Miocene carbonate sequences from the Syn-rift Sardinia Graben Subbasin (Italy)

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During the active tensional tectonics that characterised the Mediterranean region (Mediterranean Sea s.s., Paratethys, Red Sea) in Oligo-Miocene times, an articulated rift system developed in relation to complex crustal dynamics. As a result, syn-rift sedimentary basins formed on blocks, where intense tectonic activity, relative sea level changes and localised ecological factors contributed to the formation of complex depositional sequences. Rift-related break-up unconformities bounded these sequences at the base where carbonate sediments are frequently intercalated and/or associated with immature terrigenous deposits.

The sedimentary successions in the syn-rift sub-basins of Sardinia document the onset of marine conditions in the early syn-rift phases (Fig. 1). In the Isili area, a fault-block rotation-controlled sedimentary basin is recognisable characterised by a distinctive wedge-shaped sedimentary body (Cherchi & Montadert, 1982; 1984). Palaeomorphological controls acted strongly on this depositional system, resulting in complex calcareous bodies covering an area of over 30 km^2 with total thickness of as much as 200 m.

CARBONATE FACTORIES

Carbonate factories developed during the Aquitanian times in these tectonically controlled small depositional subbasins, where terrigenous input might have been significant because of erosion of the uplifted pre-Neogene substrata. Terrigenous deposits generally acted as passive substratum for pioneer communities of rhodalgal-type (red algae, ostreids, bryozoans) and locally evolved into coral-dominated assemblages. Carbonate facies composition and distribution were mainly controlled by local syn-sedimentary tectonics and eustasy as well as by climate. Although the inception of the carbonate factories was presumably not synchronous, their growth represented the response to a relative regional rise of the sea level subsequent to impressive episodes of clastic supply, the expression of an early syn-rift stage

Carbonate production areas close to tilted, uplifted blocks as well as along the articulated basement margins, developed with a modality of organic colonization and facies characteristics strongly depending on environmental peculiarities.

In sectors close to the hinterland area, with a higher fresh-water input and a consequent significant clastic input, coral-dominated assemblages grew during long periods of quiescence between flash floods. Repeated coral-rich community colonization episodes developed on thick wedges of terrigenous debris in the related successions. Thick clastic accumulations with lower erosive boundaries characterize the successions. During periodical deposition stases, the exposed uppermost clastic surfaces typically became stabilized by sessile and encrusting communities. A marine interpretation for the terrigenous

