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Lateglacial–early Holocene vegetation history of the Tiber delta (Rome, Italy) under the influence of climate change and sea level rise

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ABSTRACT

A new pollen and plant macrofossil record from Pesce Luna (Fiumicino, Rome) provides the reconstruction of the vegetation history in the Tiber Delta region between 13,000 and 8400 cal. BP. Marked fluctuations of hydro- and hygrophytes depict a variety of marsh–lagoon conditions reflecting marked changes in water-table level and salinity, determined by the transition from a continental environment with a strong fluvial influence, to a freshwater/brackish environment typical of an inner estuary, followed by a saline outer estuary environment. Both deciduous (mostly *Quercus*, *Corylus*, *Tilia*, *Ulmus* and *Fagus*) and evergreen elements (evergreen *Quercus* and Ericaceae) were already present during the Younger Dryas, being possibly enhanced by water availability and the vicinity to the sea that may have favoured long-term persistence of tree populations. Evergreen populations progressively increased during the early Holocene. Despite the strong effect of local environmental processes, a comparison of the Pesce Luna pollen record with other southern European sequences and the GISP2 $\delta^{18}O$ record indicates that the vegetation development was also influenced by centennial-scale climate processes acting at global scale. In particular, a mid-Younger Dryas climate reversal can be recognized at Pesce Luna, similar to other Mediterranean sites both in marine and continental environments. This study improves our knowledge on the vulnerability and resilience of coastal-estuarine wetlands to the global warming and sea level rise of the last deglaciation, adding insights into the response of coastal environments to the predicted global climate changes.

1. Introduction

The climate processes of the Lateglacial and early Holocene represent a paramount source of information to understand how the Earth's climate systems may rapidly switch from a glacial to an interglacial stage. During the last decades, these climate changes have attracted an ever-increasing interest and have been the subject of intense research concerning their origin, propagation mechanisms, geographical extent and effects on ecosystems. Different expressions of these climate changes are now evident all around the world, especially from marine and terrestrial biostratigraphical records in Europe and North America (e.g. Shuman et al., 2004; Fletcher and Sánchez Goñi, 2008), North Atlantic marine cores (e.g. Walker et al., 2001; Roucoux et al., 2005), Antarctic and Greenland ice cores (e.g. Blunier and Brook, 2001; Rasmussen et al., 2006), and from records of Northern and Southern hemisphere glacier shifts (e.g. Glasser et al., 2004; Schindelwig et al., 2009; Boex et al., 2013). These studies depict for the last deglaciation a complex climate scenario at a global scale (see Shakun and Carlson (2010) for a recent review). The overall global warming triggered by changes in insolation was accompanied by changes in ice sheets, greenhouse gas concentrations, and other amplifying mechanisms that produced distinctive regional and global responses. Episodes of rapid sea level rise and abrupt changes of air-mass circulation determined additional regional climate signals (Clark et al., 2012). As such, the spatial extent and intensity of the millennial and shorter timescale climate fluctuations of the last deglaciation, as well as the associated ecosystem responses, are often difficult to assess. In particular, the transmission mechanisms of the climate signals through different climate regions are still poorly constrained. In this respect, the documented atmospheric relationships between the North Atlantic Ocean and the Mediterranean Basin offer a valuable chance to investigate this topic.

In recent years major efforts have been devoted to obtain new continuous palaeoclimate proxy records from the Mediterranean regions. However, few pollen sites in Mediterranean coastal and estuarine areas record the Lateglacial and early Holocene (Laval et al., 1992; Schmidt et al., 2000; Pantaléon-Cano et al., 2003). This is mainly due

