The Classic Marine Isotope Substage 5e

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Since its identification nearly fifty years ago, Marine Isotope Stage 5 (MIS 5) has been placed onto absolute time scales on the basis of three independent approaches. Cesare Emiliani, who set up the isotope stages (Emiliani, 1955), depended on uranium-series dating of the sediments, a method that today is regarded as not generally capable of yielding useful precision or accuracy. Broecker and van Donk (1970) pioneered the approach of correlating to radiometrically dated marine coral terraces; this has been much aided in recent years by improvements in the precision and accuracy of these age determinations that have flowed from the development of thermal ionization mass spectrometry (TIMS) for uranium-series dating (Edwards et al., 1986). The third approach is to use the astronomical record as a guide to the time scale. Martinson et al. (1987) generated a detailed time scale for MIS 5 using this approach. These authors suggested that the overall average error was of the order ±5000 yr, although the error would be smaller during interglacial periods with high precession-related variability, such as MIS 5. At that time, the suggested confidence limits were smaller than typical values quoted for the radiometric dating of corals (typically ±6000 yr). Today the accuracy of the time scale of Martinson et al. (1987) is challenged by high-precision TIMS dates with quoted uncertainties of the order ±1000 yr or better. From the point of view of achieving a better understanding of the last interglacial period, the more serious disadvantage of the Martinson et al. (1987) time scale is the underlying hypothesis that all the proxy palaeoclimate records represent smoothly varying responses to changes in insolation; hence, there is no basis for estimating the duration of an extended interval with northern ice sheet volumes static at a size no greater than at present. From this point of view, the model of Gallée et al. (1993) is more promising, but that model is not at present sufficiently realistic to provide a reliable independent time scale.

We have therefore chosen to depict the oxygen isotope record of core MD95-2042 (37°48’N, 10°10’W, water depth of 3146 m) on a time scale (Shackleton et al., 2001) that is based only on making use of selected radiometric dates obtained from fossil corals to calibrate the isotope record.

Figure 1 shows the various records of core MD95-2042 (Shackleton et al., 1999) on this time scale. Steps in the accumulation rate indicate the position of the age controls. The benthic δ18O values are based on several different genera, necessitating corrections for species-dependent departure from isotopic equilibrium. If we define the base of MIS 5 (and of MIS 5e) at the midpoint of the transition in benthic δ18O values (about +4.1‰) and the base of MIS 5d at the midpoint of the subsequent transition (about +3.7‰), MIS 5e would last from about 132,000 B.P. to about 115,000 yr B.P. Within this interval, the “plateau” of MIS 5e (mean value +3.15‰) covers 128,000 to 116,000 yr B.P. During this time, sea level cannot be constrained better than to within ±10 m of its present level on the basis of isotope data (+0.1‰), but it probably fluctuated over a much smaller range by analogy with the Holocene. In the same core, the Eemian Interglaciation, as delimited by Sánchez Goñi et al. (1999) from their pollen data, lasted from about 126,100 to 109,700 yr B.P.
Putting the record of core NEAP18K (52°46′N, 30°21′W, 3275 m water depth; Chapman and Shackleton, 1999) on the same time scale enables estimation of the stratigraphic position in MD95-2042 of the cold events that have been identified in the central North Atlantic (McManus et al., 1994), and these are indicated by arrows in Fig. 1. Cool event C24 is clearly correlative with the Melisey I interval that immediately follows the Eemian. Thus, the minor cool event identified by Chapman and Shackleton (1999) as C25, at a point where the benthic δ18O value is about +4.1‰, probably has an age of about 111,000 yr B.P. (based on aligning the benthic δ18O record of core NEAP18K with that of MD95-2042). However, within the analytical noise in the isotopic data, event C25 could also correlate with a slightly shallower position in core MD95-2042, in which case both C25 and C24 would correlate with the Melisey I episode. The planktonic δ18O data in core MD95-2042 also suggest a cooling between about 113,000 and 111,000 yr B.P., which is certainly within the Eemian as interpreted from the pollen data (Sánchez Goñi et al., 1999).

Chapman and Shackleton (1999) point out that the most prominent cooling of surface waters at the site of NEAP 18K is significantly earlier, at about 115,000 yr B.P. on our time scale. Adkins et al. (1997) demonstrate a dramatic change in deep-water circulation at a site on the Bermuda Rise that, within the limits of stratigraphic correlation, also appears to be synchronous with this earlier cooling. This event, at about 115,000 yr B.P. on our time scale, may have marked the end of interglacial vegetation in Britain, since the surface-water cooling documented at the latitude of Britain in core NEAP18K implies temperatures almost as cold as during the C24 event (although without the ice-rafting that characterizes C24). In core MD95-2042 this cooling is also marked by a distinct change to a less-Mediterranean and more-oceanic vegetation (Sánchez Goñi et al., 1999). However, the apparent brevity of the Melisey I episode in its type area in the Vosges (Woillard, 1978), as in core MD95-2042, supports the idea that the Eemian–Melisey transition identified by Sánchez Goñi et al. (1999) is indeed synchronous with the same transition in the type area.

It is interesting to attempt to compare the ages given above with the time scale of Martinson et al. (1987). Event 5.4, the glacial extreme of MIS 5d, is probably equivalent to our C24, for which our age of 107,000 yr B.P. is somewhat younger than the value in Martinson et al. (1987) of 111,000 ± 6000 yr. Events 5.51 and 5.53 are probably not meaningful. We have assigned an age of 132,000 yr B.P. to the point that represents approximately the midpoint of the transition from MIS 6 to MIS 5e. Martinson et al. (1987) give an age of 130,000 ± 3000 yr B.P. for event 6.0, but inspection of their Table 2 shows that, in fact, the midpoint of the isotopic transition in the stacked benthic δ18O data has an age closer to 128,000 yr B.P. Thus, the overall effect is that the use of TIMS radiometric dates on corals implies a slightly longer interval within which to accommodate the Eemian.

Figure 2 compares the record of MIS 5e from MD95-2042 on this time scale with the output of two models, that of Imbrie and Imbrie (1980) and that of Gallée et al. (1993). Both are forced by the insolation variations of Berger and Loutre (1991). At the base of MIS 5, the transition generated by Gallée et al. (1993) is 2000 yr older than that of Imbrie and Imbrie (1980), which is the basis used by Martinson et al. (1987). Our age is in turn 2000 yr older than that of Gallée et al. (1993). This might imply that the instability that permits rapid deglaciation at the end of a major glaciation is in reality even more extreme than is built into the model of Gallée et al. (1993). At the termination of MIS 5e, the inception of ice growth in Gallée et al. (1993) is delayed with respect to that found by Imbrie and Imbrie (1980) because it starts from a condition of zero “Laurentide” ice, and the Gallée
et al. (1993) result agrees well with our time scale. The glacial extreme of MIS 5d is slightly earlier in Gallée et al. (1993) than in our reconstruction; however, our time scale is unconstrained here. This discussion demonstrates that the SPECMAP time scale of Martinson et al. (1987) is not suitable for detailed comparison with precise radiometric dates, nor can the validity of astronomical models for the ice age cycle be tested by evaluating the Martinson et al. (1987) time scale for MIS 5e.

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REFERENCES