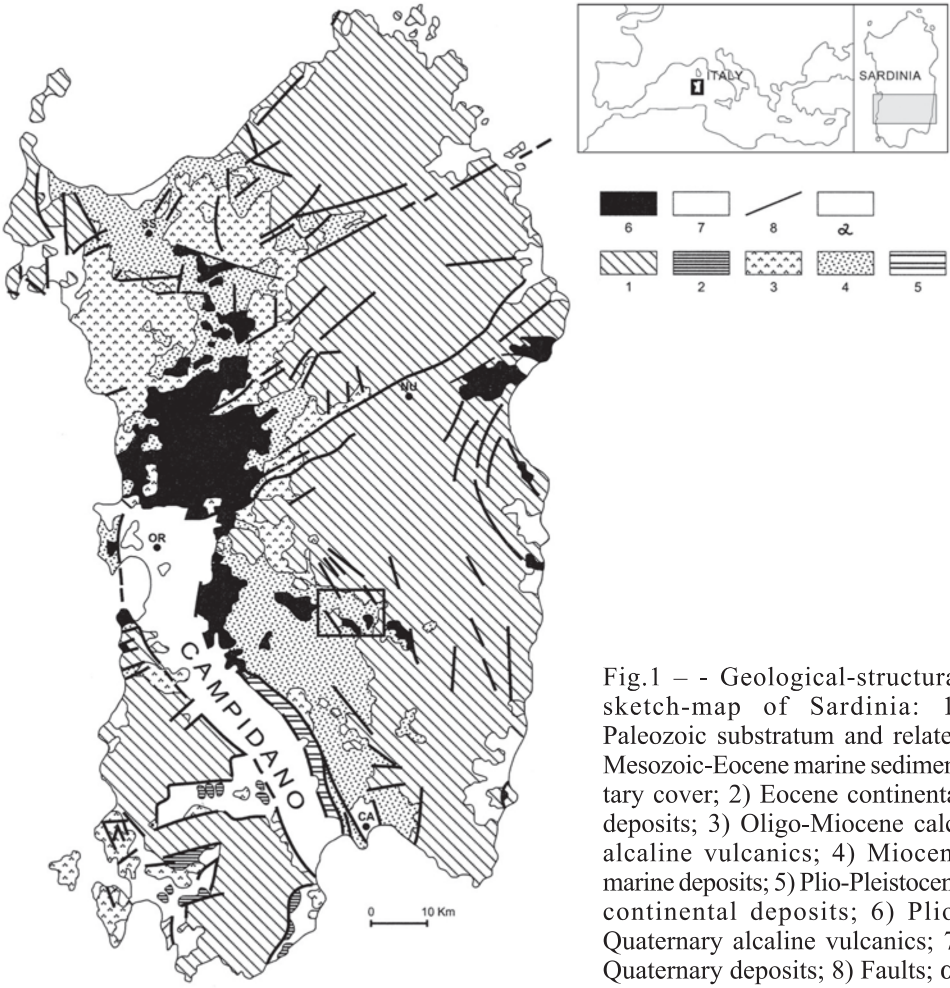

Fig.1 – - Geological-structural sketch-map of Sardinia: 1) Paleozoic substratum and related Mesozoic-Eocene marine sedimentary cover; 2) Eocene continental deposits; 3) Oligo-Miocene calc-alcaline vulcanics; 4) Miocene marine deposits; 5) Plio-Pleistocene continental deposits; 6) Plio-Quaternary alcaline vulcanics; 7) Quaternary deposits; 8) Faults; α) Studied area.

wedges is supported by marine encrustations on some clasts and by admixed marine skeletal material in the matrix. The skeletal components, generally missing or contained in minor amount in the lower intervals of these gravitative flow-related deposits, becomes more and more abundant in the upper intervals where the lack of fine terrigenous matrix seems to document an increased washing action by the sea. These upper levels supported a more or less well-developed organogenic construction, only partially similar to real “reefs”. They bear similarities with many recent and ancient examples of interrelated coral reefs and siliciclastic deposits, described among others by Friedman (1988), Santisteban & Taberner (1988) and Roberts & Murray (1988). The growth of the studied organogenic structures is likely to have been periodically interrupted by a terrigenous influx whose erosion might have dramatically interacted with the organic dwelling. According to the general characteristics (e.g., dominance of pebbles and coarse sands, relative lack of reddish mudstones plus the above marine depositional evidence) the depositional bodies seem to have been deposited as fan deltas in a sub-benthic substratum at the mouth of a probable braided river system. Coarseness of the terrigenous debris and presumable long periods of quiescence between flash-floods suggest the terrigenous input was less of a problem for the building organisms, favouring the survival of the communities, whereas turbidity currents carried the finer fraction into the deeper waters. An autogenic control on the facies alternation cannot be excluded although relative changes in sea level could have controlled the general evolutional trend. An early relative sea level low stand (early syn-rift related phase) resulted in dramatic flash-floods able to construct large fan deltas. The ensuing transgressive phase diminished the clastic supply enabling the benthic assemblages to flourish. As a result, organogenic boundstones grew during major quiescence periods. In the first interval of the section, the exclusive presence of shiaphile communities dominated by echinids and bryozoans seems to suggest darker, cooler and/or nutrient-richer water during early stages of dwelling. Subsequently, clearer and/or meso-oligotrophic water conditions resulted in the emergence of coral communities, which developed in thicker and more complex biogenic concentrations

