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Record of the Messinian Salinity Crisis in the SW Mallorca area (Balearic Promontory, Spain)

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ABSTRACT

The current interpretation of the Messinian Salinity Crisis (MSC) involves the deposition of the so-called "peripheral or marginal" evaporites in onshore basins, as well as the erosion of the margins and the formation of thick evaporites in the deep parts of the basins. The present study focuses on intermediate depth basins, i.e. located between the onshore outcrops and the deep basins. Indeed, the Balearic Promontory shows small stepped basins filled with MSC deposits between its western extremity on the Alicante shelf and its eastern end around the Menorca block. New and already available seismic reflection profiles and onshore data allow us to investigate the nature and geometrical relationships of these deposits in the area between the islands of Ibiza and Mallorca.
Our observations suggest the existence of three MSC-related units in this area. The lowermost transparent seismic unit can be interpreted as a 100 to 200-m-thick salt layer deposited in the deepest part of the Central Mallorca Depression. These evaporites pass laterally and upward into a thin-bedded seismic unit, which could be lithologically equivalent to the Upper Evaporites of the deep basins. All around the borders of the Central Mallorca Depression, this bedded seismic unit onlaps a Slope Unit which shows bedded to chaotic and rafted facies. The Messinian continental shelf is eroded and incised by a valley extending from the Palma onshore area to the Mallorca downslope domain. Our results suggest the presence offshore of at least two generations of diachronous MSC deposits. The observation of salt on a continental high and the widespread MSC deposits on the margins of the Central Mallorca Depression call into question the location of halite preferentially in the deep abyssal basins and the significance of the deep basin MSC units that onlap onto the Margin Erosional Surface (MES), as observed all around the passive margins of the Northwest-Mediterranean Basin. The dual terminology used for peripheral/deep MSC evaporites cannot be applied to any of the MSC units found in the study area.

1. Introduction

The Messinian Salinity Crisis (MSC) has attracted much interest through numerous studies carried out since the drilling of evaporites in the Mediterranean basins in the 1970s (Hsü et al., 1973a,b; Ryan et al., 1973). Indeed, the desiccation of the Mediterranean caused the deposition of thick evaporites in the deep basins and erosion of its margins, along with the formation of evaporite deposits and erosion surfaces in the so called "peripheral or marginal" basins (PLG after CIESM, 2008) which mostly crop out onshore. Deposits in deep basins are geometrically disconnected from those on the margins, and their correlation and timing are still subject to uncertainties (Rouchy and Caruso, 2006; Ryan, 2009; Roveri et al., in press).

The increasing quality of seismic data now allows us to identify and image the MSC seismic markers (bounding surfaces and depositional units) with good confidence at the scale of the Mediterranean (Lofi et al., 2011a, and the references therein). In the Northwest Mediterranean, several studies have focused on the shelf-slope–deep basin transition, mainly in the Gulf of Lions, due to the existence of a reliable database (Guennoc et al., 2000; Lofi et al., 2005; Gorini et al., 2005; Bache, 2008; Lofi and Berné, 2008; among others), and more recently on the Sardinian and Provençal margins (Sage et al., 2005; Cornée et al., 2008; Obone-Zué-Obame et al., 2011; Gaullier et al., 2014). These investigations have been mainly concerned with the study of the widespread Margin Erosion Surface (MES) and its relationship with the deep basin MSC deposits located downslope. Only a few studies have dealt with MSC deposits accumulated on the continental slopes, mainly because these areas were dominated by erosion during the crisis. Such deposits are generally described as fan-shaped accumulations with complex internal architecture, and are interpreted as clastic deposits related to the

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erosion of the margin (Lofi et al., 2005; Sage et al., 2005; Maillard et al., 2006; Garcia et al., 2011; Lofi et al., 2011a,b). However, topographic lows possibly containing MSC deposits have been locally described on seismic profiles on the continental slopes of Western Corsica (Guennoc et al., 2011), Eastern Corsica (Thinon et al., 2004) and the flanks of the South Balearic Promontory (Maillard and Mauffret, 2013). Some of these MSC deposits could even contain thin salt layers, as in the depression south of the Formentera sub-basin (Camerlenghi et al., 2009), and on the west Sardinia deep margin (Geletti et al., 2014). Such deposits represent a MSC record located at intermediate depths between the peripheral outcrops and the deep basins, and could thus provide a key to reconstructing a unified MSC scenario. For these reasons, this study focuses on the Balearic Promontory, which is composed of the islands of Ibiza, Mallorca and Minorca as well as the surrounding continental highs, characterized by a set of stepped Messinian basins distributed from onshore to the deep offshore domain (Fig. 1). One of these basins lies in the Central Mallorca Depression (CMD) between the islands of Ibiza and Mallorca. In this study, we describe the MSC-related markers observed on seismic data, extending from the shelf to the CMD (Fig. 2). Onshore boreholes and offshore seismic reflection data have been combined to integrate land and sea observations in order to understand the spatial and temporal relationships between MSC units occurring in the CMD, as well on the slope, and also in the Palma Basin on land.

