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Research paper

Post-rift sequence architecture and stratigraphy in the Oligo–Miocene Sardinia Rift (Western Mediterranean Sea)

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A B S T R A C T

Rift basins provide important sedimentary archives to reconstruct past tectonic and climatic conditions. Understanding their sedimentary history is, however, largely hampered by the competing influence of tectonic versus climatic forcing. The aim of this study is to comprehend the effects of local to regional tectonic and global climatic/eustatic changes on shallow marine depositional systems in the Sardinia Rift (Western Mediterranean Sea). For this purpose the stratigraphic and depositional relations of a mixed siliciclastic-carbonate ramp at the Porto Torres Basin margin were studied along extensive proximal to distal transects. Three depositional sequences (DS1 to DS3) of late Burdigalian to early Serravallian age have been identified, which are separated by erosional unconformities. Each contains a lower transgressive part and an upper regressive part. The former includes shoreface sandstone (DS2) or coral reef (DS3) deposits on the proximal ramp and channelized sheet sandstone (DS1) or basinal mudstone (DS2, DS3) deposits on the distal ramp, typically recording an upsection trend of sediment starvation. The latter is represented by basinward-prograding coralline red algal carbonate wedges due to enhanced shallow water carbonate production rates. In the long term, the depositional evolution from DS1 to DS3 reveals basin margin progradation associated with decreasing siliciclastic supply. Integrated calcareous nannoplankton-foraminiferal-pectinid biostratigraphy links the depositional sequences to third-order sea-level cycles and allows to correlate the erosional unconformities at the top of DS1 and DS2 with the Bur 5/Lan 1 and Lan 2/Ser 1 sequence boundaries. The improved sequence stratigraphic framework enables better regional and global correlations. This shows that rhodalgal carbonate slopes started prograding in the western branch of the Sardinia Rift during the late Burdigalian because (1) of a worldwide bloom of rhodalgal facies, and (2) decreasing tectonic activity at the transition from the syn-rift to the post-rift stage caused a continuous reduction of the siliciclastic sediment input.

1. Introduction

Rift sequence stratigraphy requires a detailed knowledge about the depositional setting because the creation of accommodation space within a rift basin is variable, and zones of high accommodation rate develop close to zones with no accommodation or even erosion (Howell and Flint, 1996; Holz et al., 2014). Erosion and sedimentation processes in rift basins are largely controlled by their complex, fault-related topography and subsidence history (Bosence, 1998; Martins-Neto and Catuneanu, 2010). Early stages of rifting are often dominated by siliciclastic sedimentation with sediment transport driven by evolving extensional fault systems and their oblique transfer zones (Bosence, 2005). During marine transgression, clastic systems will be pushed landwards so that deposition is focused in the coastal zone and in structural lows (Bosence, 2012). There are certain sites that favor shallow marine carbonate platforms under warm-temperate to tropical climate conditions after the rift basin has been flooded by marine waters. The most common site is on footwall or horst highs and intervening slopes isolated from clastic supply (Bosence, 1998, 2012; Cherchi et al., 2000). Creation of syn-rift accommodation is strongly related to the mechanical subsidence regime, with rapid episodic

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pulses of extension that generate space for sediment accumulation at very fast rates. Stages of rapid mechanical subsidence are typically followed by longer periods of tectonic quiescence, when sediment supply gradually consumes and fills the available accommodation space (Martins-Neto and Catuneanu, 2010). In contrast, the post-rift stage is characterized by long-term thermal subsidence due to cooling and an increase in density of the lithosphere and asthenosphere. Since it affects a larger area than subsidence generated by extensional tectonics and the subsidence rates are much lower, this phase of basin evolution often results in extensive prograding carbonate platforms having their stratigraphic architecture controlled largely by cyclic sea-level fluctuations (Bosence, 1998, 2012; Martins-Neto and Catuneanu, 2010).

The Western Mediterranean Sea consists of rifted continental margins surrounding the deep Algero-Provençal and Tyrrhenian basins (Gamberi and Marani, 2006). Because of the close linkage between tectonics and sedimentation processes in the Sardinian rift basins their sedimentation patterns and stratigraphic architecture have been widely applied for the large-scale reconstruction of the tectono-sedimentary history of the western Mediterranean region (e.g., Cherchi and Montadert, 1982; Sowerbutts and Underhill, 1998; Sowerbutts, 2000; Casula et al., 2001). This study presents a depositional framework for shallow marine deposits of early to middle Miocene age, which are exposed along a large cliff below the town of Sassari in the Porto Torres Basin (western branch of the Sardinia Rift). Two conflicting depositional models have been previously suggested for this sedimentary succession. Firstly, Martini et al. (1992) suggested deposition at the slope of a carbonate platform that developed on the shelf margin of the basin and recognized three major transgression–regression cycles that could not be dated precisely but have been indicated to tentatively correlate with eustatic sea-level changes. More recently, it has been interpreted as deposited in an aggradational submarine channel system, the so-called Sassari Channel (Vigorito et al., 2006; Murru et al., 2015). Up to six stacked and partly nested discrete channel fill units (Units A–F) have been identified and related to two main phases of submarine channel inception and infilling spanning the late Burdigalian to early Serravallian time interval. It is considered that the Sassari Channel belongs to a vast network of submarine channels in the Sardinia syn-rift basins and that tectonics largely controlled the location and trend of sediment pathways (Carannante and Vigorito, 2001; Murru et al., 2001, 2015; Vigorito et al., 2005, 2006; Bassi et al., 2006). Despite of the presumed tectonic influence, local episodes of carbonate production, resedimentation and channel abandoning in the Sassari Channel have been connected with global climatic changes and related glacioeustatic oscillations (Murru et al., 2015). Due to the significantly deviating depositional models and the resultant large-scale implications concerning not only the regional palaeogeography and geodynamic evolution but also general tectono-sedimentary models for rift basin carbonate sedimentation and the relationships between local skeletal grain associations and the global climatic evolution (Vigorito et al., 2006; Murru et al., 2015), we take another critical look at the facies, depositional environment and sequence stratigraphy in the Porto Torres Basin. The aim is to reassess the influence of local to regional tectonic vs. global eustatic/climatic changes on shallow water sedimentary systems in the Sardinia Rift.