In areas, devoid of (or with a very reduced) terrigenous supply, open carbonate factories grew with an aggradational-progradational trend. The resulting pure calcareous successions are organized in sequences, bounded by primarily tectonic-related discontinuity surfaces (e.g. Isili area). Palaeomorphological controls acted strongly on the related depositional systems thus resulting in complex calcareous sedimentary bodies which, in some cases, cover more than 30 square km and whose total thickness may reach 200 m. Carbonate production areas (carbonate factories) were generally located on morphological highs (e.g.: Punta Trempu, Nurallao areas) where up to 200 m of pure skeletal neritic limestones accumulated resting over clastic wedges and/or Palaezoic substrata. Lithofacies within the carbonate factory sequences show foramol associations (*sensu* Lees, 1975; Lees & Buller, 1972) particularly rich in red algae and pelecypods (rhodalgal assemblages *sensu* Carannante *et al*., 1988). These limestones are coarse rhodolith-rich skeletal grainstones to rudstones with a matrix of grainstone and silty packstone. Skeletal components of the matrix are mollusks, bryozoans, barnacles, benthic foraminifers and, in some cases, planktonic foraminifers. Organic assemblages dwell in their own detritus, largely produced by bioerosion processes (Cherchi *et al*., 2000). Foramol/rhodalgal deposits were laid down forming a loose sediment sheet in open depositional settings. Ostrea banks spread over patchy areas often covering discontinuous hardgrounds or erosive surfaces. Both these discontinuity surfaces which intercalate into the carbonate succession may suggest repeated relative sea level variations. Tectonic activity interacting with sea level changes are to be considered as a major control over the factory growth and skeletal sand supply to marginal areas, where impressive sand bodies were developing. Displaced skeletal fragments constitute the bulk of these structures in which only minor *in situ* carbonate production by local assemblages presumably occurred (Cherchi *et al*., 2000). Field analysis evidenced that productive areas were recurrently shaved with major redepositional events occurring mainly during relative sea level drops.

Channel network

In the Isili area a complex channel network acted as sediment passway toward deeper depositional areas, ensuring an efficient drainage of the shallower productive areas. One main channel (Isili Channel) and a significant number of minor order channels (both tributaries and distributaries) were recognised at outcrop (Murru *et al*., 2001; Simone *et al*., 2001). These channels vary greatly in dimensions ranging from few metres wide to deep scours up to about 1 km wide and 60 m deep within the main channel.

In its proximal reach the Isili Submarine Channel ran W-E draining both the Punta Trempu and Nurallao carbonate factories and deflected southward in its medial-distal reaches. The corresponding submarine fan system was built about 2 km southeast of the

