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Components, facies and ramps: Redefining Upper Oligocene shallow water carbonates using coralline red algae and larger foraminifera (Venetian area, northeast Italy)

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ABSTRACT

Chattian mixed carbonate-siliciclastic deposits from two palaeogeographic units of Southern Alps, the Lessini Shelf and Venetian foreland basin of northeast Italy, are studied with respect to facies distributions and controlling ecological factors on dominant biogenic components. These ramp depositional systems are located in the western Southern Alps on the Lessini Shelf, and in the eastern Southern Alps in the Venetian foreland basin. The successions show an extensive geographic distribution of at least 150 km × 40 km at the southern margin of the Southern Alps. Palaeoenvironments are inferred following microfacies characteristics and floral and faunal indicators, especially those of coralline red algae and larger foraminifera. An inner- to middle homoclinal ramp morphology is reconstructed based on facies distributions and taxonomic and coralline algal growth-form proxy data.

The distribution along depositional strike shows variation from thinner, carbonate dominated sequence in the west (Monti Berici and Monti Lessini) to a more variable, mixed carbonate-siliciclastic dominated environment to the east (Vittorio Veneto, Alpago). Facies character and occurrence are controlled by local hydrodynamic conditions and varying water turbidity of the studied ramp depositional system. The general facies succession shows a transgressive sequence from the proximal inner- to proximal middle ramp. A shoal belt of trough cross-bedded sandstones occurs in a proximal inner ramp position in all of the studied areas. In a gentle-dipping homoclinal ramp, most benthic organisms inhabited the relatively quite environments off these shoals in a distal inner ramp setting. Basinward environments (proximal middle ramp) constitute areas of maximal carbonate production and consist primarily of larger foraminiferal facies and rhodolith pavements. Larger foraminifera, represented by two larger foraminiferal assemblages, are most diversified in the shallower settings (near the fair-weather wave base, distal inner/proximal middle ramp), whereas coralline algae predominate in deeper areas (proximal middle ramp) constructing extensive rhodolith pavements. Rhodolith pavements are distinguished with respect to rhodolith shape, size, growth-forms and coralline algal taxonomic composition. Larger foraminifera are interpreted with respect to shell structures, shell architectures and comparable Recent counterparts.

The analysed benthic communities thrived in a mesotrophic regime within trophic gradients constrained by fluvial influence. Coralline algal dominance and a moderately diverse larger foraminiferal assemblage suggest a tropical/warm temperate transition. The considerable stability imposed on sediments by the rhodolith pavement must also have significantly contributed to the maintenance of a middle ramp profile bulge. This study will contribute to a better understanding of Oligocene carbonates which have received less attention than their Eocene or Miocene counterparts.

1. Introduction

Oligocene carbonate and mixed siliciclastic–carbonate platforms are characterized by the re-establishment of shallow water marine benthic communities following major changes at the Eocene/Oligocene boundary (e.g. Berggren and Prothero, 1992; Ivany et al., 2000; Prothero, 2003) The Oligocene epoch represents a time span dominated by larger foraminiferal and coralline algal facies in carbonate environments. These facies were superseded in the tropics in the Neogene by coral reefs and associated facies which dominate today's ice house, aragonite seas (e.g. Ridgwell and Zeebe, 2005).

In general, Oligocene carbonates have received far less attention than their Eocene or Miocene counterparts. This situation is partly due to the lack of outcrops, but also due to previous misdating as older or,

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as in the present case study, younger (Early Miocene) successions. In the Circumalpine region, for example, Eocene sediments are represented in part by extensive, thick successions of shelf carbonates (e.g. Nebelsick et al., 2005; Rasser et al., 2008) while the Miocene sediments consist not only of a thick successions of Molasse type terrigenous sediments, but also of bryomol carbonates (Early Miocene of the North Alpine Foreland Basin; e.g. Nebelsick, 1989) or coralline red algal dominated as well as biostromal coral facies (in the Middle Miocene of the Vienna Basin; Rögl, 1998; Riegl and Piller, 2000; Harzhauser and Piller, 2007).

Within the Oligocene of the Circumalpine region, Lower Oligocene (Rupelian) shallow water carbonate sedimentary sequences are more prominent than Upper Oligocene (Chattian) ones (e.g. Ungaro, 1978; Nebelsick et al., 2000; Rasser and Nebelsick, 2003; Rasser et al., 2008). These Upper Oligocene carbonate successions are rare being represented by a mixed carbonate–siliciclastic ramp succession in the North Alpine Foreland Basin of Upper Austria (Kaiser et al., 2001). Further south, Chattian carbonate sediments are present in Central Italy (Montagna della Maiella; Pignatti, 1995), Southern Italy (Silvestri, 1929; Luperto, 1962; Parente, 1994; Bosellini, 2006), Malta (Brandano et al., 2009a) and in Greece (Bursch, 1947; Accordi et al., 1998). Oligocene shallow water benthic communities north and south of the Alps are characterized by coralline red algae, larger foraminifera and bryozoans often associated with abundant echinoderms and bivalves. Locally, coral and coralline red algal reefs developed (northern Italy; Bosellini and Perrin, 2008). Such shelf benthic communities were more diversified than their Upper Eocene counterparts and successfully persisting through the Early–Middle Miocene.

Although extinction events eradicated many key Paleogene larger foraminiferal taxa at both the Middle/Upper Eocene and Eocene/Oligocene boundaries (e.g., Cahuzac and Poignant, 1997; Serra-Kiel et al., 1998), they still play an important role in Oligocene carbonate successions and can dominate specific facies (Nebelsick et al., 2005). Larger foraminifera are especially sensitive to light quality (as organisms harbouring photo-symbionts) as well as to substrate conditions and can be used to make inferences with respect to temperature and nutrient regimes (e.g. Betzler et al., 1997; Hottinger, 1997). As biostratigraphic markers, various larger foraminifera are also key organisms for dating shallow water successions using the shallow benthic zones (SBZ) which have also been introduced for the Oligocene and Miocene (Cahuzac and Poignant, 1997).

