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Research paper

Messinian Salinity Crisis deposits widespread over the Balearic Promontory: Insights from new high-resolution seismic data

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ABSTRACT

The current interpretation of the Messinian Salinity Crisis (MSC) involves the deposition of peripheral or marginal evaporites in onshore basins as well as the erosion of the margin and the deposition of thick evaporites in deep basins. The so-called intermediate basins are formed in domains between the onland outcrops and the deep basins. The Balearic Promontory is a bathymetric high located between the deep Algerian and Liguro-Provençal basins and the onland Spanish basin. The SIMBAD project aims to investigate the spatial variability of the MSC-related deposits and to assess the extent of post-MSC reactivation over the Balearic Promontory. We present here the first results of the SIMBAD high-resolution seismic survey (January 2013) which imaged for the first time a thin MSC-related unit widely distributed in small sub-basins over the Balearic Promontory.

Borehole analyses have shown that this unit could be correlated with primary gypsum formations linked to the peripheral evaporites. Locally, in the Central Depression between Mallorca and Ibiza islands, a thicker MSC unit is observed whose lowermost transparent part could correspond to a salt layer. Geometrical relationships suggest that the MSC in the Central Depression could postdate the primary gypsum. The occurrence of a halite layer in the Central Depression, at depths of 1000 to 1500 m, favours the hypothesis that the evaporites precipitated passively in closed or partially closed perched sub-basins, possibly as a result of evaporative drawdown at different depths and possibly diachronously, at least with respect to the deep-basin evaporites.

1. Introduction

The Messinian Salinity Crisis (MSC) has been the focus of much research since the drilling of evaporites and salt in the Mediterranean basins during the 1970s (Hsü et al., 1973a, 1973b; Ryan et al., 1973).

The widely accepted model for the two-stage development of the MSC (Clauzon et al., 1996; CIESM et al., 2008) proposes that, during stage 1 (5.97–5.60 Ma, Gautier et al., 1994; Krijgsman et al., 1999; Manzi et al., 2013), primary shallow-water evaporites (Primary Lower Gypsum, PLG) accumulated in semi-enclosed marginal (or peripheral) basins now cropping out onshore. During stage 2 (5.60–5.33 Ma, Gautier et al., 1994, Krijgsman et al., 1999; Manzi et al., 2013), a substantial fall in sea level of the Mediterranean accounts for the deposition of thick MSC halite units in the deep basin (1–2 km of halite), while the marginal areas and slopes were subject to intense and polygenic erosion (the MES, Margin Erosion Surface, Lofi et al., 2005, 2011a). However, debate is still continuing about the amplitude of the sea-level fall, as well as the timing and depositional environment of the salt (formation of brines by

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evaporation of shrinking basins: Ryan, 2008; Lofi et al., 2011b; resedimented evaporites and cumulates with moderate fall in base level: Roveri et al., 2008, 2014; salt precipitation after dessication in shallow water: Bache et al., 2009).

Until now, no stratigraphic or lithological calibration could be established between the depositional units of the deep offshore basins and the onland succession. Both kinds of deposits are geometrically and geographically disconnected and their correlation and timing are still subject to uncertainties and controversy (Rouchy and Caruso, 2006; CIESM et al., 2008; Ryan, 2009).

For these reasons, we focus on the Balearic Promontory, which provides a record of the MSC extending spatially from the onshore basins of the Eastern Spanish margin and Mallorca Island to the abyssal plains of the Algerian and Valencia basins. The recent acquisition of high-resolution seismic reflection data supplemented by a large data base resulting from industrial and academic research allows us to characterize for the first time a MSC-related seismic unit widely developed over the entire Promontory. The mapping of this unit reveals a set of stepped Messinian basins at various depths distributed nearly continuously between the onland outcrops and the deep basins. The preservation of such MSC unit at shallow depths provides us with targets to study the MSC event, since only a widely developed erosion surface (the Margin Erosion Surface, MES, Lofi et al., 2011a) is observed on the other passive margins of the NW Mediterranean which is the offshore outcome of the Messinian Erosional Surface observed onland. The MSC unit of the Balearic Promontory is correlated with well data and its significance is discussed with regard to other known MSC units.

2. Physiography and geological setting of the Balearic Promontory

The Balearic Promontory is a continental rise (500-km-long, 120 km-wide) which includes the Balearic Islands, surrounded by narrow platforms and steep slopes toward the surrounding basins (Fig. 1). It is bounded to the North by the Valencia continental Basin, an aborted rift subject to extensional tectonics from the Oligocene to the Serravalian/Tortonian (Maillard et al., 1992; Mauffret et al., 1992; Roca and Guimera, 1992). The southern border of the Balearic Promontory shows a steep slope (6.5–8°), which is composed of the Mazarron and Emile Baudot escarpments (Acosta et al., 2001a, 2002, 2013), separating the Promontory from the oceanic Algerian Basin where water depths exceed 2400 m (Figs. 1 and 2). The adjacent Algerian and Valencia basins are connected by two channels cutting through the Promontory, the Ibiza Channel and the Mallorca Channel, respectively. The Balearic domain is bounded to the east by the Menorca slope, descending abruptly towards the Liguro-Provençal oceanic Basin and prolonged to the south by a topographic high, the Menorca Rise (Fig. 1).

