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MEDITERRANEAN POLLEN STRATIGRAPHY ACROSS THE EARLY-MIDDLE PLEISTOCENE BOUNDARY

Francesco Toti, Adele Bertini

Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italy
Corresponding author: F. Toti <francesco.toti@unifi.it>

ABSTRACT: The Mediterranean preserves a detailed history of the past climate cycles and brings together an elevated number of GSSPs. In the recent years, the efforts to establish the GSSP for the Middle Pleistocene in the Mediterranean have received substantial assistance from palynology. In the present paper, we compare pollen data from two successions both encompassing the Early-Middle Pleistocene boundary: the Montalbano Jonico section and ODP core 976. Other coeval Mediterranean and extra-Mediterranean records were evaluated to corroborate the climate structure and stratigraphy revealed across the Stage boundary.

KEYWORDS: Early-middle Pleistocene, GSSP, MIS 19, pollen, Mediterranean, Montalbano Jonico, ODP 976

1. INTRODUCTION

Southern Italy is a 'hot-spot' for the Neogene and Quaternary stratigraphy hosting, at present, four ratified Global Boundary Stratotype Sections and Points (GSSPs; http://www.stratigraphy.org/index.php/ics-gssps). The relevance of the Southern Italian sedimentary archives is enhanced by their rich biostratigraphical content (e.g. calcareous plankton, pollen, ostracods, dinocysts) as well as by the continuous nature of the successions, thereby promoting reliable reconstructions and correlations.

Pollen records from Southern Italian sites illustrate the impact of the Quaternary glacial-interglacial (G-IG) cyclicity in the central Mediterranean (e.g. Combourieu Nebout et al., 1995, 2015; Joannin et al., 2008; Bertini et al., 2010, 2015), as revealed by changes in the relative abundances of steppe vs thermophilous forest communities. Once pollen records are complemented by other proxy data (e.g. stable isotopes, calcareous plankton), they are highly relevant for the studies consecrated to the establishment of a GSSP.

The marine succession of Montalbano Jonico (MJ), cropping out in the Basilicata Region (40°17'N and 16° 34'E, Fig. 1), contains the Early-Middle Pleistocene boundary, which approximates the Matuyama-Brunhes (M/B) boundary and marine isotope stage 19 (MIS 19) (Channell et al., 2010). The MJ section has been under consideration for the GSSP of the Middle Pleistocene SubSeries/SubEpochs (Marino et al., 2016), after a large number of studies emphasizing the richness of its biological and inorganic proxies, representative of both marine and terrestrial environments (e.g. stable isotopes, calcareous plankton, ostracods, pollen, …). The pollen investigation performed at MJ highlights a peculiar structure of climate variability during the MIS 19 interglacial complex (e.g. Bertini et al., 2015; Maiorano et al., 2016). Many features of this interglacial are a benchmark for correlations at both regional and global scale, especially regarding the climate records derived by the pollen spectra (Bertini et al., 2015; Maiorano et al., 2016). Below we present a summary of the main palynological phases and events described at MJ at the Early-Middle Pleistocene boundary and their significance at regional and extra-regional scale. Our analysis emphasizes the correlation between MJ and deep-sea cored successions (ODP Site 976) to enhance the importance of the palynology in the frame of the Quaternary stratigraphy.

2. MATERIALS AND METHODS

Palynological data were collected from two marine successions in the Mediterranean (Fig. 1): the MJ section (Southern Italy) and ODP core 976 (Alboran Sea), both covering MIS 19. The strategy of analysis and the complete pollen dataset from the two successions were developed in the frame of a PhD thesis (Toti, 2018) and also in dedicated papers (Bertini et al., 2015; Marino et al., 2016; Toti et al., in preparation), to which the reader is referred. The chronology of the successions was developed adopting the same orbitally-driven $\delta^{18}O$ variability observed in the Mediterranean during the last deglaciation (Simon et al., 2017; Nomade et al. submitted; Toti et al., in preparation), on the assumption that MIS 1 and MIS 19 are very close orbital analogues (e.g. Tzedakis et al., 2012; Yin & Berger, 2012). The timing of the M/B reversal is revealed, at MJ, by the peak of $^{10}Be/^{9}Be$, which corresponds to the collapse of the geomagnetic dipole (e.g. Simon et al., 2017).

