Suggestions that the duration of the Eemian interglacial was about 11,000 yr, based on annually laminated sediment sequences in Germany, have been challenged in favor of a much longer interval. However, biostratigraphic evidence demonstrates why the Eemian sequences at Grande Pile and Ribains cannot be reliably used for alignment with the marine sequence, as applied by Kukla et al. (2002, this issue) to estimate the duration of this interglacial. The long chronology they propose would imply not just coniferous but, for up to 5000 yr, fully temperate forest in central France coexisting with treeless heath and steppe tundra conditions in northwestern Europe, an unlikely climatic and ecological scenario. The proposal that the Eemian Interglacial in western Europe lasted for 17,000 or even 23,000 yr is rejected. A duration of no more than 13,000 yr is preferred, at least for sites north of the Alps and Pyrenees. The duration of temperate conditions in the Mediterranean region is less certain.

Key Words: Eemian; last interglacial; Melisey 1; Herning Stadial; interglacial duration.

THE DURATION OF THE EEMIAN INTERGLACIAL

For many years the Eemian Interglacial has been regarded as having a duration of about 11,000 yr, originally based on studies of the interglacial site at Bispingen in northern Germany (H. Müller, 1974). At this site the deposits spanning the earlier part of the interglacial, the pre-temperate, and early-temperate substages, consist of laminated sediments, the laminations being well developed and generally countable. The annual nature of the laminae has been demonstrated by fine-scale pollen analysis, which gave evidence for seasonal patterns. At Bispingen a good part of the sediment representing the later span of the interglacial, including the Carpinus zone (E5), is also finely laminated but too indistinctly for detailed counting to be feasible. Nevertheless, Müller concluded that the scale of the lamination and its constancy, the uniformity of sedimentation, and the apparently unbroken pollen record, which made stratigraphic hiatuses extremely unlikely, provided sufficient evidence for making a reasonable estimate of the total length of the interglacial interval.

Subsequently, Müller’s estimates have been supported by further studies of similar sequences at Quakenbrück and Gross Todtshorn (Hahne et al., 1994; Caspers, 1997; Caspers et al., 2002, this issue), which provide lamination counts not only for part of the early-temperate zones but, more importantly, for the late-temperate Carpinus zone (E5) and part of the post-temperate record (zone E6). Finally, in southern Germany, Frenzel and Bludau (1987) have reported annually laminated sediments from the final Pinus–Picea zone of the last-interglacial site at Krumbach, which show that this lasted “at least 1650 years,” Müller’s estimate being 2000 yr. Thus, in Germany a good lamination record now covers virtually the entire interglacial, and at all four sites supports remarkably well Müller’s original estimate of a duration of 11,000 yr. Allowing for any possible underestimation, it is difficult to believe that this figure could be increased to more than 12,000 or, at most, 13,000 yr.

Nevertheless, Kukla (2000; Kukla et al., 1997) has suggested that the Eemian Interglacial at Grande Pile in eastern France lasted 17,000 or even 20,000 yr and so encompassed not only marine isotope stage (MIS) 5e but much of MIS 5d as well. The basis for this suggestion was simply alignment of the nonarbooreal pollen curve from Grande Pile with the curve for the left-coiling form of Neogloboquadrina pachyderma in Atlantic marine core V29-191. It relies crucially on two assumptions: (a) a constant rate of sedimentation at Grande Pile and (b) a lack of any gaps in that sequence. Furthermore, Kukla’s proposals would imply that pollen biozones within the interglacial itself were far from contemporaneous in different areas (Fig. 1). This raises serious problems. It suggests the persistence of interglacial temperate deciduous and, later, coniferous forest in the Vosges, on the threshold of northern Europe, at the very time when Britain, the Netherlands, and northern Germany supported open tundra conditions. Such a scenario and climatic gradient seems highly unlikely given the pattern of influence of the North Atlantic on the climate of western Europe. In the present issue, Kukla et al. (2002) go further, extending their scheme to the interglacial site at Ribains in the Massif Central, which they also claim shows a constant rate of sedimentation and would give a duration of 23,000 yr for the interglacial, and to core SU-8132 off the Iberian coast (Kukla et al., 2002, this issue, Fig. 2).
FIG. 1. Pollen biostratigraphy of last interglacial sequences from (a) marine core SU-8132 (Turon, 1984), (b) Ribains (de Beaulieu and Reille, 1992b), (c) Grande Pile (Woillard, 1978), and (d) Bispingen (H. Müller, 1974), using the chronological framework proposed by Kukla (2000; Kukla et al., 2002), where the interglacial at sites (a) to (c) is assumed to have lasted from 130,000 to 107,000 yr B.P., but at site (d) in northern Europe, only until 117,000 yr B.P. Pollen zones E1 to E6 are defined in Table 1 (Turner, 2000a, this issue). The integrity of pollen zone E6 at Grande Pile (c) is queried in discussion, but generally the top of zone E6 is regarded as the interglacial/stadial boundary. NAP: nonarboreal pollen.
CORRELATION WITH THE DEEP-OCEAN RECORD