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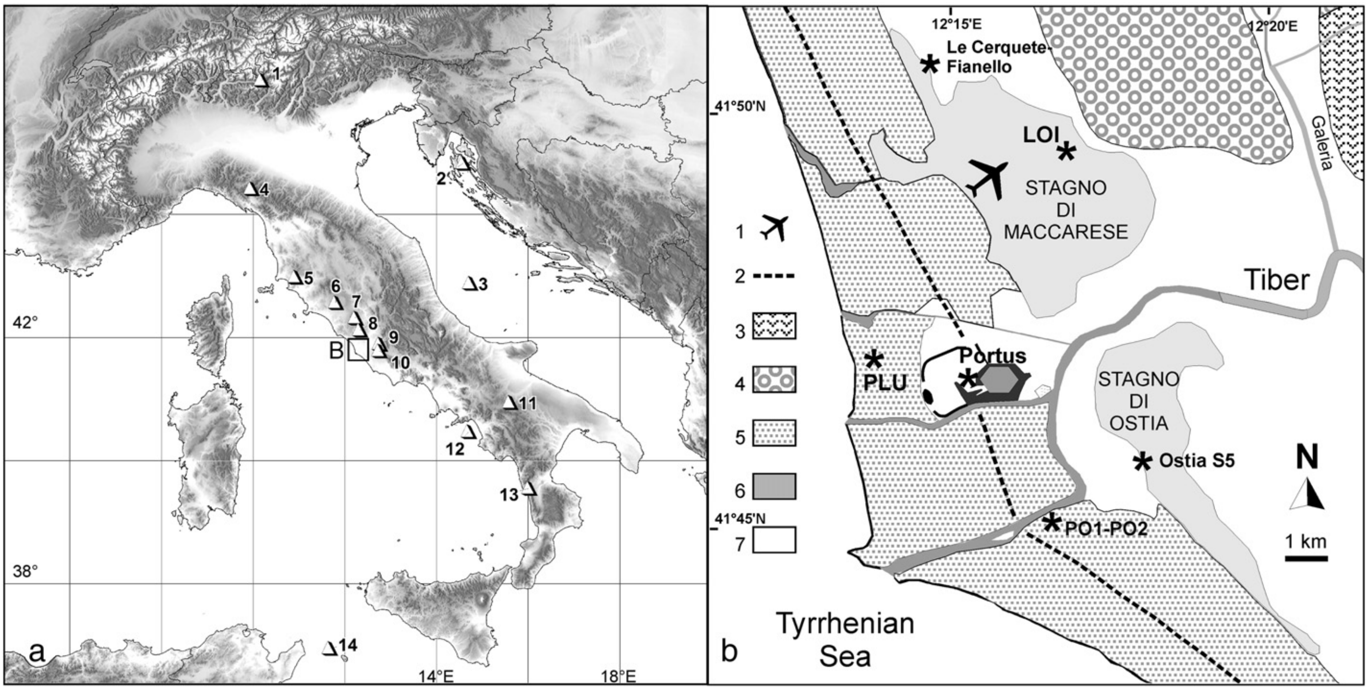

Fig. 1. a: Location of the sites mentioned in the text. 1. Pian di Gembro (Pini, 2002); 2. Lake Vrana (Schmidt et al., 2000); 3. CM92-43 (Asioli et al., 2001); 4. Lagdei (Bertoldi et al., 2007); 5. Lago dell'Accesa (Magny et al., 2006; Drescher-Schneider et al., 2007); 6. Lagaccione (Magri, 1999); 7. Lago di Vico (Magri and Sadori, 1999); 8. Stracciacappa (Giardini, 2007); 9. Valle di Castiglione (Di Rita et al., 2013); 10. Lago Albano (Lowe et al., 1996);11. Lago Grande di Monticchio (Huntley et al., 1999; Allen et al., 2002); 12. C106 (Russo Ermolli and Di Pasquale, 2002); 13. Lago Trifoglietti (Joannin et al., 2012); 14. MD04-2797CQ (Desprat et al., 2013). b: Location of the records from Pesce Luna (PLU), Lingua d'Oca-Interporto (LOI; Di Rita et al., 2010); Portus (Pepe et al., 2013), Ostia S5 (Bellotti et al., 2011), Le Cerquete Fianello (Di Rita et al., 2012), PO1–PO2 (Goiran et al., 2014); 1. Fiumicino Airport, 2. coast line of the 1st century AD (from Tuccimei et al., 2007), 3. Plio-Pleistocene sands, 4. Middle and Upper Pleistocene sands and gravels, 5. Holocene beach ridges, 6. Ancient ponds near the Tiber delta, 7. Holocene alluvial deposits (modified from Di Rita et al. (2010)).