In Fig. 2 we present selected pollen curves obtained by analyzing 59 samples (MJ section) plus 104 samples (ODP site 976) that span the interval from late MIS 20 to the end of MIS 19 (ca. 800-755 ka). Percentages of pollen taxa were normalized to a sum excluding *Pinus*, because this taxon is over-represented in both successions. The Pollen Temperature Index (PTI), given by the ratio between mesothermic (e.g. deciduous *Quercus*,

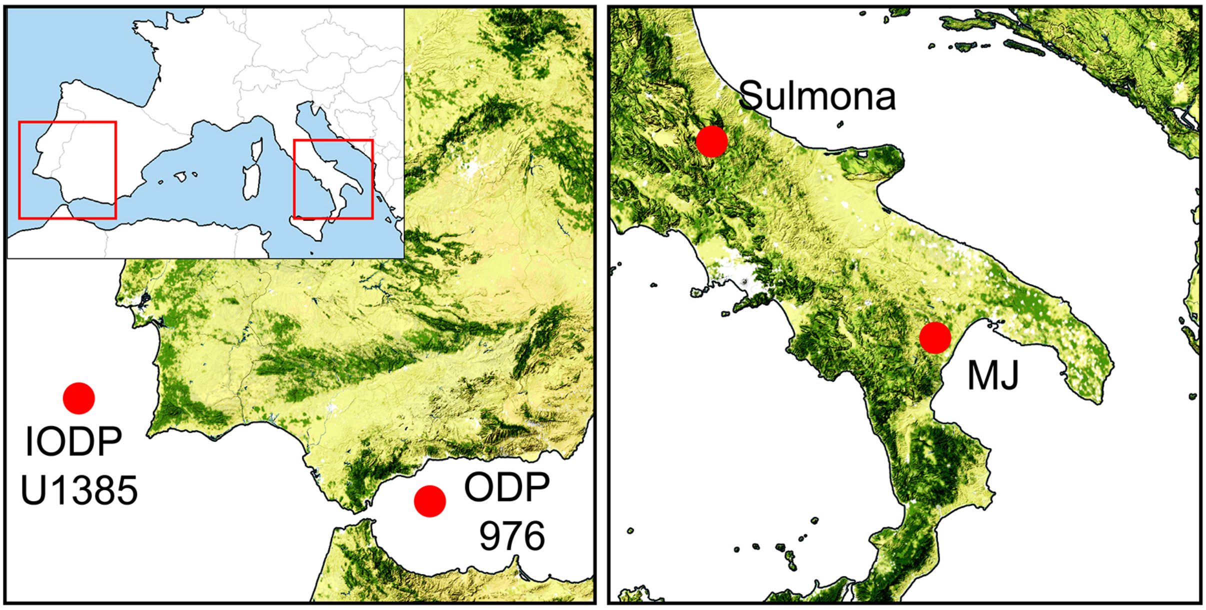

Fig. 1 - Location map showing the study successions (MJ: Montalbano Jonico; ODP Site 976) and other sites cited in the text.

Carpinus spp.) and steppic pollen (*Artemisia*, *Ephedra* and Amaranthaceae) (Suc et al., 2010; Joannin et al., 2011) permits to summarize the main climate variability.

3. RESULTS

Pollen records from the MJ section and ODP Site 976 provided a reconstruction of the vegetation and climate in the central and western Mediterranean across the Early-Middle Pleistocene boundary (Toti, 2018). At both studied locations, the MIS 20-19 transition is characterized by a dramatic expansion of steppe and semi-desert taxa, suggesting very (cold-)dry conditions on land. This phase ranges from ca. 795 to 785 ka and approximates the phase of maximum IRD deposition in most of the North Atlantic sites (Fig. 2). The increasing values of the polar water foraminifer *N. pachyderma* (left-coiling) in the North Atlantic (Wright & Flowers, 2002; Alonso-Garcia et al., 2011; Sánchez Goñi et al., 2016) and in the Mediterranean (Marino et al., 2015; Maiorano et al., 2016) also testifies a prominent influence of cold melt-water at the mid-latitudes. During a 5 kyr-long interval centered at 790 ka the regional pollen signal is marked by a large expansion of Cupressaceae (Fig.2). Since 784 ka, the pollen records suggest a major expansion of temperate deciduous taxa, consistent with the main terrestrial interglacial, dominated by relatively high precipitations and temperatures. Repeated phases of decline/expansion of the temperate forest taxa are, however, evidenced by the PTI curve between 784 and 773 ka. Although the different samples resolution at the two sites prevents unambiguous correlations among the temperate deciduous taxa curves, PTI can be used to trace at least three short-lived phases of relative precipitation-temperature increase, having regional significance: A1 (ca. 783 ka), A2 (ca. 778 ka) and A3 (ca. 774 ka). Such phases seem not to be expressed with the same magnitude at the two sites, probably because of the modulation by some local factors. Nonetheless, their systematic pattern within MIS 19 suggest that they are a robust feature of the full interglacial phase in the terrestrial realm. At 773 ka, a short-term, low-amplitude expansion of steppic and semi-desert taxa traces the end of the MIS 19 full interglacial at both sites. Cold conditions are also documented by the first episode of increased *N. pachyderma* (left-coiling) percentages and IRD deposition in the records from the North Atlantic Ocean (Wright & Flowers, 2002; Alonso-Garcia et al., 2011; Sánchez Goñi et al., 2016). The analysis of the uppermost part of the sequence reveals higher precipitations and temperatures during two intervals centered around 770 ka (event B) and 762 ka (event C). These intervals are terminated by abrupt cooling-drying phases as well as by concomitant episodes of IRD deposition and polar melt-water influx (Fig. 2).

