Palaeogeography, Palaeoclimatology, Palaeoecology 399 (2014) 52–66

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Biogeochemical and redox record of mid–late Triassic reef evolution in the Italian Dolomites

Fabio Tosti [a,*], Adelaide Mastandrea [b], Adriano Guido [b], Fabio Demasi [b], Franco Russo [b], Robert Riding [a]

[a] Department of Earth and Planetary Sciences, University of Tennessee, 1412 Circle Dr., Knoxville, TN 37996, USA
[b] Dipartimento di Biologia, Ecologia e Scienze della Terra, Università della Calabria, 87036 Rende, Italy

ARTICLE INFO

Article history:
Received 8 October 2013
Received in revised form 24 January 2014
Accepted 31 January 2014
Available online 9 February 2014

Keywords:
Biogeochemistry
Biomarkers
Carbonates
Dolomites
Reefs
Triassic

ABSTRACT

Geochemical signatures and carbonate microfacies highlight contrasts between two distinctive mid–late Triassic reef communities in the Dolomite Alps, Italy. In the first community, sponges, bryozoans, calcified cyanobacteria and problematic organisms (*Archaeolithoporella*, *Shamovella*), together with a variety of micritic fabrics, formed compact reefs in high energy shallow-water at the margins of high-rise Ladinian–Carnian carbonate platforms. Debris from these margins created steep foreslopes, and some large blocks of the allochthonous material (Wengen–Cassian formations, Cipit Boulders) were buried in basinal shales that protected them from subsequent alteration and regional dolomitization. In the second and slightly younger community, small Carnian patch reefs (Heiligkreuz Formation, Alpe di Specie) developed in quieter shallow water, where they too were protected against alteration by enclosing shales. They were constructed mainly by scleractinian corals, sponges and red algae, and contain relatively large framework cavities with clotted-peloidal micrite. These early examples of coralgal reefs have broad similarities to present-day examples, whereas the community represented by the Cipit Boulders has more in common with Late Permian reefs.

Both bioconstructions preserve primary microfabrics and biomarkers. The Cipit Boulder samples contain bacterial, mainly cyanobacterial biomarkers, lack specific molecules typical of sulfate-reducing bacteria (SRB), and have Rare Earth Element (REE) values indicative of oxic conditions. These signatures are consistent with their original high-energy platform margin location, compact structure, and presence of calcified cyanobacteria such as *Cladogirvanella* and *Girvanella*. In contrast, the coralgal patch reefs contain SRB biomarkers, lack specific molecules typical of cyanobacteria, and have REE values indicative of sub-oxic conditions. These signatures are consistent with their lower energy depositional conditions and well-developed skeletal framework that created protected low-oxygen micro-habitats. The SRB biomarkers can be linked to the associated clotted-peloidal fabrics which resemble those commonly present in younger coral-reef frameworks. These details of redox conditions and bacterial processes underscore the important biotic, structural and environmental changes that affected shallow marine reefs during the Triassic.

1. Introduction

The late Permian to mid–late Triassic was an interval of profound change in reef development (Flügel and Stanley, 1984; Stanley, 1988; Flügel, 2002). Within a period of ~25 Ma, Permian-type reefs, dominated by sponges, bryozoans, calcified crusts and microbes, were replaced by more modern-looking reefs with scleractinian corals and calcareous red algae (Zankl, 1969; Stanley, 2003, 2006). The mid–late Triassic phase of this development is preserved in northern Italy where the Dolomite Mountains contain outstanding examples of reefal carbonates (Richthofen, 1860; Mojsisovics Von Mojvar, 1879; Ogilvie, 1893; Salomon, 1895; Hummel, 1928; Pia, 1937; Leonardi, 1955, 1968; Bosellini and Rossi, 1974; Wendt, 1974; Fürsich and Wendt, 1977; Gaetani et al., 1981; Wendt, 1982; Bosellini, 1984; Hardie et al., 1986; Rudolph et al., 1989; Russo et al., 1991, 1997; Mastandrea et al., 1997; Gianolla, 1998; Kenter, 1990; Russo, 2005; Schlager and Keim, 2009; Stefani et al., 2010). These include remarkable Ladinian–Carnian high-rise platforms that prograded basinward over their marginal reef talus (Bosellini, 1984). Although many of these limestones were subsequently dolomitized, fragments thought to represent the platform margin reefs are locally exceptionally well-preserved (Wendt, 1974, 1975; Scherer, 1977; Russo et al., 1997) as meter-scale allochthonous blocks. The lithology and biota of these 'Cipit Boulders' contrast with those of younger small patch-reefs that are well-preserved in the late Julian Substage (Early Carnian) at the base of the Heiligkreuz/Dürrenstein Formation. These are dominated by a biota of calcified demosponges, scleractinian corals and calcified red algae that anticipates the 'modernization' of reef-building

