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# Climate signatures through Marine Isotope Stage 19 in the Montalbano Jonico section (Southern Italy): A land–sea perspective

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ABSTRACT

A multi-proxy record based on calcareous plankton, dinocysts, pollen, mineralogy and grain size has been acquired from the "Ideale" section, the portion of Montalbano Jonico succession (Southern Italy) that could host the GSSP for the Middle Pleistocene. The direct correlation between marine and terrestrial proxies provides a valuable indication of atmospheric and oceanic connections. The record shows a distinct climate variability well expressed by the vegetational changes, sediment input into the basin and sea surface–water modifications. Biotic proxies indicate that, during the study interval, periods of prevailing subpolar/transitional surface–water conditions were concurrent with steppe and halophytic vegetation. Erosional processes on the hillslopes and terrigenous supply, during these periods, were likely favored due to reduced arboreal vegetation, as attested to by sediment composition and pollen assemblages. Temperate/subtropical surface water conditions were concomitant with prevalent expansions of thermophilous arboreal plants and moister conditions on land, which likely promoted chemical weathering leading to an enhanced supply of kaolinite and smectite in the basin. A relationship between mineral content and the nature of the outcropping units in the source area, as well as sea-level fluctuations, has also been considered. A well-defined period of polar–subpolar water incursion, ranging from 793.2 ka to 788.1 ka, matches the major expansion of steppic vegetation on land and the increase of terrigenous supply into the basin. It likely represents the local response to North Atlantic ice-rafted debris deposition. Short-lived warming/cooling episodes punctuate the latest part of MIS 20 and are tentatively correlated with analogue climate phases predating MIS 1 inception. Full interglacial conditions of MIS 19c, lasting 10.6 kyr, started at 784.3 ka and were characterized by warm, oligotrophic and stratified surface–waters coupled with forest expansion, suggesting prevalent warm and humid conditions on land. A potential sapropel-like interval is identified within MIS 19c and correlated to i-cycle 74. The MIS 19c/19b transition is marked, at 773.2 ka, by the reestablishment of millennial-scale variability, similarly to North Atlantic marine and ice-core records. The results improve the paleoclimate framework of a Middle Pleistocene reference section and add further insight regarding climate development across MIS 19 and on potential similarities with its closest Holocene analogue.



## 1. Introduction

Paleoenvironmental and paleoclimatic reconstructions are key tools for modeling and understanding future climatic changes. Interglacial Marine Isotope Stage (MIS) 19 is considered a potential analogue of the present interglacial (Tzedakis et al., 2012a; Ferretti et al., 2015). Similarities between MIS 1 and MIS 19 are essentially driven by the astronomical analogies of radiative forcing of the corresponding orbital configurations (Tzedakis et al., 2009, 2012a; Tzedakis, 2010; Yin and Berger, 2012, 2015). Evidence of the response of the climate system to orbital forcing essentially relies on isotope records and atmospheric gas concentration measurements (Tzedakis et al., 2012a). Only recently, the deglaciation history associated with the beginning of MIS 19 has been suggested to be interrupted, in analogy with the last deglaciation, by a Younger Dryas-like cold event recorded in lacustrine deposits in central Italy (Giaccio et al., 2015). However, the subject is still not extensively explored and deserves further consideration. Special attention has been given to the duration of the early half of MIS 19 that is MIS 19c, which could provide an indication of the next glacial inception and therefore of when the hypothetical end of the current interglacial might be expected (Tzedakis et al., 2012a). Recent high resolution results from the North Atlantic indicate relatively stable conditions during the peak warmth of MIS 19, based on benthic and planktonic foraminiferal $\delta^{18}O$ values (Ferretti et al., 2015). Evidence from surface water proxies has revealed that MIS 19c was characterized by stable warm

