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Messinian paleoenvironmental evolution in the lower Guadalquivir Basin (SW Spain) based on benthic foraminifera

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ABSTRACT

Benthic foraminiferal assemblages of a drill core from the lower Guadalquivir Basin (northern Gulf of Cádiz, SW Spain) have been analyzed in order to reconstruct the paleoenvironmental evolution in the vicinity of the Betic seaways during the Messinian. The core consists of marine sediments ranging from the latest Tortonian to the early Pliocene. Changes in the abundance of certain marker species, planktonic/benthic ratio (P/B ratio), paleodepth estimated with a transfer function, content of sand grains and presence of glauconitic layers indicate a complete transgressive–regressive sea-level cycle from the bottom to the top of the section. An abrupt sea-level rise, from inner-middle shelf to middle slope, is recorded at the lowermost part of the core (latest Tortonian–earliest Messinian), followed by a relatively rapid shallowing from middle slope to outer shelf. Magnetobiostratigraphic data show that this sea-level fall postdates the onset of the Messinian salinity crisis (MSC) in the Mediterranean. Finally, the early Pliocene deposits are interpreted as inner-middle shelf.

Changes in the benthic foraminiferal assemblages through the core are mainly controlled by the trophic conditions, specifically by the quantity and quality of the organic matter reaching the sea floor. The upper slope and part of the outer shelf assemblages are highly diverse and dominated by shallow infaunal species, indicating a generally mesotrophic environment with moderate oxygenation. These environments have likely been affected by repeated upwelling events, documented by increased abundance of *Uvigerina peregrina* s.l., an opportunistic species thriving in environments with enhanced labile organic matter supply. The assemblages of the transitional interval between upper slope to outer shelf, and of the outer shelf are generally characterized by a relatively low diversity and epifaunal-shallow infaunal taxa, indicating oligotrophic and well-oxygenated conditions. The inner-middle shelf assemblages are characterized by very low diversity and dominance of intermediate to deep infaunal taxa, suggesting an eutrophic environment with low oxygen content. These assemblages are dominated by *Nonion fabum* and *Bulimina elongata*, two taxa that are able to feed from continental low-quality organic matter, most likely derived from river run-off. The paleoenviromental evolution on the Atlantic side of Betic and Rifian seaways is similar during the Messinian, with a Messinian continuous sea-level lowering driven by regional tectonic uplift and upwelling-related waters reaching the upper slope. This study will further contribute to understand the role of tectonics on the sea-level changes as well as on the closure of the Atlantic–Mediterranean gateways that led to the MSC, and on the paleoceanography on the Atlantic sides of these corridors.

1. Introduction

The Messinian was a time of drastic paleoenvironmental and paleogeographic changes in the Mediterranean (Hsü et al., 1973, 1977). During this time interval, tectonic processes together with glacioeustatic sea-level oscillations led to the isolation of the Mediterranean triggering the formation of thick evaporite deposits during the so-called Messinian salinity crisis (MSC) (Benson, 1986; Benson et al., 1991; Martín and Braga, 1994; Esteban et al., 1996; Riding et al., 1998; Martín et al., 2010). This event took place at around 6 Ma (Gautier et al., 1994; Krijgsman et al., 1999a) as a consequence of the closure of the different gateways connecting the Atlantic and the Mediterranean in the Betic Cordillera in southern Spain (Esteban et al., 1996; Soria et al., 1999; Martín et al., 2001; Betzler et al., 2006; Aguirre et al., 2007; Martín et al., 2009) and the Rifian counterparts in northern Morocco (Benson et al., 1991; Esteban et al., 1996; Krijgsman et al., 1999b; Barbieri and Ori, 2000).

The paleoenvironmental changes that occurred before, during and after the MSC in the Mediterranean and its satellite basins have been intensively studied. Nonetheless, the detailed paleogeographic evolution

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and the precise timing of the different processes leading to the MSC and the later Mediterranean reflooding are still discussed controversially (Riding et al., 1998; Krijgsman et al., 1999a; Aguirre and Sánchez-Almazo, 2004; Braga et al., 2006; Roveri and Manzi, 2006). Various studies addressed the Messinian paleoenvironmental evolution on the Atlantic side of the Rifian corridors (Hodell et al., 1989; Benson et al., 1991; Gebhardt, 1993; Hodell et al., 1994; Barbieri, 1998; Barbieri and Ori, 2000). The results of these studies show a significant sea-level fall (about 300 m) indicating the onset of the MSC, a reversal water flux through the Rifian corridors and cooling during the Messinian.

The Betic marine passages connected the western Mediterranean with the Atlantic Ocean throughout the Guadalquivir Basin. There are papers dealing with the biochronology of the late Neogene deposits filling the Guadalquivir Basin (Perconig, 1973; Perconig and Granados, 1973; Viguier, 1974; Sierro, 1985; Aguirre et al., 1995; Sierro et al., 1996) and with the tectonostratigraphic framework (Riaza and Martínez del Olmo, 1996; Sierro et al., 1996). However, the available studies on the Messinian paleoenvironmental evolution of the basin are scarce (Berggren and Haq, 1976; Gläser and Betzler, 2002). According to these studies a sea-level drop from middle slope to inner shelf related to the MSC took place during the Messinian.