The most direct evidence for correlation between the continental and ocean records comes from the work of Sánchez Goñi et al. (1999, 2000) from marine core MD952042 (southwestern margin of the Iberian peninsula). In this case, the end of the Eemian Interglacial is placed at the boundary between pollen zones MD42-6 and -7, as is typical in Mediterranean pollen diagrams, a level marked by a rise in Artemisia and Chenopodiacae and the elimination of Carpinus, Alnus, and evergreen oaks, although deciduous oaks decline but persist. The critical horizons with regard to the dating of this boundary are the C24 and C25 cool marine polar episodes (Chapman and Shackleton, 1999). The latter is suggested by Shackleton et al. (2002, this issue) to have an age of about 111,000 yr B.P. based on selected radiometric dates. Originally, it was believed that C24 was broadly correlative with Melisey 1, but that C25 lay within the Eemian, thus determining the age of 110,000 yr B.P. suggested for the end of the Eemian in Sánchez Goñi et al. (2000). However, it now seems that C25 and C24 may both be associated with Melisey 1 (N. J. Shackleton, personal communication, 2002). In either event, this gives a duration of 15,000 to 16,000 yr for the interglacial and suggests that the end of the interglacial at the MD952042 site was younger than a substantial cooling event demonstrated at other sites in the North Atlantic about 115,000 yr B.P. The precise ages vary according to different age models used for the deep ocean record. More palynological work is needed on similar cores along the western coast of Europe, not only to test and confirm these results, but also to give a clearer picture of the MIS 5e/5d boundary in relation to regional pollen assemblages.

Figure 1 presents the pollen data from the three sites reviewed by Kukla et al. (2002) and from Bispingen in northern Germany, using the chronology proposed by Kukla (2000; Kukla et al., 2002, this issue). Addition of some extra pollen data and, more importantly, the Eemian pollen biozone boundaries, highlights the contradictions and problems raised by this proposed chronology:

a) It implies that at the same time that open-vegetation heath and steppe tundra conditions existed in northwestern Europe after the end of the Eemian, there were up to 7000 yr of deciduous forest dominance in the Vosges and Massif Central, followed by 2000–3000 yr of boreal forest dominance. Pons et al. (1990) proposed mean annual temperatures 1–3°C higher than those of the present for much of this period at Grande Pile. Such a north–south temperature gradient (i.e., virtually between the latitude of Paris and that of Amsterdam) seems highly improbable.

b) The pollen zone boundaries are seriously asynchronous, not just between Bispingen and the other sites, but also between Ribains and Grande Pile. It is not possible to maintain that these sites could have had a constant rate of sedimentation. The most serious discrepancy relates to the base of E5, the Carpinus zone. Carpinus is a late immigrating or expanding tree in European vegetation in virtually every interglacial interval of the Middle and Late Pleistocene. As clearly demonstrated by Zagwijn (1996), it does not indicate the climatic optimum of the Eemian Interglacial, as some authors have assumed (Kukla et al., 1997; Sánchez Goñi et al., 2000). This tree probably expanded at Ribains slightly earlier than it did farther north and east in Europe, an observation suggesting an Iberian refuge during the preceding glacial stage. A delay of 5000 yr before it reached Grand Pile is highly improbable, if not impossible, particularly when it is well established that this tree became established in northern Germany only about 4000 yr after the beginning of the interglacial.

c) Given the evidence from Ribains, it is highly unlikely that Carpinus expanded late in Iberia as well, as implied by Kukla’s chronology for SU-8132. Indeed, the attempt to fit the curves for this site to those at Ribains, simply emphasizes the further discrepancy between the Kukla chronology and that proposed by Sánchez Goñi et al. (2000) for the more southerly marine core MD952042.