4. DISCUSSION AND CONCLUSIONS

MJ exhibits an extraordinary exposure of marine deposits, accumulated in a relatively short time-span (450 m in ca. 600 kyr, from MIS 37 to MIS 17: Ciaranfi et al., 2010 and references therein) and without major sedimentary disturbances such as hiatuses and tectonic deformations. Calcareous plankton (foraminifers and nannofossils) records provided one of the primary tools for long-range correlations (e.g. Ciaranfi et al., 2010). In order to improve the frequency of chronologically significant events and the overall quality of palaeoclimate reconstructions, the previous data were fruitfully integrated by concomitant registrations, including stable isotopes and pollen (Marino et al., 2016). Within this framework, the pollen results turned out to be a versatile tool for monitoring the assumed chronostratigraphic

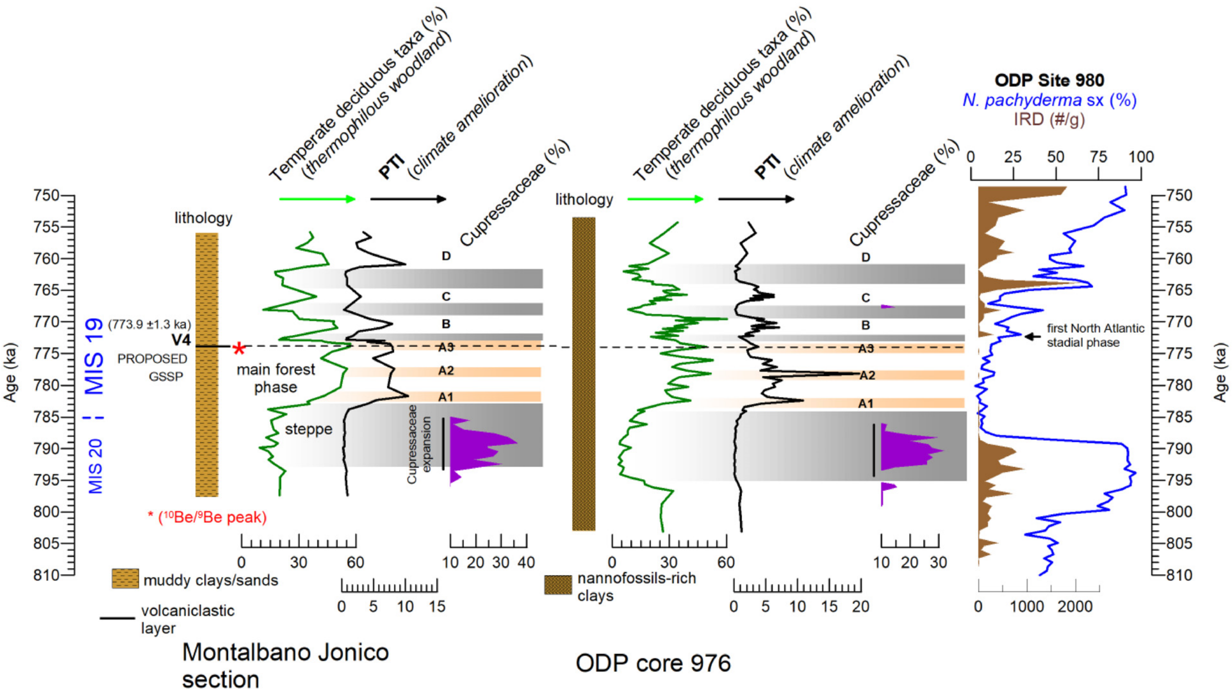

Fig. 2 - Selected pollen indices against age (ka) obtained from the study of MIS 19 at Montalbano Jonico (left) and ODP Site 976 (left); pollen temperature index (PTI) is calculated as the ratio between mesothermic and steppic taxa. On the right edge, the IRD and *N. pachyderma* left-coiling records from ODP Site 980 (Wright & Flower, 2002).

correlations. The accuracy of pollen-derived reconstructions relies on the relatively large sensitivity of vegetation to climate perturbations (e.g. Tzedakis et al., 1997). In the Mediterranean context, pollen results from MJ are effectively supported by those obtained from ODP Site 976, especially in terms of magnitude of long-term changes and timing of suborbital-scale features (Fig. 2). Specifically, both pollen spectra suggest the development of an open-dry vegetation during MIS 20, including a shorter interval marked by the spread of Cupressaceae. Pollen spectra also highlight strong similarities regarding the main interglacial phase of MIS 19 (ca. 784-773 ka) and the following stadial-interstadial oscillations (Fig. 2). It is worth mentioning the presence of close similarities in the pollen record from IODP Site U1385 Atlantic margin of Iberia (Sánchez Goñi et al., 2016), and in the δ^{18}O record from the Sulmona lacustrine basin, Southern Italy (Giaccio et al., 2015). Coeval records from even more distant sites, like those located in the high-latitude North Atlantic (e.g. IODP U1314, Ferretti et al., 2015; ODP 980, Wright & Flower, 2002; ODP 983, Kleiven et al., 2011; Channell et al., 2010) corroborate the above described climate variability.

