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The Role of the Syndepositional Cementation and the Microbial Boundstone Accumulation in the Depositional Dynamics of the Triassic Platforms of the Italian Dolomites

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The understanding of the carbonate platform reservoirs can be improved through the comparative analysis of outcropping analogous, such as the Triassic ones from the Italian Dolomites (Fig. 1). The study of the different platform generations outcropping in this region is particularly worthy in clarifying the dynamic relationships between the changing carbonate production and the depositional architecture. This analysis suggests that the sedimentary composition of the platforms can be inferred from their depositional geometry and vice versa, because of the strong genetic linkage of these two depositional features. This relationship shows up while analysing the clinostratified slope bodies, forming the largest volume of the Anisian, Ladinian and Carnian platforms outcropping in this portion of the Italian Southern Alps. The study limestones are dominated by large volumes of calcareous cements and microbial boundstones, both associated with micro-dispersed organic matter, whereas the calcareous metabionts generally form only a tiny portion of the rock mass, despite their high taxonomic diversity.
The primary sediment composition and depositional geometry indirectly affected the present-day rock porosity and permeability, by influencing the carbonate diagenetic evolution. Even if quantitative estimates are still beyond our possibilities, the predictive potential for the 3D subsurface interpretation is already clear. The strongly peculiar features of these Triassic platforms however suggests that care has to be used in applying this data to the interpretation of reservoirs from other chronological intervals.

The pre-volcanic platforms
In the Dolomites region, during the Lower Triassic, laterally continuos mixed terrigenous-carbonate deposits accumulated, in a storm-dominated shallow sea, whereas no carbonate platform developed. It was indeed a period of severe evolutionary crisis for the reef building organisms, colonizing the platform margin areas, due to the massive Permo-Triassic mass extinction. The resilience of the biological systems was however soon to generate renewed reef-building comunities, early in the Middle Triassic. These evolutionary "new comers" were dominated by

small organism associations, rich in problematica, quite different from the younger Mesozoic ones.
During the earliest Middle Triassic, a complex pattern of tectonic structures was activated in the Dolomites region, probably with a transtensive dynamics. Quickly subsiding areas coexisted alongside temporaneously uplifting zones. During the Anisian, this dynamic framework influenced the development of several platform generations (Fig. 2), associated with small, moderately deep depressions, where significant organic carbon concentrations often accumulated. The different platform generations (Lower and Upper Serla, Contrìn Fm.s) are separated by emersion sequence boundary, associated with continental conglomerates. In these Anisian platforms, encrusting and building organisms locally appeared, but loose calcarenitic and micritic sediments, often rich in Dasicladacean algae, still dominated the sedimentary scene. Due to the abundance of loose micritic mud and the reduced depth of the basins, the slopes were short, comparatively gently inclined, and rich in slumped beds and debris flow deposits. The first steep planar clinostratifications however developed in the last of these generations (Contrin platforms).
During the younger Anisian, the regional subsidence sped up dramatically, probably exceeding 300 m/Ma. The carbonate production was unable to keep pace with such a huge relative sea level rise and the largest portion of the area therefore drowned, entering into deepening, anoxic conditions; a widespread level of potential source rocks therefore accumulated, rich in marine organic matter. Only a few small platforms were able to keep pace with the fast subsidence, thus quickly becoming isolated pinnacles, struggling to remain in shallow water euphotic conditions.
A few short lived isolated platforms (e.g. Cernera) were eventually terminated by a delayed drowning evolution, since their carbonate factory was unable to support the fast platform volume increase, forced by the aggradation; in these builtups the slope deposits became thinner and thinner, while the margin was back-stepping; the drowned carbonate pinnacles were then covered by condensed pelagic limestones and deep water stromatolite-like structures.
Meanwhile, a similar lengthening and steeping up evolution was experienced also by the slopes of the coeval platforms, growing in comparatively less subsiding areas; these carbonate systems were however able to keep and eventually catch up the relative sea level rise (e.g. Latemàr Platform). While the platform core shallowed from subtidal environments to cyclic emersions, the adjacent slope deposits evolved from debris-flow and slumped micritic beds into hard block accumulations, thus progressively increasing the slope stability angles. These breccia are dominated by huge volumes of marine freatic cement concretions (Evinospongiae Auct., e.g. Marmolada Platform) and show very steep planar clinostratifications. The statistical compositional analysis demonstrates that margin and slope systems share a very similar composition, largely dominated by the synsedimentary cements (Fig. 3).
The subsidence then progressively slowed down, enabling the platforms to laterally prograde (e.g. Rosengarten-Catinaccio), conquering large areas throughout the Dolomites. In this phase, the basins often exceeded one kilometer in depth and the slopes were still very steep and rich in well cemented margin derived boulders; since very few margin bodies are preserved in situ from this phase, the direct examination of margin systems is normally impossible.