In this paper, we study the Montemayor-1 core, located in the westernmost part of the northern margin of the Guadalquivir Basin (SW Spain) (Figs. 1 and 2). It covers a complete Messinian sedimentary record (Larrasoaña et al., 2008). The location of the core is exceptional to investigate the paleoenviromental evolution in an area close to the last Betic gateway to be closed, the Guadalhorce corridor (Martín et al., 2001), during the Messinian.

Among the most abundant organisms in the studied sediments are benthic foraminifera. It is largely proved that these organisms are very useful to reconstruct the paleoenviromental conditions in marine settings, as their distribution depends on several physical, chemical and biological factors (Murray, 1991, 2006). They can be used as proxies of oceanographic parameters such as water depth, substrate, oxygen content and organic matter supply (Jorissen et al., 2007). Thus, the analysis of the variations in the benthic foraminiferal assemblages allows us to infer the key paleoenvironmental factors controlling their distribution, composition, diversity and microhabitat preferences during the Messinian in an Atlantic-linked basin close to the Guadalhorce corridor. The main objectives of this study are to characterize the benthic foraminiferal assemblages along the core and to assess the changes in the main components of the assemblages in relation with variations in paleoenvironmental parameters, such as sea-level fluctuations, source of organic matter (whether continental or primarily produced in marine contexts), and oxygen content around to the seafloor–substrate interface.

This study aims to improve our understanding of the paleoenvironmental and tectonic evolution of the Atlantic–Mediterranean gateways during the MSC, with particular emphasis on the Betic corridor.

2. Study area

The Montemayor-1 core, a continuous core located very close to Moguer (Huelva, SW Spain) (Fig. 2) has been studied. The core was drilled in the northwestern margin of the lower Guadalquivir Basin, an ENE-WSW elongated Atlantic-linked foreland basin of the Betic Cordillera (Sanz de Galdeano and Vera, 1992; Braga et al., 2002). It is limited to the N by the Iberian Massif and to the S by the Subbetic nappes of the Betic Cordillera, and is opened to the Atlantic Ocean to the W (Fig. 1). The Guadalquivir Basin was originated in the earliest Tortonian (late Miocene) as a consequence of the uplifting of the Subbetic Zone of the Betic Cordillera that closed the so-called North Betic Strait (Aguirre et al., 2007; Martín et al., 2009; Braga et al., 2010).

After the closure of the North-Betic Strait, the Guadalquivir Basin was established as a wide, open marine embayment opened to the Atlantic Ocean (Martín et al., 2009). This basin was filled with marine and continental sediments ranging from the early Tortonian to the late Pliocene (Aguirre et al., 1995; Roldán, 1995; Sierro et al., 1996; González-Delgado et al., 2004). The sedimentary infilling produced a migration of the depocentre approximately along the longitudinal axis of the basin, from the ENE to the WSW. This sedimentary succession has been divided into five depositional sequences (A–E) that have been correlated with third-order cycles of the Haq et al. (1987) global sea-level curve (Sierro et al., 1996).

In Huelva and neighbouring areas, the Neogene deposits have been divided into four lithostratigraphic units formally described as formations. The lowermost unit is the Niebla Formation (Civis et al., 1987; Baceta and Pendón, 1999). It consists of late Tortonian carbonate–siliciclastic mixed deposits that unconformably onlap the Paleozoic–Mesozoic basement of the Iberian Massif (Baceta and Pendón, 1999). The second unit, latest Tortonian–Messinian according to planktonic foraminifera and calcareous nannoplankton (Sierro, 1985, 1987; Flores, 1987; Sierro et al., 1993), is the Arcillas de Gibraleón Formation (Civis et al., 1987). This unit, which begins with 2–4 m of glauconitic silts (Baceta and Pendón, 1999), consists mostly of greenish-bluish clays. The third

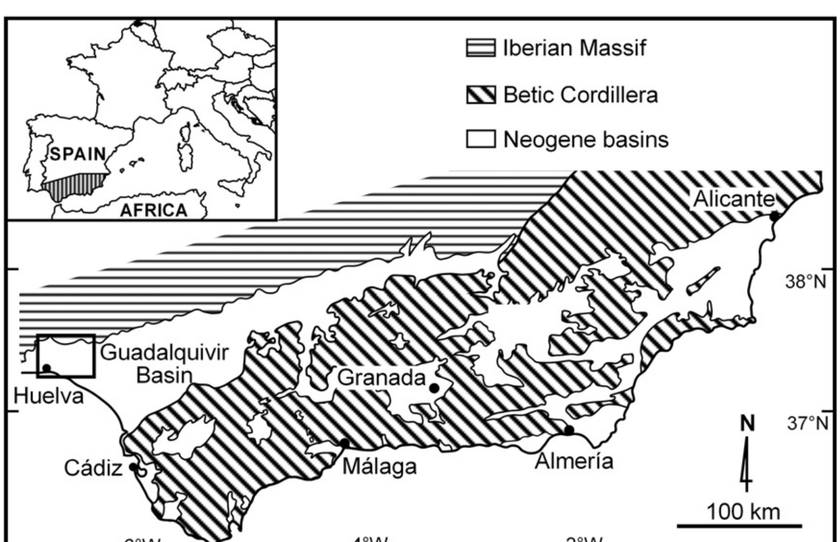

Fig. 1. Geological map of the Betic Cordillera showing the Guadalquivir foreland basin (modified from Martín et al., 2010). The inset is shown in Fig. 2.