2. Geological setting

The Sardinian Rift is the easternmost branch of a complex system of rifts in the Western Mediterranean Sea, which was initiated during the late Eocene in relation with the west European Rhône-Bresse graben system (Séranne, 1999). Following Cherchi and Montadert (1982), it represents a continuous intracontinental graben that crosses western and south central Sardinia from north to south on a distance of 220 km. This graben was considered to have formed by long-lived active expansion from the late Rupelian to mid-Aquitanian. It is distinguished from the Pliocene–Pleistocene Campidano Graben, which is superimposed on the southwestern part of the Oligocene–Miocene rift, but in an oblique NW–SE direction (Cherchi and Montadert, 1982). More recent studies (e.g., Sowerbutts and Underhill, 1998; Sowerbutts, 2000; Funedda et al., 2000) interprete the Sardinia Rift as a system of relatively small intra-arc basins that developed from the middle late Oligocene to middle Miocene in response to multi-phase, extension and transtension controlled by normal and strike-slipe faults. In both models, rift evolution was linked to the counterclockwise rotation of the Corsica-Sardinia Block due to the opening of the western Mediterranean back-arc basin (Algero-Provençal Basin) and the subduction of oceanic crust to the east of Sardinia (Cherchi and Montadert, 1982; Thomas and Gennessaux, 1986; Casula et al., 2001; Faccenna et al., 2002; Speranza et al., 2002; Helbing et al., 2006; Oggiano et al., 2009).

Northwestern Sardinia (western rift branch), cromprises a western and an eastern N–S trending halfgraben system (Sowerbutts, 2000). The western halfgraben system consists of the Porto Torres Subbasin to the north, where the study locality is situated, and the southern Logudoro Subbasin (Funedda et al., 2000; Oudet et al., 2010). The eastern halfgraben system contains the Castelsardo and Pèrfugas subbasins (Benisek et al., 2010; Fig. 1). Rift sedimentation in northwestern Sardinia started in lacustrine and alluvial environments, which existed from the late Oligocene to Aquitanian. Contemporaneous calcalkaline volcanism played a major role in the supply of basin filling material and changed the topography locally (Oggiano et al., 1995; Sowerbutts, 2000; Lustrino et al., 2009). The continental deposits are overlain by mixed siliciclastic-carbonate marine sediments of late Burdigalian to Serravallian age (Martini et al., 1992; Sowerbutts, 2000; Bossio et al., 2006; Vigorito et al., 2006; Benisek et al., 2010; Oudet et al., 2010; Murru et al., 2015), which are subject of this study (Fig. 1). The marine ingression was related to a phase of extension in northern Sardinia that occurred during the period of fastest rotation of the Corsica-Sardinia Block in the early–middle Burdigalian (Oudet et al., 2010). According to Funedda et al. (2000), it is consistent with a nearly ENE-oriented tensile stress as the border faults of the Porto Torres and Logudoro subbasins are characterized by NNW trends. The studied sedimentary succession is located in the hangingwall of a major normal fault (Osilo Fault) bordering the Porto Torres Subbasin against the andesitic horst of Osilo in the east (Fig. 1), which was a palaeohigh during the late Burdigalian–Serravallian time interval (Murru et al., 2015). In the west, the Miocene basin-fill onlaps Mesozoic carbonates of the Nurra structural high (Funedda et al., 2000; Bossio et al., 2006; Fig. 1). An E–W trending transfer zone separates the Porto Torres Subbasin from the Logudoro Subbasin (Fig. 1). It is marked by complex structural highs, which developed due to interference between the NNW oriented fault system and the nearly E–W striking S. Martino and Ittiri faults and were already existent in the late Burdigalian–Langhian (Funedda et al., 2000). A palaeogeographic reconstruction of the Porto Torres and Logudoro subbasins during late Burdigalian–Langhian time is given in Funedda et al. (2000).

3. Locality and methods

The study was carried out along two transects that intersect and provide a three-dimensional insight into the depositional architecture of the eastern margin of the Porto Torres Subbasin. We distinguish between (1) the Cliff transect (about 1.3 km long) along