The post-volcanic platforms

During the Ladinian, a short-lived tectono-magmatic event largely disrupted the platforms growth. Several platforms were directly involved by the magmatic processes and at least partially buried and sealed within volcanic and terrigenous accumulations.

Over a short time span, significant paleoecological and paleogeographic modifications took place, triggering an important change in the platform depositional dynamics. The basins were now fed by large quantity of volcanoclastic sediments, associated with significant amounts of residual organic matter, continental in origin. The syn- and post-volcanic late Ladinian platforms (e.g. Schlern Platform, Sella Platform) were therefore growing within an ecological and paleoocenographic framework different from the pre-volcanic one. The large cement concretions suddenly disappeared, giving place to the dominance of automicrite and boundstones facies. Peloidal automicrite boundstones quickly became the dominant component of the slopes, that were changing their shape, showing a concave profile. In the meanwhile, resedimented bioclastic or oolitic graded calcarenites appeared in the adjacent basins. In near slope settings, margin derived large boulders also accumulated, being quickly buried by the terrigenous-volcanoclastic materials, the lower permeability of which prevented the carbonate blocks from being dolomitized. Whereas the pervasive late diagenetic dolomitization often obliterate the primary features of the in situ margin bodies, this isolated blocks generally preserve their microfacies in quite an exquisite a way, enabling the statistical analysis of the limestone component to be performed in an accurate way (Fig. 4). In this phase, the basinal sedimentation rates sharply increased, while the subsidence was slowing down. The whole of these factors induced both a shallowing up evolution of the basins and a widespread lateral progradation of the platforms. In several areas, especially in the central eastern portion of the region, the subsidence was however still significant, enabling the aggradational evolution of several well stratified platform top successions. The subsidence was on the contrary quite reduced in the western portion of the Dolomites. The prograding platforms therefore filled up the available accommodation space at different times in the different areas, starting form the western zones towards the central depocenter (near Cortina d'Ampezzo). This moving "growth wave" of platforms is recorded by the younging of the sedimentary infilling towards the depocentral area. During the Carnian, a late generation of prograding platforms (e.g. Lastoi di Formìn) was characterized by gently inclined micritic slopes, recording an increased carbonate mud production and making transition to ramp settings.

In the next evolutionary phase, the shallowed basinal area were colonized by aggrading, shallowing upward platforms, while "modern" building coral communities were appearing for the first time. The reef bodies were now dominated by larger building organism associations, rich in corals, as suggested by their statistical investigation (Fig. 5).

The shallow lagoon and tidal flat deposits were by now recording spectacular reptile-footprint assemblages, confirming the almost complete infilling of the sedimentary space. The younger Carnian shallow water carbonates were influenced by the transition from arid to moist climates, associated with the preservation of the oldest known ambers, providing new valuable palaeoecological information.

The synthesis of this complex depositional evolution confirms that the modification affecting the carbonate factory played a major role in the shaping of the depositional geometry; in turn the platform morphology certainly affected the carbonate production, particularly in the platform margin settings.

Fig. 1 Geographic location of the Italian Dolomites study region.

