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A short overview on the Palaeozoic sequence of the Carnic Alps

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Abstract: *An overview of the geological evolution of the Carnic Alps during the Palaeozoic is presented: the Variscan sequence, the Permo–Carboniferous sequence and the basal part of the Alpine sequence were deposited between the Late Ordovician and the Middle Triassic.*

Introduction

The Carnic Alps are located across the Italian-Austrian border. One of the better exposed and complete Palaeozoic sequence of the world, ranging from Upper Ordovician to Upper Permian is here exposed.

The "Palaeocarnic Chain" is considered as part of the Hercynian ancient core of the Eastern Alps in the Southalpine domain, and extends as a narrow strip for more than 100 km in a W-E direction, with a N-S width that rarely exceeds 15 km. To the North it is bordered by the Gailtail Line, the eastern segment of the Insubric Lineament, separating the Austroalpine domain from the Southalpine domain; towards the South it is unconformably covered by Upper Palaeozoic and Triassic successions (VENTURINI & SPALLETTA, 1998, SCHÖNLAUB & FORKE, 2007). The Palaeocarnic Chain can be splitted into two parts (Fig. 1), separated by the Val Bordaglia Line, a prominent N50°E trending fault: the western zone is made exclusively of greenschist facies metamorphic rocks, and the eastern zone which consists prevalently by sedimentary not metamorphic successions (VENTURINI & SPALLETTA, 1998) except for the northernmost part where banded limestones occur.

In this paper the sedimentary sequence and the evolution of the depositional basin of the eastern zone is briefly exposed.

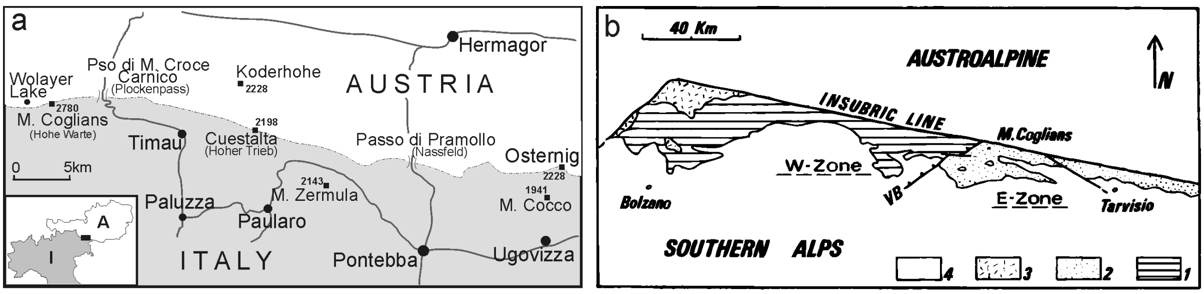

Fig. 1: (a) location map of the Carnic Alps. (b) simplified geological map of the Southern Alps showing the partition of the Palaeocarnic Chain into a West and a East Zone (after VENTURINI & SPALLETTA, 1998). VB: Val Bordaglia line; 1: low to middle grade metamorphic basement; 2: non- to anchi-metamorphic units; 3: Variscan intrusive bodies; 4: post-Palaeozoic units.

Review of the stratigraphic sequence

Rocks deposited between Late Ordovician and the Middle Triassic are exposed in the Carnic Alps. They are organized into three sequences: the Variscan, the Permo–Carboniferous and the Alpine

sequences. The Variscan sequence includes rocks of Late Ordovician to early Late Carboniferous age, that were affected by the Variscan orogeny during the Moscovian (SCHÖNLAUB & FORKE, 2007); the Permo–Carboniferous sequence ranges from Late Carboniferous to Early Permian. The youngest Palaeozoic rocks of the Carnic Alps represent the basal terms of the Permo–Triassic succession that is part of the so-called 'Alpine' sequence (VENTURINI, 1990).
The most ancient rocks of the Carnic Alps belong to the Uqua shales (Katian–Hirnantian). They are represented by up to 100 m of pelites, sandstones and rare conglomerates deposed in shallow water at medium-high southern latitudes (Fig. 2). Fossils, mainly bryozoans, brachiopods, echinoderms, trilobites and gastropods, are abundant. In the western part of the basin a coarser grained sandstone unit (Himmelberger Sandstone) and even basic and acid volcanics ("Comelico Porphyroid") are present.

