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High-resolution strontium isotope stratigraphy of the Messinian deep Mediterranean basins: Implications for marginal to central basins correlation

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ABSTRACT

New $^{87}Sr/^{86}Sr$ data from DSDP–ODP Messinian cores from deep Mediterranean basins suggest that the usually envisaged correlation of offshore Upper Evaporites with onshore Upper Gypsum deposits of Sicily, Cyprus and Crete recording the stage 3 (5.53–5.33 Ma) of the Messinian salinity crisis may be not entirely correct. High-resolution stratigraphic calibration of Sr isotope data indicates that only a very thin unit (commonly <50 m) in the uppermost part of the "seismic" Upper Evaporites is characterized by the typically lower values for Sr isotopes with respect to the global Ocean which characterize stage 3 onshore successions ("Lago Mare event"). These deposits mainly consist of interbedded clastic or cumulate gypsum and marls; halite recovered from cores in the Upper Evaporites unit is actually characterized by Sr isotope values consistent with stage 2 deposits of onshore successions. According to these results, the Messinian trilogy of the western Mediterranean basin could be as a whole correlated with the halite unit of the eastern basin, suggesting that different hydrologic conditions characterized the two deep areas during the peak of the salinity crisis.

1. Introduction

In the early 1970s, immediately after the discovery of the giant salt bodies buried below its abyssal plains (Hsü et al., 1973a; Fig. 1), it became clear that near the end of the Miocene an exceptional event had occurred in the Mediterranean basin and surrounding areas. This event, now known as the *Messinian salinity crisis* (MSC), had a dramatic impact on the marine and terrestrial biota and would have had important consequences even for the subsequent geologic evolution of the whole Mediterranean area. Now, forty years after the beginning of this great scientific adventure, the giant salt deposits buried below the deep Mediterranean basin are still virtually unexplored, thus hampering any attempt to fully understand why, when and what actually happened before, during and immediately after the MSC.

Based on: 1) the ascertained deep basin nature of the Mediterranean before the MSC onset, 2) the supposed very shallow-water origin of the deep basin evaporites, and 3) the widespread development of erosional features along the continental margins (Clauzon, 1973; Ryan and Cita, 1978), a scenario envisaging the almost complete desiccation of the Mediterranean was suggested. This scenario, known as the "shallow-water deep-basin" model (Hsü et al., 1973b), became very popular and still represents the MSC paradigm.

A few (DSDP–ODP) boreholes drilled through the Plio-Pleistocene sedimentary cover reached and recovered the uppermost tens of meters of the Messinian evaporite unit, but its main body (up to 2 km-thick in the eastern Mediterranean), as well as its lateral and underlying deposits are still known only from seismic data.

The advancements achieved in the comprehension of the MSC issues, summarized in the CIESM Consensus Report (CIESM, 2008), are mainly based on onshore data, including both shallow- and relatively deep-water deposits. This resulted in the very high-resolution chronostratigraphy of Messinian events proposed by Hilgen et al. (2007) and in the progressive refinement of evaporite facies models (Manzi et al., 2009, 2011, 2012, 2013; Lugli et al., 2010). The deep evaporite suite has been classically subdivided into three units (the "Messinian trilogy", namely, from the bottom, Lower Evaporites (LE), Messinian Salt and Upper Evaporites (UE); Montadert et al., 1970, 1978) based on their peculiar seismic attributes. A thorough revision recently carried out on the seismic dataset (Lofi et al., 2011a,b), resulted in a new, more descriptive and objective classification of these basinal Messinian units and of their bounding surfaces (see Section 2.4). In the early '70s the three seismic units have been tentatively correlated with the Sicilian onshore record (Decima and Wezel, 1971), which shows a similar threefold subdivision in Lower Gypsum, Halite and Upper Gypsum (Fig. 2). However, onshore successions are physically disconnected from their abyssal plain counterparts and any attempt to correlate them (through

