Duration of Last Interglacial Conditions in Northwestern Greece

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A new astronomical calibration method for long pollen records from southern Europe is applied to the last interglacial interval of the Ioannina sequence, northwestern Greece. This shows that the last interglacial in this region, as defined by the presence of forest communities, lasted ca. 15,500 yr, from 127,300 to 111,800 yr B.P. Interglacial conditions developed within marine isotope substage (MIS) 5e and persisted into MIS 5d, lagging changes in global ice volume.© 2002 University of Washington.

A comparison of astronomical curves of Berger (1978) with palynological changes in southern European records of the last 200,000 yr for which an independent age could be established, and found two recurring situations:

Case 1: All intervals with perihelion occurring in northern winter (from December solstice to March equinox) were associated with a reduction in forest extent, culminating at the time of March perihelion. Berger et al. (1981) pointed out that the highest radiative loss through surface albedo in middle and high latitudes occurs in spring. Thus, relative minima in shortwave absorption would occur during intervals when a large part of the annual radiation is delivered at this time (i.e., March perihelion configuration), and this pattern could provide a mechanism for the observed periodic coolings and related impact on ecosystems.

Case 2: Within each temperate stage, expansions of certain Mediterranean elements (Olea, Pistacia, Phillyrea) were consistently associated with perihelion in northern summer, with peaks closely following (by 1000 yr, on the basis of 14C dates in the early Holocene) the timing of June perihelion. Increased summer radiation and associated higher temperature and evaporation regimes provide a competitive advantage for summer-drought-resistant species, leading to population expansion.

The identification of these two patterns provides a starting point for the development of astronomically calibrated timescales for long pollen records from southern Europe: (i) the timing of March perihelion is assigned to culminations of AP minima at the end of the interval associated with perihelion in winter, just before AP values begin to rise again; (ii) the timing of June perihelion, with a lag of 1000 yr, is assigned to the levels of expansion of Olea/Pistacia/Phillyrea. This procedure is applied here to the last interglacial interval of the Ioannina I-284 record (39°45’N, 20°51’E, 473 m altitude), a long lake sequence.
from northwestern Greece. According to the I-284 chronological framework, based on accelerator mass spectrometry radiocarbon dating, palaeomagnetic excursion data (including the Blake Event (122,000 ± 10,000 yr B.P.) (Frogley, 1997) and correlation with an earlier studied adjacent core (I-249; Tzedakis, 1993), the 319-m sequence contains a record of the last ca. 430,000 yr. A detailed discussion of the last-interglacial palynological and isotopic changes has been presented elsewhere (Frogley et al., 1999; Tzedakis et al., in press). Here, we discuss the results of the pollen-orbital tuning as they relate to duration of the interglacial and timing of events. This new chronology represents a departure from the one published earlier (Frogley et al., 1999), especially as regards the age of the interglacial–stadial transition, but in our view, it constitutes a considerable improvement, as it relies on orbital–climate–vegetation links rather than assumed synchronous vegetation–global ice-volume changes.

In biostratigraphical terms, the onset of the last interglacial at Ioannina is defined at the point where arboreal pollen (AP) frequencies rise consistently well above 50% and AP concentrations (providing a measure of tree population densities) increase by an order of magnitude to more than 200,000 grains cm$^{-3}$. Conversely, the onset of the ensuing stadial interval is defined by equivalent, but opposite in sign, changes in AP values. The last interglacial is thus represented by the interval 96.7–83.4 m (127,300–111,800 yr B.P.) (Fig. 1). Preceding this is a late-glacial period between 98.5 and 96.7 m (129,300–127,300 yr B.P.) that contains an interstadial–stadial complex. The first part of the interglacial (96.2–90.7 m; 126,800–120,300 B.P.) is characterized by presence of Mediterranean taxa and maximum tree population densities. After that, the pollen data suggest a progressive reduction in tree biomass, with forest becoming increasingly more open in character, especially above 85.65 m (114,200 yr B.P.) when open vegetation expanded. This was briefly interrupted by a re-expansion of Quercus deciduous populations before the onset of stadial conditions. Evaluation of the environmental signal as reflected in the δ$^{18}$O isotopic record shows that the amplitude of changes during full-interglacial time is markedly smaller than that of the intervals before and after. During the two-step late-glacial interval, temperature and moisture availability oscillated significantly. The transitional period recorded toward the end of the interglacial period also contained considerable climate instability. By comparison, changes within the interglacial period were less pronounced, occurring in a series of subdued steps.

