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The changing climate framework and depositional dynamics of Triassic carbonate platforms from the Dolomites

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A B S T R A C T

The Triassic of the Dolomites offers a valuable opportunity to investigate the relationships between climate fluctuations and the changing depositional dynamics of carbonate platforms. The reconstruction of the large palaeoclimatic modification is based on the synthesis of multiple sedimentological, palaeobotanical, pedological, and geochemical proxies. The Triassic climate fluctuations were generally fast in nature and were probably associated with a latitudinal shift of the monsoon belts. During the Triassic, the Dolomites were placed at an intertropical northern latitude of about 16–18° and were generally dominated by dry climate and elevated temperature. At least five pulses toward moister climate are however documented, dated to Early Olenekian, Middle Anisian, Late Ladinian, “Middle” Carnian, and Late Norian times. Within this variable climatic scenario, the carbonate systems record a global evolutionary trend from Late Permian–Early Triassic regional shelves, rich in loose micrites and bio-calcarenites, to Anisian–Ladinian, synsedimentary cemented, steep sided (35–40°), high-relief platforms, and back to Carnian low angle ramps. Moist transgressive episodes were surprisingly prone to the spreading of corals and other colonial reef organisms, probably because of the reduced space competition by syndepositional cementation structures. The Permo-Triassic boundary extinction dramatically impacted on the calcified organism communities, but the carbonate depositional architecture nevertheless stayed almost unaffected through the boundary. The Early Triassic and earliest Anisian were commonly associated with hyperhaline, sometimes evaporitic conditions. Intervals of moister climate and efficient river discharge are however documented by earliest Induan and early Olenekian sediments. The latter terrigenous deposits matched a crisis in the carbonate production. After a return to arid conditions, during the Anisian, a fluctuation toward moister climate developed, associated to a massive continental vegetation cover. The Anisian tectonic activation of the region fragmented the previous carbonate shelf, triggering the development of three generations of fast prograding, but globally backstepping, isolated platforms, recording an increasing role of the synsedimentary cementation. A dry climate dominated the Late Anisian and Early Ladinian interval. At the time, a fast subsidence pulse was associated with platform drowning and basinal anoxia. Only a few aggrading pinnacles were able to survive, providing the nuclei for larger prograding platforms. During a dry climate interval, massive syndepositional cementation generated a major source of carbonate. Carbonate production stayed active through the Ladinian magmatic phase, but the onset of volcanism was associated with a large modification in the platform carbonate facies, which became dominated by automicrites. Moist climate phases are well documented again during the Late Ladinian, followed by a return to dry conditions. The Late Ladinian–Early Carnian platforms prograded toward the eastern Dolomites depocentre, eventually infilling almost the whole of the accommodation space. The middle portion of the Carnian recorded renewed, sharply moist phases, associated with the demise of the rimmed platforms and with the return to loose sediment ramps. At least four separated humid fluctuations can be identified in this Carnian interval alone. Climate then returned to persistent aridity, until the Late Norian moist phase.

1. Introduction

The geological landscape of the Southern Alpine Dolomites (Figs. 1 and 2) is dominated by thick Triassic platforms, often well preserving both their depositional geometry and sedimentary facies. Since the Nineteenth Century seminal realisation (von Richthofen, 1860; von Mojsisovics, 1879) of the biogenic, “reefal” nature of the succeeding

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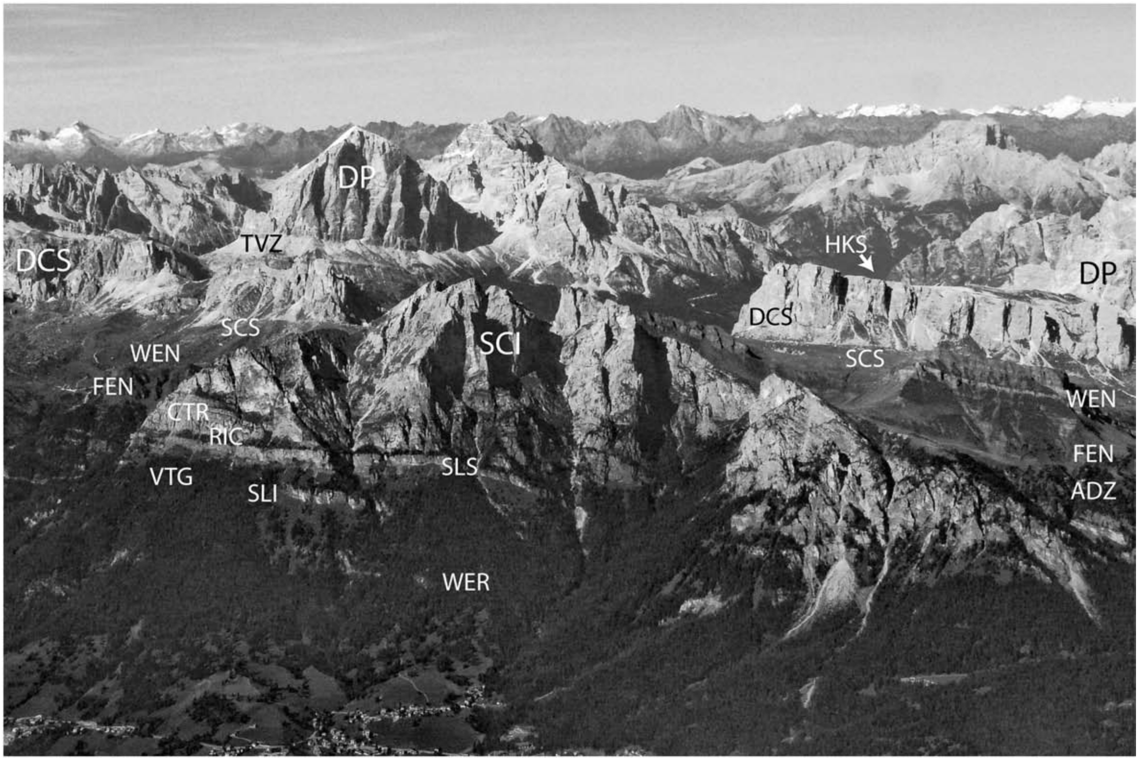