* Corresponding author. Tel.: +1 865 684 0190.
E-mail addresses: ftosti@utk.edu (F. Tosti), a.mast@unical.it (A. Mastandrea), aguido@unical.it (A. Guido), fabio.demasi@unical.it (F. Demasi), francorusso44@gmail.com (F. Russo), rriding@utk.edu (R. Riding).

0031-0182/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.palaeo.2014.01.029

communities on a global scale between the Late Carnian and the Norian–Rhaetian (Fürsich and Wendt, 1977; Wendt, 1982; Russo et al., 1991; Flügel, 2002).

Very few studies have examined both Rare Earth Element (REE) and biomarker data in Phanerozoic reefs. We combined these approaches, together with carbonate microfacies analysis, to elucidate the depositional conditions and biogeochemistry of reef limestones during this period of mid–late Triassic transition. We compared samples of microbial-sponge reef limestones preserved in Cipit Boulders at Punta Grohmann (near Campitello di Fassa) that were derived from the last episode of widespread high rise platform development (Cassian Dolomite, ~225–229 Ma) in the area, with younger coral patch reefs in the Heiligkreuz Formation (~222 Ma) 40 km to the ENE at Alpe di Specie (Fürsich and Wendt, 1977; Russo et al., 1991, 1997; Russo, 2005) (Figs. 1, 2). We examined the organic matter preserved in these limestones, analyzed it for biomarkers, and analyzed REE values in the samples. We found evidence that the platform margin samples (Punta Grohmann) formed under oxic conditions and contain biomarkers for cyanobacteria, whereas the younger Alpe di Specie coral patch reefs formed under sub-oxic conditions and contain biomarkers for sulfate reducing bacteria.

2. Localities and samples

In the Dolomites, Ladinian–Carnian platforms prograded basinward over their marginal reef talus (Bosellini, 1984), and most of the Cipit Boulders are thought to be derived from their upper slopes or margins (Richthofen, 1860; Mojsisovics Von Mojvar, 1879; Leonardi, 1968; Wendt and Fürsich, 1980; Biddle, 1981; Russo et al., 1997; Gianolla et al., 1998; Gianolla and Neri, 2007). Accommodation space was significantly reduced during the Julian Substage and patch reefs developed at Alpe di Specie in the Heiligkreuz/Dürrenstein Formation (Russo et al., 1991; Keim et al., 2001; Stefani et al., 2004).