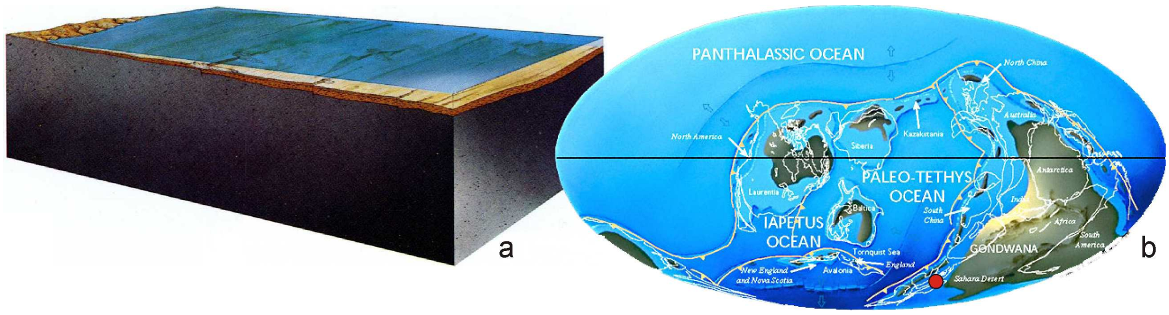

Fig. 2: Upper Ordovician. (a) Block diagram of the of the Carnic Alps depositional environment. (b) Palaeogeographic map (after Scotese.com): the red circle indicates the position of the Carnic Alps.

The basal clastic sequence is capped by an encrinitic parautochthonous limestone (Wolayer Lms) in the western part of the chain and by the deeper water limestones of the Uqua Lms. Both these units are fossilifeorus, with abundant echinoderms, bryozoans and conodonts.
The global glacially-induced regression of the the Hirnantian is documented by the calcareous sandstone of the Plöcken Fm. It resulted in erosion and local non-deposition, testified by the fact that the Silurian strata rest disconformably upon the late Ordovician sequence (SCHÖNLAUB & HISTON, 1999; HAMMARLUND et al., 2012).
Silurian deposits (Fig. 3) are irregularly distributed within the Carnic Chain, and range from shallow water bioclastic limestones to nautiloid-bearing limestones, interbedded shales and limestones to black graptolitic shales and cherts ("lydites"). The overall thickness does not exceed 60m. The Silurian transgression started at the base of the Llandovery, and, due to the disconformity separating the Ordovician and the Silurian, a varying pile of sediments is locally missing, which corresponds to several conodont zones of Llandovery and early Ludlow age (SCHÖNLAUB & HISTON, 1999; ŠTORCH & SCHÖNLAUB, 2012).
The Silurian of the Carnic Alps is subdivided into four lithological facies (Fig. 3c), representing different depths of deposition and hydraulic conditions (WENZEL, 1997). The Wolayer-facies is characterised by proximal sediments, the Bischofalm-facies by deep water euxinic deposits; the Plöcken-facies and the Findenig-facies are intermediate between the ones mentioned above. In rough approximation, the four facies seem to be distributed north-west to south-east in the western-central sectors of the chain. The depositional features suggest an overall transgressional regime from Llandovery to Ludlow. Uniform limestone sedimentation within the Prídoli suggests that more uniform conditions were developed at that time (SCHÖNLAUB, 1997).
In terms of the recently established new lithostratigrapic subdivision, in correspondence of the calcareous proximal parts of the basin, three units follow each other: the Kok Fm (Llandovery–lower Ludlow), the *Cardiola* Fm (Ludlow) and the *Alticola* Lms (upper Ludlow–Pridoli). All these units are mainly represented by "*Orthoceras* limestones", a wackestone-packstone with high bioclastic content. The colour gradually turns from dark red and black in the lower Silurian levels to light grey-ochre in the Pridoli. Nautiloid cephalopds are very abundant, trilobites, bivalves and conodonts are common; crinoids, gastropods and rarer ostracods, brachiopods, chitinozoans are also present (CORRADINI et al., 2010).
In the deeper part of the basin, the Bischofalm Fm deposited: it is a monotonous sequence, up to 60 m thick, of black siliceous shales, with cherts interbedded and clayish alum slates, mainly deposited in an euxinic environment. Graptolites are generally abundant (SCHÖNLAUB, 1997).