Coralline red algae are common to dominant components in Eocene to Miocene platform carbonates (Nebelsick et al., 2003, 2005; Halfar and Mutti, 2005; Braga et al., 2010). The ubiquitous and cosmopolitan character of coralline algae is reflected in their widespread occurrence throughout a large array of facies and biogeographical settings in the fossil record since their appearance in the Early Cretaceous (e.g. Arias et al., 1995; Aguirre et al., 2000; Braga and Bassi, 2007). Present-day rhodoliths consisting of free-living, self encrusting coralline red algae can be common in marine environments, forming the basis of diverse and ecologically important shallow water benthic communities (e.g., Foster, 2001; Steller et al., 2003; Grall et al., 2006). Fossil rhodolith-dominated deposits are often present within marginal- to distal-shelf sedimentary successions from the Oligocene (e.g. Bosence and Pedley, 1982; Fravega et al., 1987; Brandano et al., 2009a) to the Early-Middle Miocene (e.g. Studencki, 1988; Carannante and Simone, 1996; Brandano et al., 2005; Bassi et al., 2006; Benisek et al., 2009; Braga et al., 2010).

The partial affinities of Oligocene carbonate facies to the present-day counterparts means that: 1) direct actualistic comparisons can be made to specific taxa and ecological communities of modern environments, and 2) modern gradients with respect to temperatures (e.g. tropical, transitional, temperate) and trophic regimes (e.g. oligo-, meso- and eutrophic) and other ecological factors can be used as a corollary to assess Upper Oligocene carbonate facies and their depositional settings.

Most of these benthic communities thrived in ramp depositional settings which are distinguished using water depth criteria based on two critical interfaces, the fair-weather wave base (FWWB) and the storm wave base (SWB) which differentiate the inner-, middle- and outer ramp settings (e.g. Burchette and Wright, 1992). Carbonate ramps occur in most types of sedimentary basin, but are best developed where subsidence is flexural and gradients are slight over large areas, as in foreland and cratonic-interior basins and along passive margins (e.g. Burchette and Wright, 1992; Gupta and Allen, 2000; Bosence, 2005). In the Mediterranean Oligocene–Miocene ramp settings, the highest carbonate productivity is found in the middle ramp which generally extended from the outer edge of poorly-developed ooid shoals to the outer part of the larger foraminiferal belt (Pedley, 1998). The middle ramp is characterized by coralgal patch reefal, coralline red algal, and larger foraminiferal facies (Buxton and Pedley, 1989; Pedley, 1998).

The studied area in northeast Italy lies at the northern boundary of the Oligocene Tethys near the open connection to the Central Paratethys (Rögl, 1998, 1999; Harzhauser and Piller, 2007; Harzhauser et al., 2007). Furthermore, the Alps and the Dinarids had just begun to act not only as a major barrier to the Paratethys, but also as a major source of terrigenous sediments. The related Alpine tectonic activity generated topographic highs and foreland basins in part determining carbonate shelf (and ramp) morphologies and facies distributions (Nebelsick et al., 2005). The Venetian area is a classic area for studying Paleogene marine shelf benthic communities. The fossil record is especially well constrained due to centuries of intensive collecting and study (see historical references in Bassi et al., 2008a). Little is known, however, about Chattian shallow water benthic assemblages thriving in mixed siliciclastic–carbonate shelf settings. These assemblages are mainly characterised by rhodolith deposits and by a moderately diverse larger foraminiferal fauna (Bassi et al., 2007).

The Upper Oligocene sedimentary successions of these units are analyzed from ten stratigraphic sections with respect to facies and benthic community composition. We concentrate on two key benthic components which are subjected to a high resolution analysis with respect to taxonomic composition and growth-form morphologies: coralline red algae and larger foraminifera. The detailed analysis of the taxonomic assemblages and the taphonomic signatures recorded in the coralline growth-forms and larger foraminifera provide details not only on vertical and lateral facies successions, but also on variations in specific floral and faunal assemblages and growth-forms. These two benthic groups can correspondingly be correlated to specific constraining environmental conditions such as water movement and irradiance environments along the ramp gradient.

2. Basinal setting: the Lessini Shelf and Venetian foreland basin

The studied area represents two major Paleogene geologic units of Southern Alps: the Lessini Shelf and the Venetian foreland basin (VFB; Fig. 1). In the western Southern Alps, the Lower Eocene–Upper Oligocene Lessini Shelf (the Lessinian homocline in Castellarin and Cantelli, 2000) is present on topographic highs represented by the uplifted blocks of the Jurassic Trento Platform (Bosellini, 1989). The Lessini Shelf, represented by the Monti Lessini–Monti Berici wedge, is a morphological and structural high ("Adige embayment" in Laubscher, 1990) which is characterized to the East by a NW trending Schio-Vicenza line (e.g. Doglioni and Carminati, 2002; Castellarin et al., 2006). This fault probably originated as a Paleogene extensional structure on the Dinaric foreland bulge (Doglioni and Carminati, 2002). South of Schio village, this fault shows a south-ward decreasing top down-to-the-east trough connected to the development of the eastern Southern Alps foredeep (Massironi et al., 2006).

The Lessini Shelf is characterized by the deposition of shallow water carbonates and widespread Paleocene, Lower-Middle Eocene and Oligocene volcanic activity and has been considered as the