Fig. 1. Central Dolomites landscape, showing the regional succession of platform generations, recording large climate fluctuations. Lower Triassic shelf deposits (WER = Werfen Formation); Lower Anisian regional carbonate ramp (I = Lower Serla Dolomite); Anisian continental conglomerates (VTG = Voltago Cgm; RIC = Richthofen Cgm); Anisian isolated carbonate platforms (SLS = Upper Serla Fm; CTR = Contrin Fm); uppermost Anisian aggradational–retrogradational carbonate pinnacle (Sciliar Fm); onlapping Ladinian turbiditic sandstones (ADZ = Zoppè Sandstones), synvolcanic Ladinian basinal deposits (IMF = Fernazza Fm); Upper Ladinian turbiditic volcaniclastics (WEN = Wengen Fm); Lower Carnian prograding carbonate platforms (DCS = Cassian Dolomite) and associated shallowing upward basinal sediment (SCS = San Cassiano Fm); Carnian terrigenous–carbonate shallow marine and coastal deposits (HKS = Heiligkreuz Fm; TVZ = Travenanzes Fm); thick Upper Triassic peritidal dolomites (DP = Dolomia Principale). At the skyline, Northern-Alpine metamorphic units are visible. (Northward aerial view from above Alleghe).

generations of buildups (Fig. 3), the region has become a classic research area for the understanding of the carbonate platforms (e.g. Bosellini, 1984; Hardie et al., 1986; Rudolph et al., 1989; Kenter, 1990; Schlager and Keim, 2009; and references therein). Bio-evolutionary trends and ecological change played a major role in the shaping of these bio-controlled edifices. The ecological equilibria affecting the carbonate production were particularly sensitive to climate fluctuations. The Permian and Triassic Periods were traditionally considered as dominated by a long-lasting aridity, throughout large portions of the Pangaea; growing evidence is however gathering that this generally dry framework was punctuated by episodes of moister climate (Simms and Ruffell, 1989; Mutti and Weissert, 1995; Twitchett and Wignall, 1996; Balog et al., 1999; Rigo et al., 2007). Humid phases are well witnessed also by the Dolomites successions (Kustatscher and van Konijnenburg-van Cittert, 2005; Keim et al., 2006; Roghi et al., 2006; Farabegoli et al., 2007; Hornung et al., 2007a,b; Posenato, 2008a,b). During the Triassic, the Dolomites area was located at the western termination of the Palaeo-Neo-Tethys seas (Fig. 2), at a northern intertropical latitude of about 15–18° (Muttoni et al., 2004). The area was therefore sensitive to the latitudinal shift of climate belts. The region is particularly well suited to provide an integrated climate record, through the interdisciplinary synthesis of multiple proxies (Figs. 3 and 11). Deep-water units can be often well correlated with shallow marine and continental successions, supporting the reconstruction of lateral environmental gradients. The evidence deriving from silicate and carbonate palaeosols can be integrated with the sedimentological and ecological records provided by platform and basinal carbonate facies and fossil biota. Pollens and plant remains are well preserved, both within continental and marine strata, and are particularly valuable for their providing accurate climatic information (Figs. 4 and 7). High sedimentation rates, detailed biostratigraphy and geochronology enable high temporal resolution, documenting the fast geological pace of the climate change. The Dolomites therefore offer a valuable opportunity to unravel the role played by climate in the changing carbonate platform dynamics. Many other factors however interacted with climate in the shaping of these buildups, particularly the violent tectono-magmatic evolution of the area, which largely influenced the terrigenous input and the creation of accommodation space. This contribution is therefore aimed at distilling the role played by climate in the depositional dynamics of these platforms. The research is grounded on the plentiful published information, integrated with our own research, mainly focused on facies analysis and 3D reconstruction of the carbonate bodies. In order to frame the available palaeoclimate information, the first part of the contribution provides an overview of the Triassic stratigraphy of the region; the palaeoclimate information is then synthesised in the second portion of the paper.

2. Sedimentary facies and depositional geometry

2.1. Lower Triassic and lowermost Middle Triassic shelf sediments

In the study area, the uppermost Permian to Lower Anisian interval consists of terrigenous–carbonate facies, accumulated into shelf-ramp environments, often under an evaporitic influence. Loose micritic and bioclastic calcarenites dominate the carbonate fraction and no buildups or early cemented carbonates were reported. The sedimentation rates almost matched the creation of accommodation space, globally keeping the area by sea level for several millions of years.