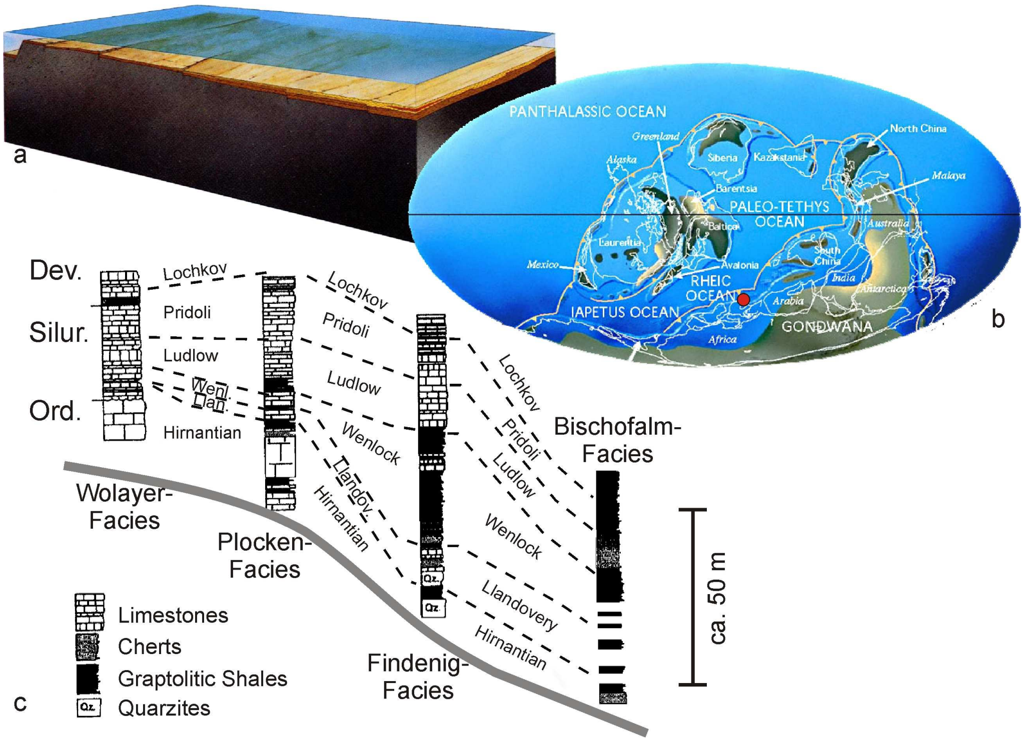

Fig. 3: Silurian. (a) Block diagram of the of the Carnic Alps depositional environment. (b) Palaeogeographic map (after Scotese.com): the red circle indicates the position of the Carnic Alps. (c) Lithology of the Silurian and lowermost Devonian sediments in the four lithofacies of the Carnic Alps (after WENZEL, 1997, modified).

Intermediate sedimentary conditions between calcareous and shaley facies are represented by the Nölbling Fm, constituted by alternating black graptolitic shales, marls and limestone beds (SCHÖNLAUB, 1997).

During the beginning of the Lochkovian the general condition remained similar to the late Silurian, whereas starting within the upper Lochkovian differences within the sedimentary basin increased: "the Devonian Period is characterized by abundant shelly fossils, varying carbonate thicknesses, reef development and interfingering facies ranging from near-shore sediments to carbonate buildups, lagoonal and slope deposits, condensed pelagic cephalopod limestones to deep oceanic off-shore shales" (SCHÖNLAUB & HISTON, 1999: p. 15).