Located between two extensional basins, the Balearic Islands result from compressional deformation associated with the Betic thrusts (Sanz De Galdeano, 1990; Ramos Guerrero et al., 1989: Roca, 2001). The Betic thrusts are well expressed on the islands of Ibiza and Mallorca (Fourcade et al., 1982; Gelabert et al., 1992, 2004; Sabat et al., 2011) and can be traced offshore in the Valencia Basin and in the lower slope domain of the Islands (Maillard et al., 1992; Mauffret et al., 1992, Fig. 2). The compression initiated during the Late Oligocene to the south and propagated northwards

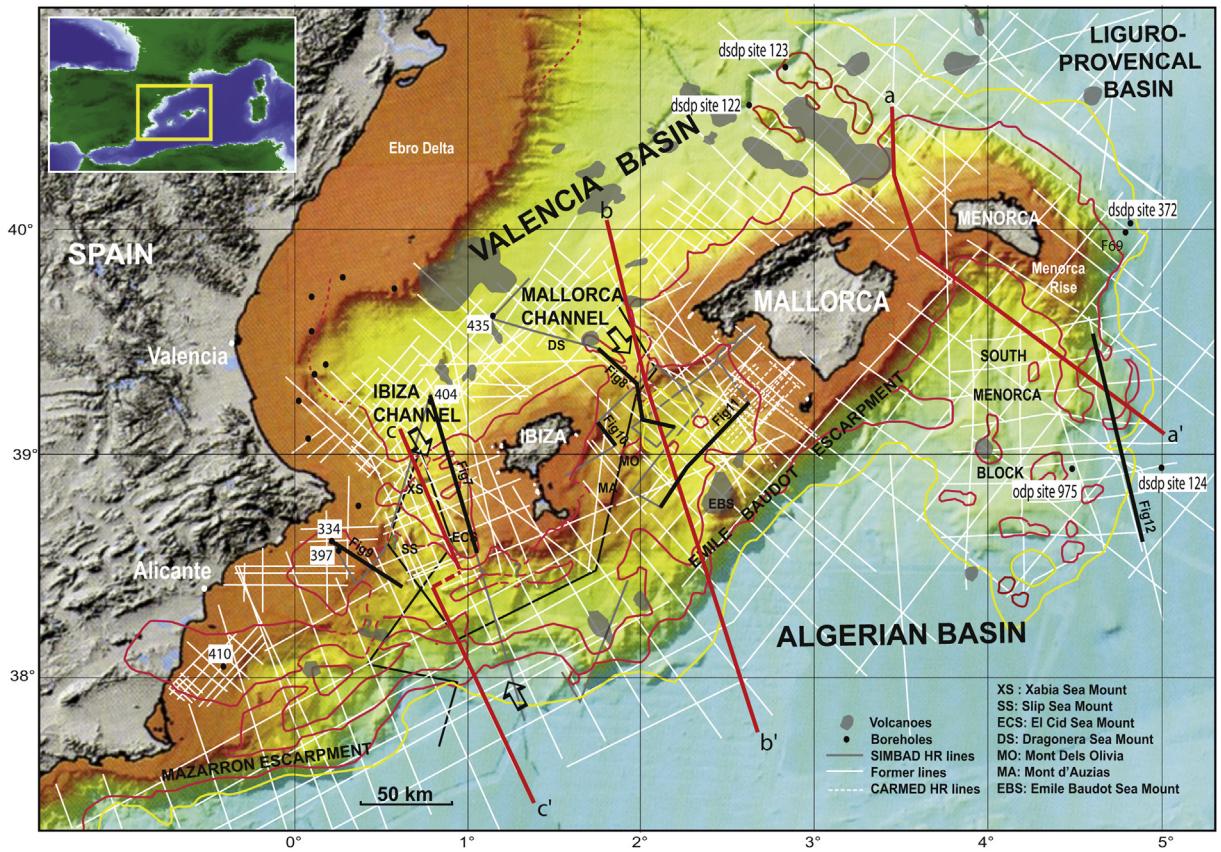

Figure 1. Bathymetric map after Brosolo and Mascle, 2008, showing location of the study area. The seismic profiles used in this study are shown as well as the location of lines aa', bb' and cc' (Fig. 3). The thick black lines show the location of the following figures. Red line represents the limit of the MSC deposits. Black arrows show the location of the channels. No MSC deposits exist on the shelves of the Balearic Islands. Yellow line represents the limit of the salt (MU). Seafloor volcanic mounts are shown as grey-shaded areas. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)