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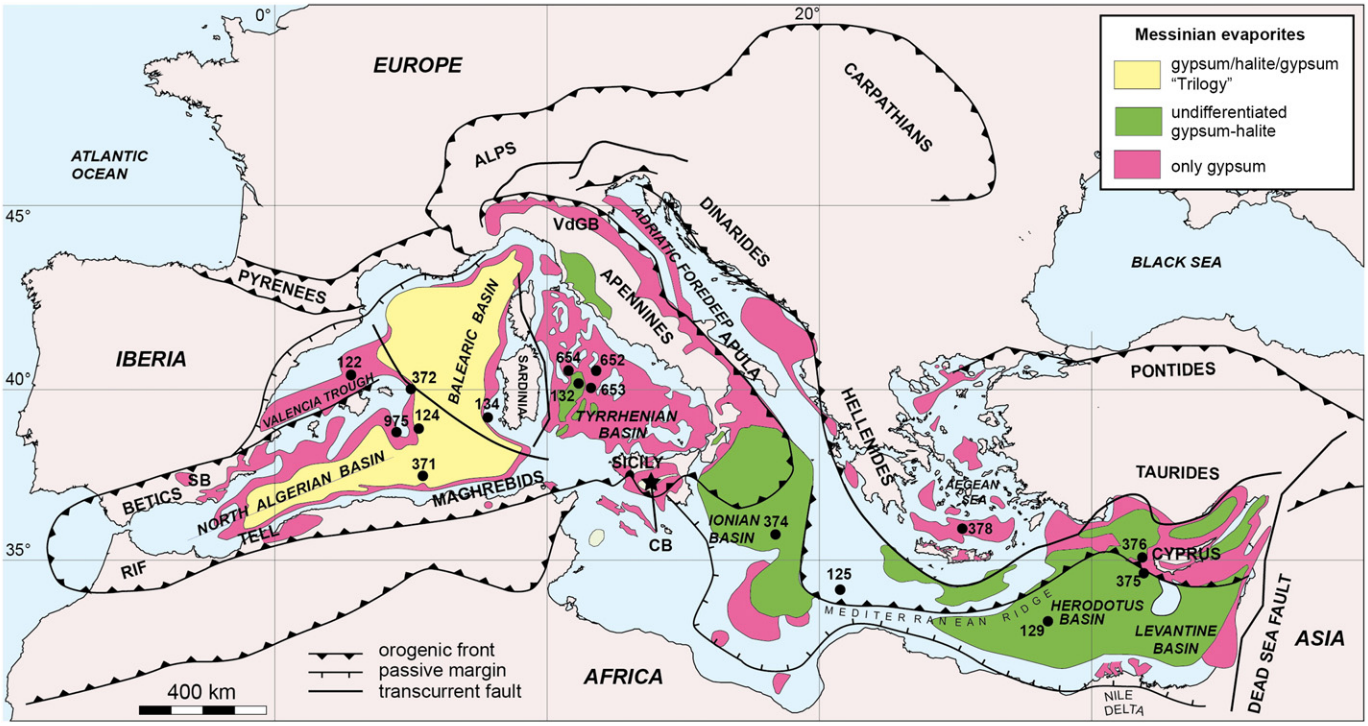

Fig. 1. General map of Mediterranean Messinian evaporites with location of the DSDP–ODP sites that recovered evaporites (modified from Rouchy and Caruso, 2006).

seismic data or using sequence-stratigraphic criteria) cannot be verified through direct and independent data.

In fact, recent studies have suggested that the offshore Lower Evaporites could be younger than the onshore Lower Gypsum (Clauzon et al., 1996; Roveri et al, 2001; Lofi et al., 2005; Manzi et al., 2005, 2007; Roveri and Manzi, 2006; Roveri et al., 2008a) and this casts many doubts about the possibility that the deep evaporites may exactly mirror the onshore succession.