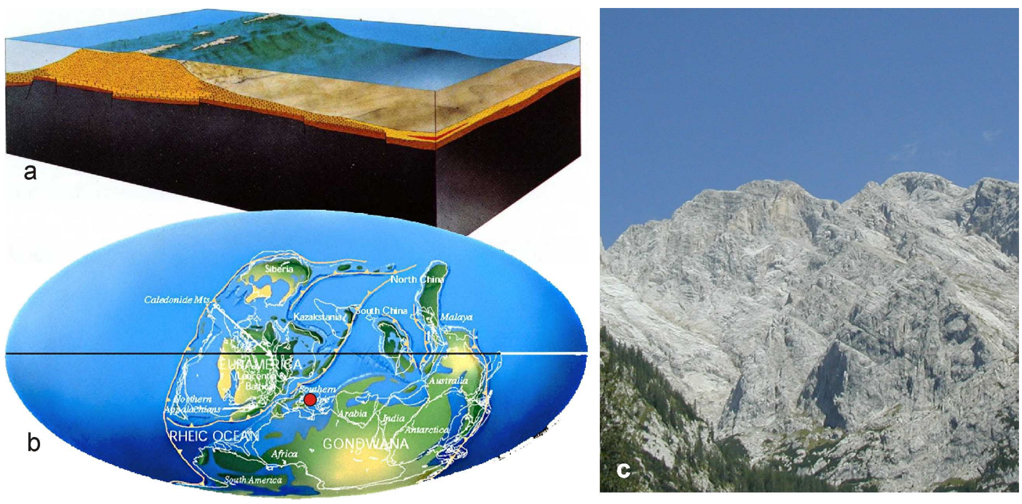

Fig. 4: Middle Devonian. (a) Block diagram of the of the Carnic Alps depositional environment. (b) Palaeogeographic map (after Scotese.com): the red circle indicates the position of the Carnic Alps. (c) the white calcareous cliffs of Mt. Coglians/Hohe Warte are constituted by more than 1000 m of reefal sediments and related facies.

During the Emsian and the Middle Devonian (Fig. 4), within short distances a strongly varying facies pattern developed, indicating a progressive but not uniform deepening of the basin. More than 1000 m of reef and near-reef limestones, and various intertidal lagoonal deposits, are time equivalent to about 100 m of pelagic limestones. Pelites and cherts deposed in the deeper part of the basin. The reefs reached their maximum extension during the Givetian and lower Frasnian, when the present Carnic Alps were about at a latitude of about 30° South (SCHÖNLAUB, 1992). Four major reefs developed, now represented by the cliffs of Mt. Coglians/Hohe Warte (Fig. 4c), Mt. Zermula, Mt. Cavallo/Roßkofel and Mt. Oisternig, beside several minor buildups. The fossil content is always very high: stromatoporoids, tabulate and rugose corals, brachiopods, crinoids, gastropods, ostracods, bivalves, cephalopods, trilobites, algae, calcispheres, and foraminifers.