Within the MIS 19 full interglacial, the MJ pollen record describes at least three millennial-scale forest expansions (A1, A2 and A3), which are also expressed at ODP Site 976 (Fig. 2). Event A3, in particular, should be emphasized as it approximates the timing of the main peak of ^{10}Be/^{9}Be which, in turn, reflects the geomagnetic field weakening associated to the M/B reversal (Simon et al., 2017). The latter event is the main criterion for the definition of the Middle Pleistocene GSSP (Head and Gibbard, 2015).

To conclude, our analysis emphasizes the relevance of the MJ section in the frame of the Mediterranean and global stratigraphy, on the base of the close similarities in the palaeoclimate and palaeovegetation patterns at the Early-Middle Pleistocene boundary. We can therefore make the following remarks:

1 Climate-based correlations are potentially the starting points to produce refined age-models, provided that reliable time-markers are selected and then correlated with radiometrically dated proxy records from different regions (e.g. Zanchetta et al., 2016).

2 However, pollen datum is itself a source of time-control points (e.g. Magri and Tzedakis, 2000). Peculiar vegetation states could be, in fact, synchronized to precise orbital configurations, based on the relative abundances of taxa sensitive to the seasonal intensity. The MJ pollen record documents several phases of expansions/contractions of floristic communities adapted to different temperature and/or seasonality contexts. This climate pattern is in agreement with that proposed by Nomade et al. (submitted and reference therein) on the base of the new high resolution calcareous plankton and benthic isotope records. Actually, more valuable information may be deduced by examining the ODP core 976 pollen dataset (Toti et al., in preparation) where there is a higher abundance of those taxa sensitive to seasonality variations, like Mediterranean elements and Ericaceae (Fletcher and Sánchez Goñi, 2008).

3 The study of the terrestrial vegetation history along a W-E transect in the Mediterranean permits definition

of a common climate pattern which is, for most, an expression of a global scale variability. The coherent response of the Mediterranean ecosystems to climate changes appreciably improves the significance of the Mediterranean sites as reference for the Quaternary stratigraphy.

4 Against this background, the analysis of the MJ data rules out problems of vertical sediment continuity. In the context of Southern Italy, the climate scenario inferred from the MJ section (Toti, 2018) forms a coherent framework with that obtained from the Sulmona section (Giaccio et al., 2015). The MJ and Sulmona sites could, therefore, be regarded as the best reference sections of MIS 19 in Southern Italy.

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