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and oligotrophic surface–water conditions (Emanuele et al., 2015), while a major expansion of Mediterranean forest cover has been documented to occur on land (Sánchez-Goñi et al., 2016). The occurrence of rapid cooling/drying episodes indicates that millennial/submillennial-scale climate variability punctuated MIS 19 (e.g., Tzedakis et al., 2012a; Giaccio et al., 2015; Marino et al., 2015; Sánchez-Goñi et al., 2016), with substantial SST decreases and fresh water pulses related to ice-sheet instability from MIS 19c/19b transition up to MIS 18. In the sedimentary records, the identification of millennial-scale oscillations related to North Hemisphere iceberg discharges is relevant in this temporal framework, since it may provide indirect proxies for defining glacial/interglacial boundaries (Tzedakis et al., 2012b). Millennial variability during the glacial inception from MIS 19 to MIS 18 has been derived from the measurement of δD (Jouzel et al., 2007; Pol et al., 2010), $CH_4$ (Loulergue et al., 2008), and $CO_2$ (Lüthi et al., 2008), as well as $N_2O$ concentrations (Schilt et al., 2010) in ice cores. The onset of such a climate variability at the end of MIS 19c is well expressed in marine North Atlantic deep-sea sequences based on oxygen isotope pattern (Channell and Kleiven, 2000; Kleiven et al., 2011; Tzedakis et al., 2012a) and on the evidence of polar melt water arrival (Naafs et al., 2011, 2013; Ferretti et al., 2015; Sánchez-Goñi et al., 2016). An asynchronous interhemispheric phasing in the millennial scale climate variability is found between North Atlantic and Antarctic records within MIS 19 and post-dates the minimum in boreal summer insolation by 2.5–4.5 kyr (Tzedakis et al., 2012a). This mechanism, known as the onset of thermal bipolar-seesaw variability (Broecker, 1998; Stocker and Johnsen, 2003), is a response to changes in interhemispheric heat transport. North Atlantic iceberg discharges is in fact believed to have shut down the density-driven meridional overturning circulation, with consequent rapid cooling of the North Atlantic and gradual warming of South Atlantic Basin and Antarctica.

In this paleoclimate framework, we have investigated a portion of the lower-middle Pleistocene on land Montalbano Jonico succession, in the "Ideale" section, which is a candidate for the definition of the Global Boundary Stratotype Section and Point (GSSP) of the Middle Pleistocene (Head and Gibbard, 2015a and references therein). The aim is to unravel, in such a reference record, high frequency climate variability in the interval straddling the late MIS 20 and the MIS 18 glacial inception. Supra-regional/global climate variations are clearly expressed in the Montalbano Jonico section (e.g., Ciaranfi et al., 2010; Marino et al., 2015); here, high sedimentation rates offer the opportunity to investigate an expanded stratigraphic succession valuable for obtaining a high-resolution dataset. The previously acquired paleonvironmental signals in the same section have essentially focused on specific proxies, such as ostracod and pollen content (Aiello et al., 2015; Bertini et al., 2015; Marino et al., 2015), combined with a benthic oxygen isotope record. In the present study we have been adopting a multidisciplinary approach at higher temporal resolution, based on both biotic (calcareous plankton, dinocysts and pollen) and abiotic (grain size and mineralogy) proxies, correlated with benthic and planktonic oxygen isotope records. In the past studies, a comparable multiproxy approach was successfully applied for the paleoenvironmental investigation of older portions of the Montalbano Jonico section (Maiorano et al., 2008; Girone et al., 2013a) in order to build confidence in inferences about past climate changes. Such an approach is particularly valuable in rather proximal setting such as the shelf–upper slope environment of the investigated section. Here, climate signatures are captured not only by typical marine proxies, but also through multiple variables, which provide valuable information to unravel climate-induced modifications acting in the borderland area, such as vegetation changes, river runoff, erosional and depositional processes. Recent studies have shed lights on the interplay between tectonics, climate and erosion/deposition during the Middle Pleistocene–Holocene in the Basilicata region (Boenzi et al., 2008; Piccarreta et al., 2011). They show that the riverine system draining the region, in which the Montalbano Jonico section is located, is sensitive to hydrological and vegetational changes, causing flooding/erosional processes which are primarily driven by climate changes. The combined occurrence of both continental and marine proxies within a single succession, as is the case for the "Ideale" section, gives an intrinsic advantage towards the correlation between land–sea processes and a more comprehensive climate reconstruction.