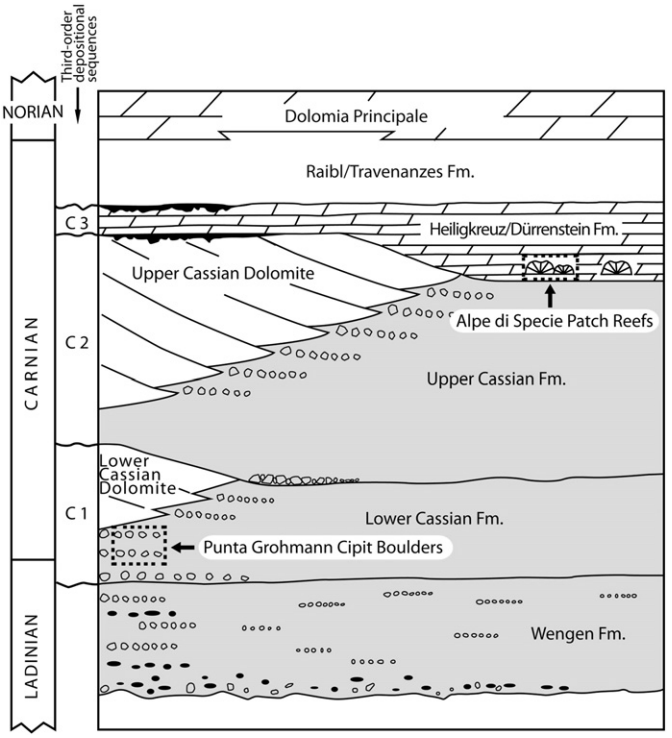

Fig. 2. Simplified stratigraphic scheme showing the mid-Triassic deposits sampled (dashed outlines). The contact between the Heiligkreutz/Dürrenstein Fm. and the Cassian Dolomite is thought to be erosional (Brandner et al., 2007).
Modified from Preto and Hinnov, 2003; Keim et al., 2006.

2.1. Punta Grohmann

This Ladinan–Carnian basinal succession (Wengen and Cassian formations) is well-exposed on a steep shaly erosion scar (Teres Neigres)

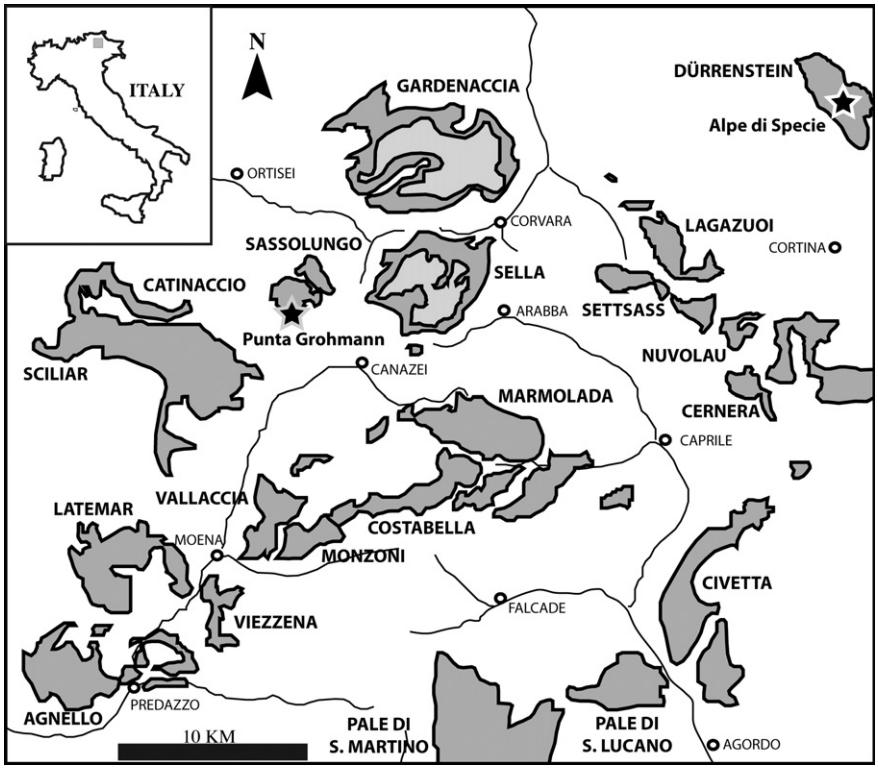

Fig. 1. Mid-Triassic carbonate platforms in the Dolomites and locations of the Punta Grohmann and Alpe di Specie sample localities.
Based on Brandner et al., 2007.