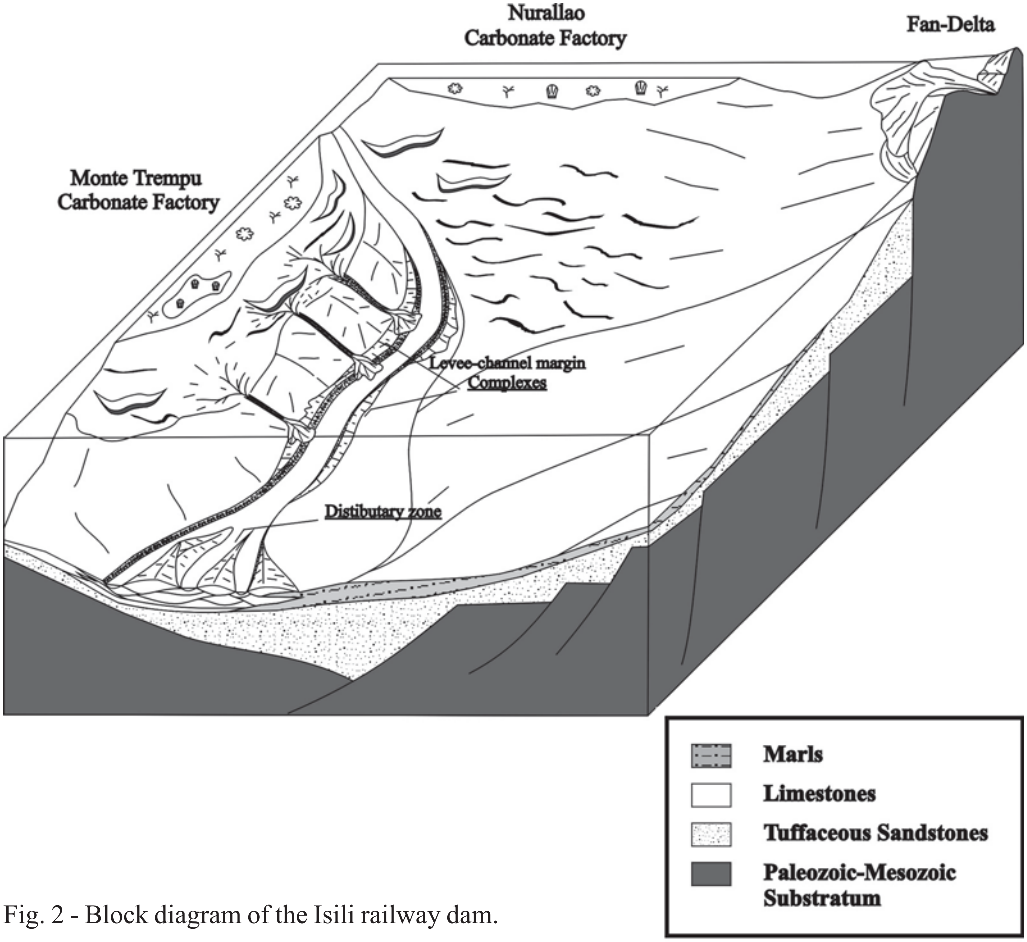

Fig. 2 - Block diagram of the Isili railway dam.

Isili village. Lobes were deposited as a consequence of slope gradient decrease and more probably by expansion and collapse of down-channel flowing sediment flows that were no longer confined by the Isili fault-block on the right side of the Isili Channel (Fig. 2).

Active tectonism, bound to rifting events, ruled planform channel distribution and internal geometries, and above all forced the main channel to run parallel to the slope base in its medial-distal reaches. Active faulting and repeated reactivation of the main fault systems led to the formation of escarpments on which main and minor channels set. In such an active and unstable tectonic context, tectonics could have controlled sea-level oscillation and triggered redeposition events.

The Isili Submarine Channel shows a well defined trough stratification, locally with minor order cross. This rather simple channel fill architecture, which is thought to reflect turbidite dominated environments, evolved trough channel life to a complex channel fill architecture, by developing impressive lateral and point bars sequences on channel margins while multiple channel-fill sequences, each showing a markedly erosive base, are found in the axial portion. High energy hydrodinamic regime, characterized by strong bottom currents, is inferred at this stage of channel-life. Channel-body internal geometry is further complicated at the tributaries inputs by interfingering, overlapping and alongsiding of tributaries depositional elements with those of the main one, and by shifting, eroding and/or aggrading of these through time .

The Isili Channel fringes, in its more distal reach, in a complex distributary network superimposed on thin relatively structureless carbonate sheets that are interpreted to correspond to the very early stages of the Isili Fan System construction. The distributary channels alternate with and/or erode into small flat-convex sedimentary bodies interpreted as lobes. The overall erosive nature of the distributary channels is interpreted to follow fan system down-basin progradation in response to relative sea level drop events. It is worth noting, that distributaries channel-fill architecture, which is commonly of transverse-type, indicates that relatively high energy environmental conditions have occurred even in this distal setting.

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