While the assumption of uniform sedimentation rates between control points is certainly simplistic, possibly leading to inaccuracies in the ages of events occurring within the interglacial period from northwestern Greece. According to the I-284 chronological framework, based on accelerator mass spectrometry radiocarbon dating, palaeomagnetic excursion data (including the Blake Event (122,000 ± 10,000 yr B.P.) (Frogley, 1997) and correlation with an earlier studied adjacent core (I-249; Tzedakis, 1993), the 319-m sequence contains a record of the last ca. 430,000 yr. A detailed discussion of the last-interglacial palynological and isotopic changes has been presented elsewhere (Frogley et al., 1999; Tzedakis et al., in press). Here, we discuss the results of the pollen-orbital tuning as they relate to duration of the interglacial and timing of events. This new chronology represents a departure from the one published earlier (Frogley et al., 1999), especially as regards the age of the interglacial–stadial transition, but in our view, it constitutes a considerable improvement, as it relies on orbital–climate–vegetation links rather than assumed synchronous vegetation–global ice-volume changes.

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period, both the onset and end of the interglacial period are constrained by control points. Therefore, a greater degree of confidence is attached to the inferred ages for stage boundaries. What emerges clearly is the extent of diachrony between marine and terrestrial stage boundaries, with interglacial vegetation lagging changes in ice volume and sea level (Fig. 1). Thus, the onset of the interglacial at Ioannina occurred well within MIS 5e (132,000–115,000 yr B.P.; Shackleton et al., this volume), after deglaciation was complete. The age of this boundary at Ioannina is influenced by the position of the June perihelion control point (126,600 yr B.P.) associated with the abrupt expansion of *Olea/Pistacia/Phillyrea* and reflects a threshold rather than a smooth response to insolation. Given that pollen evidence suggests that refugial tree populations were present during glacial times in the region (Tzedakis, 1993), this behavior in expansion is not likely to be a result of migration lag times. Instead, the threshold response reflects a climatic control: increased summer radiation and associated higher temperature and evaporation regimes provided the ideal conditions for expansion, but it was only when winter temperatures became sufficiently high for the frost-intolerant species to survive that an abrupt increase in populations occurred.

An independent test of the accuracy of the Ioannina age model may be provided by a recent high-resolution marine pollen record MD952042, located off the southwestern Iberian margin (Fig. 2) (Shackleton et al., this volume). The sequence is supported by detailed benthic and planktic δ18O stratigraphies and a chronology based on inferred sea-level changes correlated with radiometrically dated marine coral terraces. This means the pollen-stratigraphical changes can be placed in the context of changes in global ice volume, as well as within an absolute chronological framework. Although some degree of diachrony between vegetation responses in Portugal and Greece may be expected because of distance from the North Atlantic and specific location of refugial populations, such differences should be small (hundreds of years) because both sites represent changes at similar latitudes. Moreover, examination of late-glacial/early-Holocene pollen records reveals close temporal correspondence. Comparison of the last interglacial intervals of these two records reveals a similar sequence of events, including a late-glacial oscillation characterized by a return towards drier and more open vegetation conditions, which appears to be coeval with Heinrich event 11. Both records show a decline in Mediterranean taxa after 120,000 yr B.P. and an expansion of open vegetation after ca. 115,000 yr B.P. but suggest that interglacial conditions persisted well into MIS 5d, until the time of extensive ice-rafting in the North Atlantic. There is considerable agreement between the two chronologies of MD952042 and I-284 in terms of the length of the forested interval (16,400 and 15,500 yr, respectively) and the timing of the transitions (onset: 126,100 vs. 127,300 yr B.P.; end: 109,700 vs. 111,800 yr B.P.). This is particularly significant because the MD952042 timescale is based on precision TIMS uranium-series dating without any astronomical calibration and therefore is completely independent of the Ioannina chronology. Given the uncertainty (10,000–20,000 yr) associated with dating lake sediments of last interglacial age, the level of disagreement between the two timescales (1000–2000 yr) is particularly encouraging for the pollen-orbital procedure and its applicability to other terrestrial records from southern Europe.

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