to the difficulty of retrieving suitable sediments from the unstable and ephemeral sedimentary basins formed along the coasts under the influence of the eustatic sea level rise of the last deglaciation. Besides, these records are generally discontinuous, very poor in pollen, and difficult to analyse, so that pollen analysts often prefer to study more promising materials. However, they may be very fruitful, as demonstrated by the recent results on Holocene coastal sediments in the central Mediterranean Basin, providing the following:

- Recognition of atmospheric relationships with North Atlantic and African climate systems influencing the coastal vegetation dynamics (Di Rita and Magri, 2009; Tinner et al., 2009; Djamali et al., 2013);
- Definition of the impacts of climate processes at centennial/decadal timescales on the coastal environmental evolution (Calò et al., 2013; Di Rita, 2013);
- Assessment of the vulnerability of coastal ecosystems determined by sea level change and fluvial erosion and discharge (Bellini et al., 2009; Carroll et al., 2012).

On the whole, the need of new data from the Mediterranean regions concerning the climate fluctuations of the Lateglacial, the recent advances on Holocene coastal vegetation, and the conservation interest for vulnerable coastal environments, have stimulated the study of the present pollen record from the Tiber Delta region, providing the reconstruction of the vegetation history between ca. 13,000 and 8400 cal. BP, and addressing to the following aims:

- To reconstruct the vegetation dynamics of the Lateglacial and early Holocene in the Roman coastal area and to obtain new data on times and modes of the postglacial forest recovery;
- To provide insights into the relationships among the modes of sea level rise, the development of coastal environment and the vegetation dynamics at the Pleistocene/Holocene transition;
- To verify the possible influence of short-term climate oscillations recognized in Greenland and in North Atlantic records on the coastal vegetation development in a Mediterranean region.

The research presented here, whose results have been synthetically published in Milli et al. (2013), aims at investigating these issues through a detailed analysis of the estuarine deposits recognized in the Pesce Luna core, and at the same time it complements previous palynological work (Fig. 1b), mainly focussing on the Holocene natural and cultural history of the Tiber delta area (Di Rita et al., 2010, 2012), and on the impact of human activities on the landscape in the Roman settlements of the Tiber mouth (Bellotti et al., 2011; Pepe et al., 2013; Goiran et al., 2014).

2. Study area

The Tiber river delta is a micro-tidal wave-dominated delta supplied by mud-sandy sediments, stretching over some 38 km along the Tyrrhenian coast of the Latium region, 25 km SW of Rome (Fig. 1). It includes a delta plain and a submerged fan (Bellotti et al., 1994). The most recent paleogeographic reconstruction of this area during the Late Pleistocene–Holocene (Milli et al. (2013) and references therein) highlights the results of the stratigraphic and sedimentological analyses in recording the passage from a wave-dominated estuary to a wave-dominated delta (Fig. 2). The Late Pleistocene to Holocene Tiber delta succession is the result of the close interaction between global eustatic variation and sediment supply, as a result of climatic changes. The Tiber depositional architecture shows a sedimentation of alluvial and coastal systems during the regressive forced phase related to the eustatic sea level fall of the last glacial period (Early Lowstand Systems Tract of the sequence stratigraphy; Fig. 2). With the stillstand of the Last Glacial Maximum and the slow eustatic sea level rise of the early Lateglacial