The overall paleoclimate signals, identified in the "Ideale" section, are compared with global paleoclimate indicators from North Atlantic deep-sea sediments and ice-core records, in order to frame the investigated interval within a global paleoclimate context. A comparison with the succession of climate phases occurring during the Late Glacial-Holocene transition has also been attempted, to obtain further insights on the analogy between MIS 19 and the current interglacial.

## 2. The investigated area

### 2.1. Geological and paleogeographical setting

The Montalbano Jonico succession represents the middle-upper portion of the "argille subappennine" formation (e.g., Azzaroli et al., 1968; Pieri et al., 2011; Carbone, 2013), which crops out in the Lucania Basin (Balduzzi et al., 1982). The latter is part of the Bradano Trough (Casnedi, 1988), located between the Apennines Chain to the west and the Apulia foreland eastward (Fig. 1).

The Bradano Trough is considered the post-Messinian Apennines foredeep and is controlled by the eastward roll-back of the subduction hinge of the Apulia platform (e.g., Patacca and Scandone, 2007 and references therein). This basin was characterized by high rates of subsidence until the Calabrian, then it underwent a diachronous uplift, starting from the central area of the basin (the Genzano–Banzi area) in the late Calabrian and proceeding south-eastward to the actual Ionian coast until the Holocene. In the late Calabrian, the central sector of the Bradano Trough emerged while the southern sector, where the study section is located (Fig. 1), was still subsiding. Simultaneously, on the western side of the trough the uplift of Nocara ridge was taking place, isolating a western piggy-back depocenter, known as the Sant'Arcangelo Basin (e.g., Pieri et al., 1996a; Patacca and Scandone, 2007 and references therein). In particular, the study section belongs to a sedimentary succession that deposited unconformably on the external allochthonous sheets of the Apennine thrust front (falda di Metaponto, Mostardini and Pieri, 1967) and reached its maximum deepening in the Early–Middle Pleistocene (e.g., Ciaranfi et al., 1996). From the Middle Pleistocene, the study deposits underwent a shoaling-upward trend due to the uplift of the area (uplift rate of 0.1–0.5 mm/years, Doglioni et al., 1994, 1996) that proceeded until the Holocene (e.g., Pieri et al., 1996b; Patacca and Scandone, 2001). In the Early–Middle Pleistocene, the shoreline of the foredeep was about 15 km landward of its present day position (Fig. 1) and hosted deltas of the five major rivers (Sinni, Agri, Cavone, Basento and Bradano) occurring today on the Metaponto Coastal Plain (Tropeano et al., 2013). The catchment basins of these rivers, which represented the major tributary for the study succession depocenter, mainly eroded Apenninic terrains referable to the following units (Fig. 1): calcareous/dolomitic units of the Apenninic Platform (e.g., Patacca and Scandone, 2007), the calcareo-silico-marnoso succession of the Lagonegro Basin (Scandone, 1972), the Cretaceous to Paleogene shaley units of the Argille Variegate and the Flysch Rosso formations (e.g., Apat, 2007) and the Neogene arenaceous/pelitic successions of the Southern Apenninic foredeep (e.g., Pescatore, 1988). Source sediments from the calcareous Mesozoic Apulian foreland can be considered negligible due to the reduced drainage area of the catchment basins and poor drainage density, which is related to the high permeability of the bedrock. During the Early–Middle Pleistocene, the mountain front was already well developed, with a topographic gradient similar to the modern relief. It was bordered by a wide, low-gradient, fluvial plain that extended eastward from the foot of the chain to the coastline (Tropeano et al., 2002; Boenzi et al.,