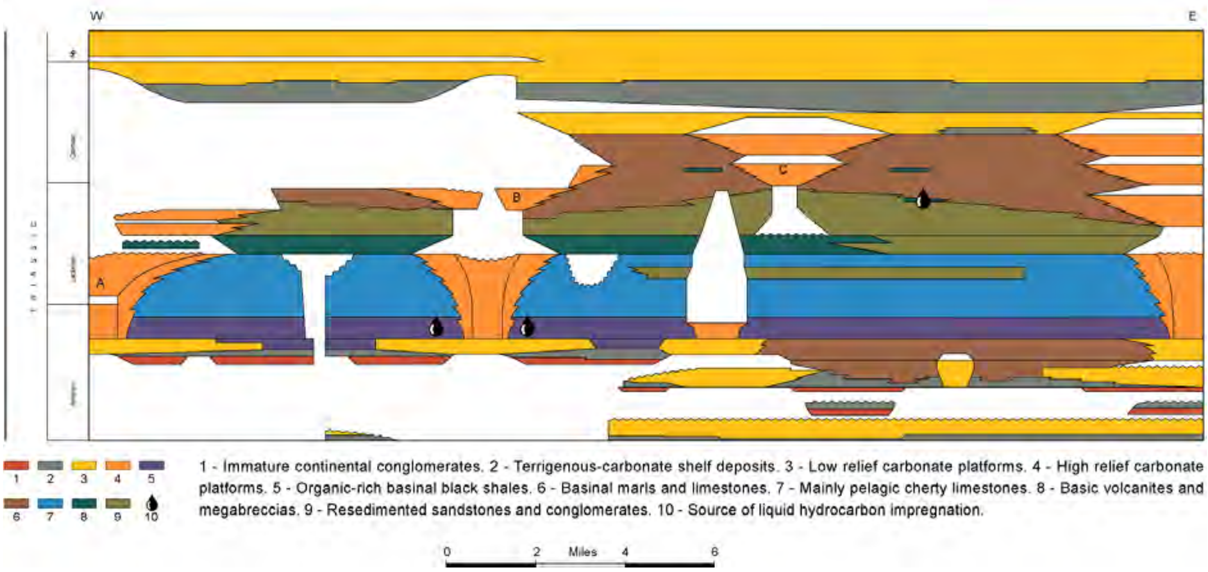

Fig. 2 The chronostratigraphic framework of the different generations of Anisian, Ladinian and Carnian platforms of the Dolomites.

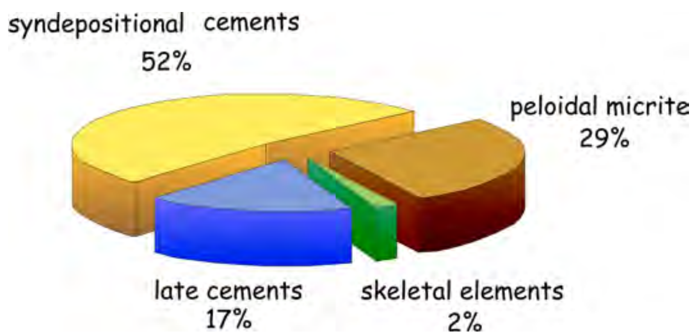

Fig. 3 Composition of the platform margin facies from the northern site of the Latemàr Platform, deposited near the Anisian-Ladinian boundary. The massive importance of the synsedimentary marine freatic cementation is clear.

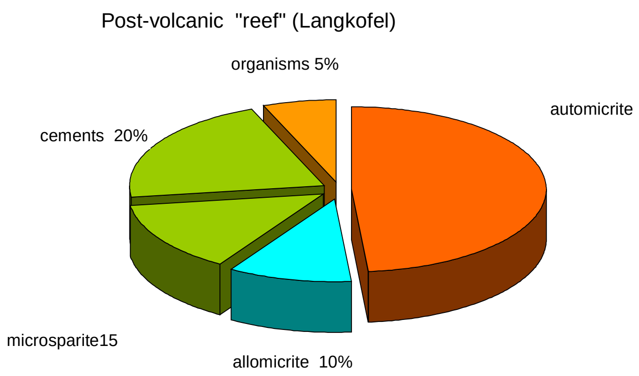

Fig. 4 Composition of the platform margin facies from the Punta Grohmann section in the Sasso Lungo Platform (Upper Ladinian). The facies are dominated by peloidal boundstones, lithified at a very early stage.

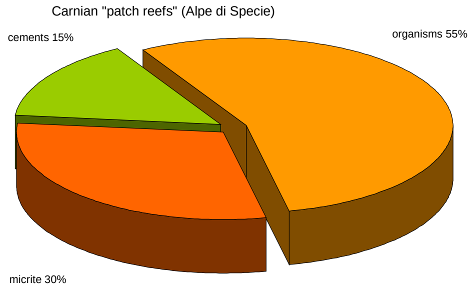

Fig. 5 Composition of the coral dominated facies in the Alpe di Specie area near Cortina d'Ampezzo (Carnian). The sediment now shows a more "modern composition", due to the massive appearance of colonial corals.