

Did the Mediterranean marine reflooding precede the Mio–Pliocene boundary? Paleontological and geochemical evidence from upper Messinian sequences of Tuscany, Italy

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Abstract

The events related to the Messinian salinity crisis are among the most deeply investigated of Earth's history. According to the current hypothesis of Neogene paleogeographic evolution, approximately 5.5 Ma ago, after evaporitic sedimentation and before the Mio–Pliocene boundary, the Mediterranean was characterized by the widespread development of non-marine environments inhabited by molluscs and ostracods of brackish affinity. The Messinian post-evaporitic deposits that testify such a dramatic environmental change are commonly referred to as ‘Lago-mare’ and have been reported from several outcrops and boreholes throughout the entire Mediterranean basin. The origin of ‘Lago-mare’ conditions is commonly interpreted as the result of the synergistic effect of both the humid climatic conditions and change of the drainage patterns at the Mediterranean scale, with the capture of Paratethyan brackish waters. A few recent studies, however, suggest that such a scenario probably represents an oversimplification of the original context, from both a paleogeographical and paleoenvironmental point of view. Unfortunately, the results of these studies have never been commonly accepted and the proposed evidences have been considered questionable. In this paper we describe the fish assemblages from the ‘Lago-mare’ deposits of two localities, Cava Serredi and Podere Torricella, located in the Neogene hinterland basins of Tuscany, central Italy. These assemblages consists of a mixture of marine euryhaline and stenohaline taxa suggesting that the depositional environments were characterized by permanently open connections with a marine basin filled with normal marine waters. In order to better define the paleontological significance of these upper Messinian fish assemblages, the oxygen, carbon and strontium isotopic composition of fish otoliths and other fossils has been measured. These isotopic compositions are strongly indicative of the presence of normal marine conditions close to the depositional environments testified by the sedimentary sequences, thereby implying that the interpretation of the geochemical results are consistent with those derived from the paleoecological analyses of the fish assemblages. Based on the integrated paleoichthyological–geochemical approach discussed in this paper it is possible to unambiguously demonstrate that normal marine rather than fresh- or brackish waters were present in the Mediterranean at least during the upper part of the ‘Lago-mare’ event, providing an unquestionable evidence that the marine refilling of the basin preceded the Mio–Pliocene boundary.

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1. Introduction

The Messinian salinity crisis represents one of the most discussed topic in Earth Sciences in the past 30 years. The possibility that during the Messinian the Mediterranean was at times completely desiccated received considerable attention in the scientific community and stimulated an unusual quantity of multidisciplinary researches, which generated cogent and often conflicting debates. The amazing development of stratigraphic techniques in the last decade greatly increased our knowledge of the events related to the Messinian salinity crisis. The refinement of the Neogene bio- and magnetostratigraphy in the Mediterranean region and the consequent improvement of a detailed astronomically-tuned time scale provided a useful tool for high resolution correlations and paleogeographic reconstructions (e.g., Hilgen et al., 1999; Krijgsman, 2002). Moreover, the accurate correlations available favoured the interpretation of a reliable sequence of environmental changes and their relationships with global and regional climatic and tectonic events (Krijgsman et al., 1999; Hodell et al., 2001; Vidal et al., 2002; Rouchy and Caruso, 2006). Nevertheless, the interpretation of many questions related to this event remain elusive and several aspects of the paleogeographical, paleoclimatological and paleoenvironmental setting of the Mediterranean and the composition of the water column through the Messinian are not completely clear and the results of the investigations often contrasting (see Rouchy and Caruso, 2006). Even though the base and top of the Messinian stage are now well constrained (Hilgen et al., 2000; Lourens et al., 2006), the chronology of Messinian events appears rather controversial. A highly influential cyclostratigraphic model (Krijgsman et al., 1999) recently redefined the classic subdivision of the Messinian stage into three phases, (1) pre-evaporitic (7.25–5.96 Ma), (2) evaporitic (5.96–5.59), and (3) post-evaporitic (5.52–5.33), of which the second and third correspond to the salinity crisis event. The interpretation of the Mediterranean paleogeographic and paleoenvironmental context of post-evaporitic phase is scarcely defined and characterized by a number of weakly supported hypotheses. The post-evaporitic phase can be defined as the interval of the Messinian history that followed the evaporitic sedimentation and ended in correspondence to the so-called terminal Messinian flood at the base of the Pliocene (McKenzie et al., 1999). According to the current interpretation of regional paleoenvironmental evolution, during the post-evaporitic phase the entire Mediterranean was characterized by non-marine sedimentation with the development of a

series of interconnected lacustrine-brackish basins. For this reason, the Messinian post-evaporitic deposits are commonly termed as ‘Lago-mare’. The term ‘Lago-mare’ was introduced in the Messinian nomenclature by Ruggieri (1967), who mutated it from the Paratethyan literature (e.g., Andrusov, 1890; Gignoux, 1936) to designate the upper Messinian fresh- to brackish water paleoenvironment testified by the mollusc-bearing deposits usually referred to as ‘*Congeria* beds’ and/or ‘*Melanopsis* beds’ (e.g., Capellini, 1880). The significance of the ‘Lago-mare’ event is poorly understood and several interpretative hypotheses have been proposed to date. ‘Lago-mare’ deposits are widespread in the Mediterranean area, in both exposed basins and deep parts, usually above the evaporites and just beneath the marine Zanclean sediments (Orszag-Sperber, 2006). Because of the highly heterogeneous nature of Messinian post-evaporitic sedimentary products (Cita and Corselli, 1990; Roveri and Manzi, 2006), the interpretation of the paleoenvironmental and paleogeographical setting of the ‘Lago-mare’ event has been mostly based on the typical biota that usually characterizes these deposits. The paleontological record of the ‘Lago-mare’ deposits is relatively scarce, and mostly consists of a recurrent assemblage of oligo-mesohaline ostracods and molluscs usually considered of Paratethyan affinity. Many of the mollusc taxa typical of the ‘Lago-mare’ assemblage were already present in the Mediterranean before the salinity crisis (Cipollari et al., 1999), while the endemic versus Paratethyan biogeographic affinities of the ‘Lago-mare’ ostracods have been extensively discussed in the past few years e.g. (Gliozzi, 1999; Bassetti et al., 2003; 2006). The widespread deposition of ‘Lago-mare’ deposits is usually interpreted as the result of both the humid climatic conditions (Cosentino et al., 2005) and the dramatic change of the drainage pattern in the whole Mediterranean that resulted in the capture of the Paratethyan brackish waters through a canyon system located in the Aegean region (McCulloch and De Deckker, 1989; Orszag-Sperber et al., 2000; Cita et al., 1978).

The main objective of this paper is to investigate the fossil remains, mostly fish otoliths, collected from the ‘Lago-mare’ deposits of two localities in Tuscany (central Italy), Cava Serredi and Podere Torricella, in the Fine and Volterra basins respectively. The fossil fishes from Cava Serredi have been cursorily presented in previous papers (Carnevale et al., 2000, 2006b), while the assemblage from Podere Torricella is presented here for the first time. In order to correctly define the paleoenvironmental significance of these upper Messinian faunas, the oxygen, carbon and strontium isotopic composition of fish otoliths and other fossils has been

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