdrawal between 15.2 and 13.0 cal. kyr based on extensive multidisciplinary data sets is outlined by Boulton *et al.* (2001). This deglaciation phase in the Baltic was characterized by high retreat rates, strong calving in the Baltic Ice Lake and rapidly flowing ice lobes due to well-developed deformable bed conditions. However, this scenario does not predict or include active glacier flow in the southern or western Baltic.

Conclusion

Given the above, we find that the mean cosmogenic exposure age of *c.* 14.8±0.4 ^{10}Be kyr, based on measurements from 27 boulders on the Pomeranian Moraine in Poland, most probably post-dates the age of the youngest moraine formation by at least a few millennia. It is noteworthy that five 'anomalously young' samples are not included in the calculation of the mean age, and it is striking that this calculation is based on highly subjective evaluations. For example, a long explanation is necessary to ensure why samples POM-1 (18.6±1.3 kyr) and POM-13 (18.0±1.3 kyr) should be regarded as part of the Pomeranian sample suite and therefore included in summarizing the mean age calculation. Without them, the age would have been even younger, but on the other hand they are among the few samples that show ages compatible with the regional ^{14}C and OSL-TL based deglaciation chronology. We believe that more than a century of research and the thoroughly developed deglaciation chronologies of the Scandinavian Ice Sheet, which are based on multiple evidences (geomorphic interpretation, lithostratigraphy, pollen stratigraphy, ^{14}C chronology, palaeomagnetics and varve time scales), cannot just be discarded by a set of modern but highly scattered age measurements no matter what the potential of the method may be.

Accepting the postulated age of the Pomeranian End Moraines implies a highly unrealistic glacier configuration in the southwestern Baltic region. It would leave southern Scandinavia including Bornholm and northwest Germany free of active glaciers, while at the same time an ice stream transgressed the coastal regions of eastern Germany and Poland. In fact, the authors themselves provide the same type of reasoning. Rinterknecht *et al.* (2005: p. 188) argue that ^{10}Be ages of 36–32 kyr obtained from two boulders on the eastern extension of the Pomeranian Moraine hardly indicate moraine formation in Poland at that time, *because ^{14}C-dates from southern Sweden indicate ice-free conditions there.*

To the best of our judgement, most cosmogenic ages therefore reflect older as well as younger 'exposure events'. These may have been inherited from pre-moraine formation cosmogenic radiation or from post-moraine formation exposure due to for example melting of dead ice or removal of permanent snow cover. If the mean age of 14.8 kyr does reflect a major exposure event, we would consider this to be the melting free onto the surface of the moraine of boulders that for long had been kept in dead ice and buried within the moraine. The cosmogenic dating therefore hardly adds anything new to the age of the formation of the moraine itself.

References

Bennike, O., Sarmaja-Korjonen, K. & Seppänen, A. 2004: Reinvestigation of the classic late-glacial Bølling Sø sequence, Denmark: chronology, macrofossils, Cladocer and chydorid ephippa. *Journal of Quaternary Science 19*, 465–478.

Berglund, B. 1979: The deglaciation of southern Sweden, 13,500–10,000 B.P. *Boreas 8*, 27–62.

Björck, S. 1995: A review of the history of the Baltic Sea 13.0–8 ka BP. *Quaternary International 27*, 19–40.

Björck, S. & Möller, P. 1987: Late Weichselian environmental history in southeastern Sweden during the deglaciation of the Scandinavian Ice Sheet. *Quaternary Research 28*, 1–37.

Björck, S., Walker, M. J., Cwynar, L. C., Johnsen, S., Knudsen, K.-L., Lowe, J. J., Wohlfarth, B. & INTIMATE members 1998: An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland ice-core record: a proposal by the INTIMATE group. *Journal of Quaternary Science 13*, 283–292.

Boulton, G. S., Dongelmans, P., Punkari, M. & Broadgate, M. 2001: Palaeoglaciology of an ice sheet through a glacial cycle: the European ice sheet through the Weichselian. *Quaternary Science Reviews 20*, 591–625.

Coope, G. R., Lemdahl, G., Lowe, J. J. & Walkling, A. 1998: Temperature gradients in northern Europe during the last glacial–Holocene transition (14–9 ^{14}C kyr BP) interpreted from coleopteran assemblages. *Journal of Quaternary Science 13*, 419–433.

Davies, S. M., Wohlfarth, B., Wastegård, S., Andersson, M., Blockley, S. & Possnert, G. 2004: Were there two Borrobol Tephars during the early Lateglacial period: implications for tephrochronology? *Quaternary Science Reviews 23*, 581–589.

De Klerk, P. 2002: Changing vegetation patterns in the Endinger Bruch area (Vorpommern, NE Germany) during the Weichselian Lateglacial and Early Holocene. *Review of Palaeobotany and Palynology 119*, 275–309.

Ehlers J. 1996: *Quaternary and Glacial Geology.* 578 pp. Wiley, Chichester.

Ehlers, J., Eissmann, L., Lippstreu, L., Stephan, H. J. & Wansa, S. 2004: Pleistocene glaciations of North Germany. *In* Ehlers, J. & Gibbard. P. L. (eds.): *Quaternary Glaciations – Extent and Chronology*, 135–146. Elsevier, Rotterdam.