In this respect, DSDP–ODP cores, despite that their penetration is limited to the uppermost part of the Upper Evaporite unit, remain helpful for testing the inferred equivalence of Upper Evaporites and Upper Gypsum. These cores have not been particularly considered after their recovery and initial studies; a partial revision by Hardie and Lowenstein (2004) challenged the original attribution of some evaporitic facies of the Upper Evaporites unit to subaerial or very shallow-water environments (i.e., above fair-weather wave base). We have carried out a complete sedimentologic and petrographic revisitation of all the available cores (Lugli et al., in prep.; Fig. 3). Our study rules out any evidence for subaerial exposure and suggests instead the compatibility of the uppermost Messinian evaporites with deposition in a fully subaqueous, deep-water environment (i.e. below the fair-weather wave base up to thousands of meters depth).

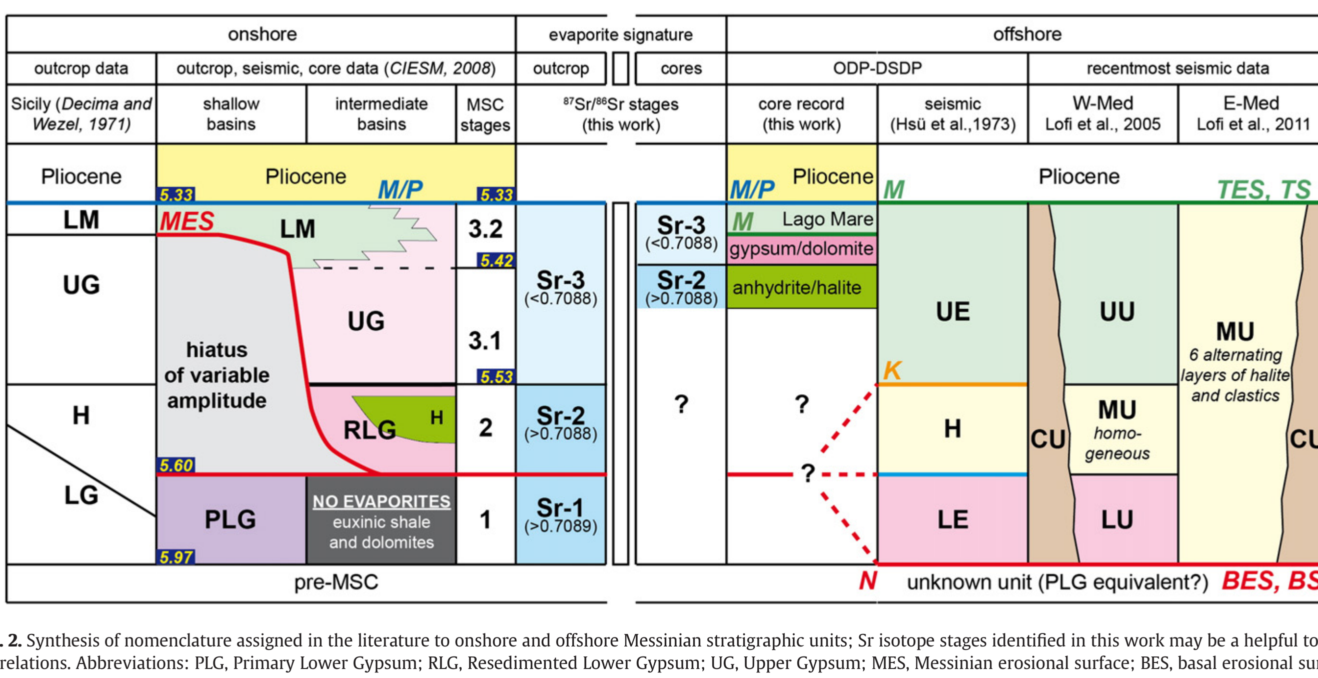

Fig. 2. Synthesis of nomenclature assigned in the literature to onshore and offshore Messinian stratigraphic units; Sr isotope stages identified in this work may be a helpful tool for correlations. Abbreviations: PLG, Primary Lower Gypsum; RLG, Resedimented Lower Gypsum; UG, Upper Gypsum; MES, Messinian erosional surface; BES, basal erosional surface; BS, basal surface; TS, Terminal surface; TES, Terminal erosional surface; N, K, M, seismic reflectors; LU, Lower Unit; MU, Mobile Unit; CU, Complex Unit; UU, Upper Unit.