There is good evidence why Grande Pile, in particular, is an unsuitable site for such a curve-aligning exercise. On one hand, it is highly doubtful that this site was a deep, stable lake, as originally supposed. On the other hand the sedimentary record appears to be incomplete. Ponel (1995), who investigated fossil coleopteran assemblages, was astonished to find that the interglacial sediments of the lake contained regular and well-represented elements of a shallow running-water beetle fauna through most of the Eemian. It is not clear how inflowing streams existed here, but these may explain the presence of thin discontinuous laminae of clastic particles. These have on occasion been erroneously inferred to represent annual lamination. Ponel was again surprised to find that the uppermost interglacial sediments, which contained a predominantly coniferous pollen assemblage (i.e., E6), were actually devoid of beetles dependent on conifers, but instead contained assemblages indicating cool, open-ground conditions, as did the thin overlying unit attributed to the Melisey 1 Stadial.

Woillard (1979) noted the abruptness of the transition from temperate to boreal forest at the base of her zone 6b (i.e., the base of the supposed E6 zone in Fig. 1c), which Ponel (1995) also noted on sedimentological and faunal grounds as a transition to deeper water sediment. The best explanation is that after the end of the interglacial, water levels fell at Grande Pile, as certainly occurred at Les Échets (de Beaulieu and Reille, 1984), where Melisey 1 sediments contain abundant reworked interglacial pollen. Although the lake never dried out, subaqueous erosion, transport, and redeposition of the finer fraction of the sediment took place across the lake floor. Thus, the hiatus lies below the apparent Eemian/Melisey 1 boundary, with organic muds containing high concentrations of reworked interglacial pollen but contemporaneous coleopteran remains. This would account both for the abrupt change to apparent boreal conditions—in fact, a hiatus with effectively the whole of Zone E6 and part of Melisey 1 missing as autochthonous sediment. This hiatus would also explain the particularly short and uneven record for Melisey 1 depicted in the published pollen diagrams from Grande Pile, compared with the much longer and more detailed pollen records for this stadial interval in cores from Ribains and
Le Bouchet in the Massif Central (Reille and de Beaulieu, 1990), Samerberg and Füramoos in the Alpine Foreland (Grüger, 1979, 1989; U. Müller, 2001), and Gross Todtshorn (Caspers, 1997), where actual patterns of vegetational change within this stadial can be inferred. Other sites, for example, Les Echets and possibly Valle di Castiglione (Follieri et al., 1988), also exhibit stratigraphic hiatuses associated with the horizon of the Melisey I stal- dial, suggesting a widespread episode of increased aridity within the stadial that resulted in lake-level fall and basin disturbance.

CONCLUSIONS

This analysis sheds doubt on the conclusions reached by Kukla et al. (2002) concerning the length of the Eemian Interglacial, at least north of the Alps and Pyrenees. Neither the Ribains nor (particularly) the Grande Pile sequence are suitable for alignment with the marine sequence, as has been carried out. The long Eemian chronology proposed by Kukla et al. would result in a serious ecological and climatic mismatch between different areas of western Europe north of the Alps, and demonstrates internal inconsistencies in terms of pollen biostratigraphy. The duration of the Eemian sequences in Germany is better established than those in France. More attention needs to be paid to continental sequences recording the Melisey I (Herning) interval, because it is there that hiatuses may occur that indicate a composite continent–ocean correlation, both by shortening the apparent duration of the stadial in some sequences and because they may be accompanied by the reworking of interglacial sediments. A major cooling in the North Atlantic took place about 115,000 yr B.P. (Shackleton et al., 2002, this issue), which is likely to have brought interglacial conditions to a close in northwestern Europe. There is certainly no other sign of major cooling within recorded pollen sequences during the interglacial. The Eemian Interglacial north of the Alps seems unlikely to have lasted for more than 13,000 yr, rather than 17,000 yr, and certainly not 20,000–23,000 yr. In the Mediterranean area, however, the pollen sequences representing the final part of the interglacial interval record significant differences in vegetational development from the pattern recorded north of the Alps and the Pyrenees, and so here precise correlations are uncertain and require further attention.

REFERENCES