Houmark-Nielsen, M. & Kjær, K. H. 2003: Southwest Scandinavia, 40–15 kyr BP: palaeogeography and environmental change. *Journal of Quaternary Science 18*, 769–786.

Hurtig, T. 1969: Zum letzglazialen Abschmelzmechanismus im Raume des Baltischen Meeres: Erläuterungen zu einer Karte. *Geographisches Zeitschrift*, *Beiheft 22*, 69 pp.

Iversen, J. 1954: The late-glacial flora of Denmark and its relation to climate and soil. *Danmarks Geologiske Undersøgelse II rk 80*, 87–119.

Iversen, J. 1973: The development of Denmark's nature since the Last glacial. *Danmarks Geologiske Undersøgelse Serie 7-C*, 126 pp.

Kjær, K. H., Houmark-Nielsen, M. & Richardt, N. 2003: Ice-flow patterns and dispersal of erratics at the southwestern margin of the last Scandinavian ice sheet: imprint after palaeo-ice streams. *Boreas 32*, 130–148.

Kozarski, S. 1988: Time and dynamics of the Last Scandinavian ice-sheet retreat from northwestern Poland. *Geographia Polonica 55*, 91–101.

Kozarski, S. & Kasprzak, L. 1987: Facies analysis and depositional models of Vistulian ice-marginal features in northwestern Poland. *In* Gradiner, V. (ed.): *International Geomorphology, Part II*, 693–710. Wiley, Chichester.

Lagerlund, E. & Houmark-Nielsen, M. 1993: Timing and pattern of the last deglaciation in the Kattegat region, southwest Scandinavia. *Boreas 22*, 337–347.

Lundqvist, J. & Wohlfarth, B. 2001: Timing and east–west correlation of south Swedish ice marginal lines during the Late Weichselian. *Quaternary Science Reviews 20*, 1127–1148.

Mangerud, J., Andersen, S. T., Berglund, B. E. & Donner, J. J. 1974: Quaternary stratigraphy of Norden, a proposal for terminology and classification. *Boreas 3*, 109–127.

Marks, L. 2002: Last Glacial Maximum in Poland. *Quaternary Science Reviews 21*, 103–110.

Noe-Nygaard, N. & Heiberg, E. O. 2001: Lake-level changes in the Late Weichselian Lake Tøvelde, Møn, Denmark: induced by changes in climate and base level. *Palaeogeography, Palaeoclimatology, Palaeoecology 174*, 351–382.

Rinterknecht, V. R., Marks, L., Piotrowski, J. A., Raisbeck, G. M., Yiou, F., Brook, E. J. & Clark, P. U. 2005: Cosmogenic ^{10}Be ages on the Pomeranian Moraine, Poland. *Boreas 34*, 186–191.

Sandgren, P., Hang, T. & Snowball, I. F. 1997: A Late Weichselian geomagnetic record from Lake Tamula, SE Estonia. *Geologiska Föreningen i Stockholm, Förhandlinger 119*, 279–284.

Smed, P. 2002: *Steine aus dem Norden, Geschiebe als Zeugen der Eiszeit in Norddeutschland.* 194 pp. Gebrüder Borntraeger, Berlin-Stuttgart.

Stankowska, A. & Stankowski, W. 1988: Maximum extent of the Vistulian ice sheet in the vicinity of Konin, Poland: a geomorphological, sedimentological and radiometric evidence. *Geographia Polonica 55*, 141–150.

Stephan, H. J. 2001: The Young Baltic advance in the western Baltic depression. *Geological Quarterly 45*, 359–363.

Stuiver, M., Grootes, P. M. & Brazunas, T. 1995: The GISP δ^{18}O climate record of the past 16,500 years and the role of the sun, ocean and volcanoes. *Quaternary Research 44*, 341–354.

Usinger, H. 1978: Bölling-Interstadial und Laacher Bimstuff in einem neuen Spätglazial-Profil aus dem Vallensgård Mose, Bornholm. *Danmarks Geologiske undersøgelse, Årbog 1977*, 5–29.

Usinger, H. 1985: Pollenstratigraphische, vegetations- und klimageschichtliche Gliederung des Bölling-Alleröd-Komplexes in Schleswig-Holstein und ihre Bedeutung für die Spätglazial-Stratigraphie in benachbarten Gebieten. *Flora 177*, 1–43.

Walker, M. J. C. 1995: Climatic changes in Europe during the last glacial–interglacial transition. *Quaternary International 28*, 63–76.

Walker, M. J. C. 2005: *Quaternary Dating Methods*. 286 pp. Wiley, Chichester.

Woldstedt, P. 1925: Die groβen Endmoränenzüge Norddeutschlands. *Zeitschrift der Deutschen Geologischen Gesellschaft 77*, 172–184.

Michael Houmark-Nielsen (e-mail: michaelh@geol.ku.dk), Geological Institute, University of Copenhagen, Østervoldgade 10, DK-1350, København K, Denmark; Svante Björck, Geo-Biosphere Centre, Lund University, Sölvegatan 12, SE-22362, Lund, Sweden; Barbara Wohlfarth, Department of Physical Geography and Quaternary Geology, Stockholm University, SE-1069 Stockholm, Sweden;
received 30th November 2005, accepted 7th April 2006.