2. Geological and geographical setting of the Balearic Promontory

2.1. Physiography of the study area

The Balearic Promontory is a 500 km-long, 120 km-wide continental rise including the Balearic Islands, which is surrounded by a narrow shelf with steep slopes toward the surrounding basins (Fig. 1). Its southern border is steep, except in the Ibiza Channel, and composed of the Mazarron and Emile Baudot escarpments (EBE), while a gentler slope connects it to the Valencia Basin to the north. This study is focused on the part of the Balearic Promontory located between the islands of Mallorca and Ibiza-Formentera (Fig. 2). The study area includes the SW shelf and

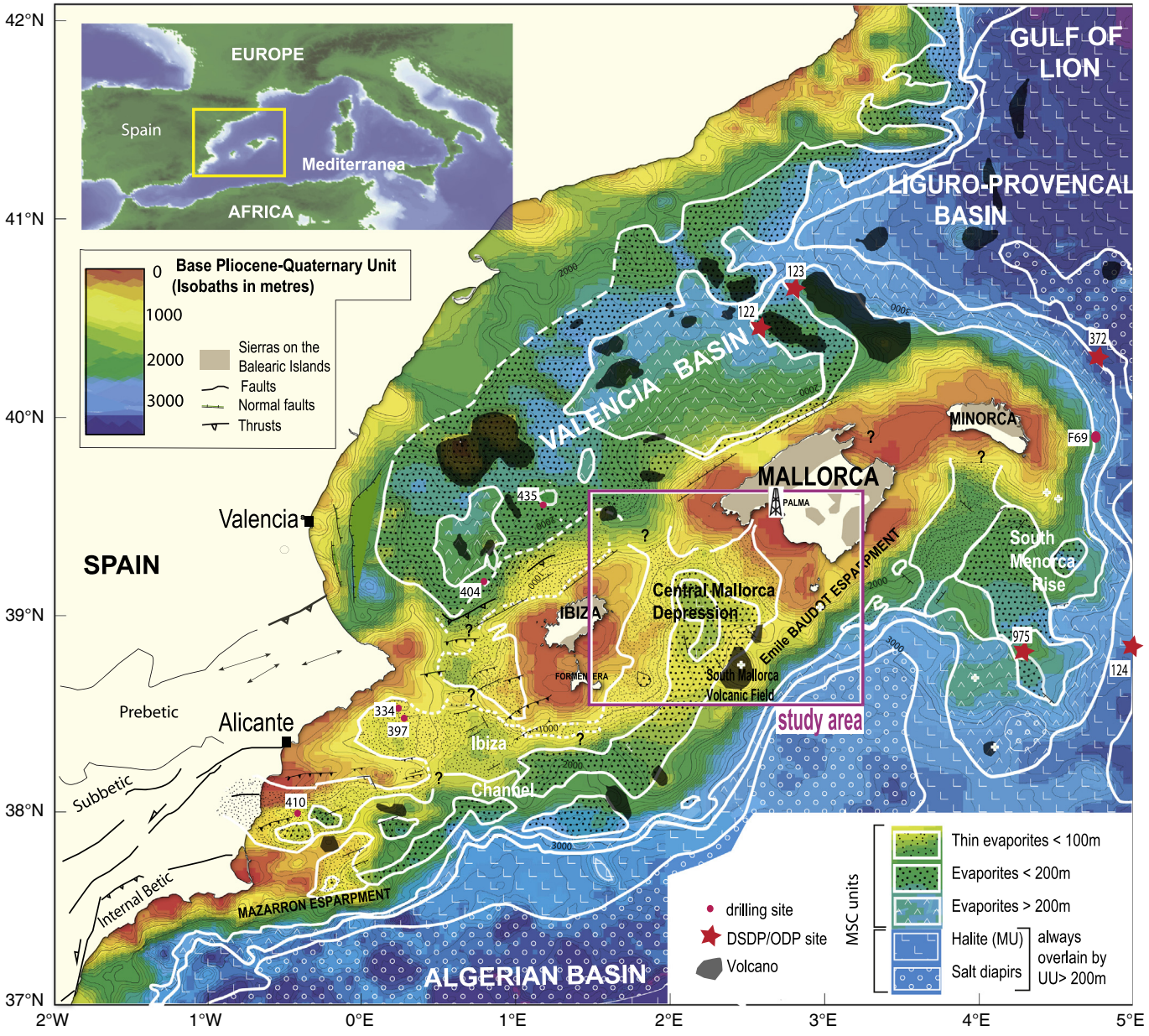

Fig. 1. Map showing isobaths of the base of the Pliocene–Quaternary unit (PQ Unit), with location of the MSC-related basins at different depths, highlighting the main geological features of the Balearic Promontory (composed of the structural high formed by the Balearic Islands) and surrounding areas. The MSC deposits filling the basins are shown in relation to their thickness.