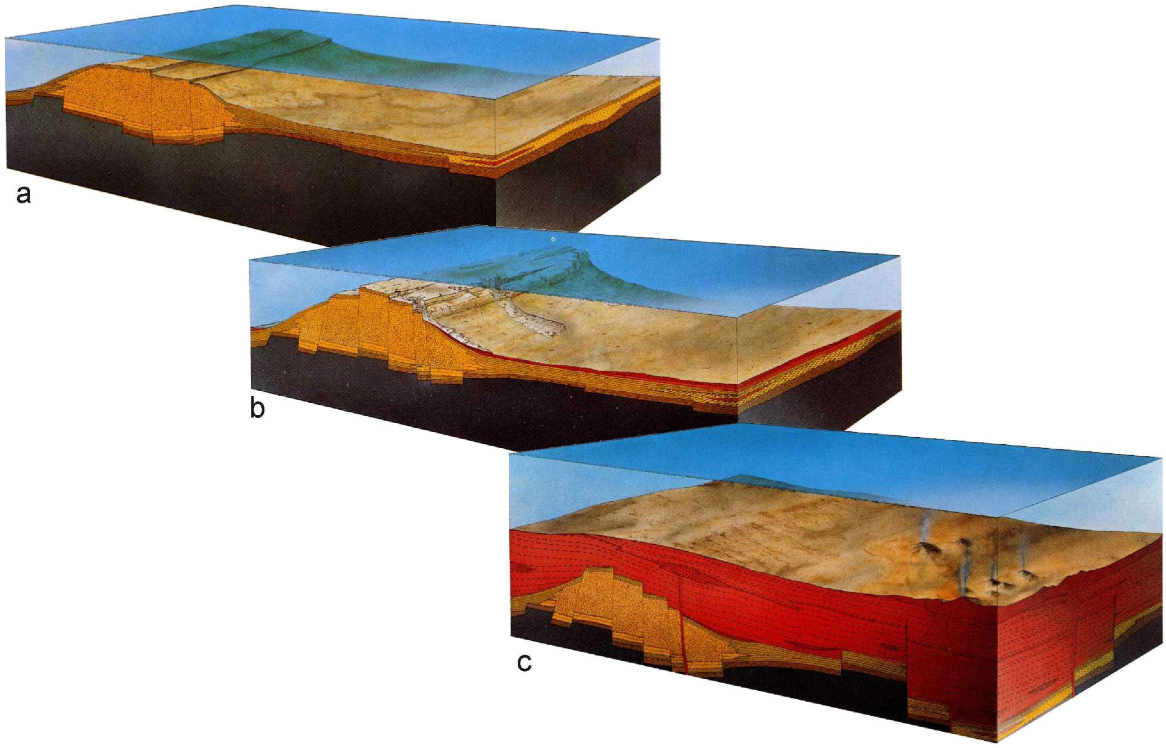

Fig. 5: Evolution of the Carnic basin from Late Devonian to early Late Carboniferous. (a) Late Devonian. (b) Early Carboniferous: beginning of the deposition of the turbidites of the Hochwipfel Fm. (c) early Late Carboniferous: deposition of the Dimon Fm volcanites.

During the early Frasnian, extensional tectonic caused collapse of the basin and consequently reefs rapidly drowned and reefal organisms died out. Starting from the upper Frasnian (Late *rhenana* Zone) a uniform pelagic environment developed (Fig. 5a), which lasted up to the lowermost Visean (SCHÖNLAUB, 1992; SCHÖNLAUB & KREUTZER, 1993; PERRI & SPALLETTA, 1998). The "Clymeniae limestone" is represented by a reddish, pinkish, greyish wackestone with cephalopods.

In the Lower Carboniferous up to 1000 m of arenaceous pelitic turbidites of the Hochwipfel Fm deposited. It is interpreted as a Variscan "flysch" sequence (VENTURINI & SPALLETTA, 1998 and references therein). This Kulm deposits indicate a Variscan active plate margin in a collisional regime following the extensional tectonics during the Devonian and the Early Carboniferous (SCHÖNLAUB & HISTON, 1999). The Hochwipfel Fm consists of quartz-sandstones and greyish shales turbidites, with intercalations of mudstones, chaotic debris flows and chert and limestone breccias. In place plant remains are common, and rare trace fossils are present. In the upper part of Early Carboniferous, the basic volcanites and volcanoclastic deposits of the Dimon Fm occur (Fig. 5c), related to crustal thinning associated to a rifting episode. These conditions continued up to the Moscovian (Upper Carboniferous), when the Hercynian orogeny in the Carnic area marked the end of the deposition of the Hercynian Sequence (SCHÖNLAUB & FORKE, 2007).

The Variscan orogeny had its climax during the Moscovian and affected the Variscan sequence, producing different systems of asymmetric folds, faults and thrusts distributed along a N 120°-140°E direction (VENTURINI, 1990).

The uplift of the Paleocarnic Chain generated an erosional-depositional sedimentary hiatus. In places (Forni Avoltri, Pramollo and Tarvisio sectors) this gap lasted until the latest Moscovian, where, because of subsidence related to a strike-slip tectonic system, the Permo–Carboniferous Sequence deposited in disconformity on top of the Hercynian Sequence. It consists of alternating cycles of fluvio-deltaic and marine deposits, caused by frequent eustatic sea level changes due to the Permo-Carboniferous glaciation. The sequence starts with basal breccias and conglomerates, resulting from the erosion of the Paleocarnic Chain.
The basal conglomerates (attributed by VENTURINI, 1990 to the Bombaso Fm) are overlaid by sediments subjected to frequent transgressive-regressive cycles, with alternating fluvio-deltaic clastic sediments and calcareous shallow water deposits (Fig. 6a). Different authors discriminate five formations belonging to the Auernig Group (VENTURINI, 1990), or several members within the Auernig Fm (FORKE et al., 2006; SCHÖNLAUB & FORKE, 2007).

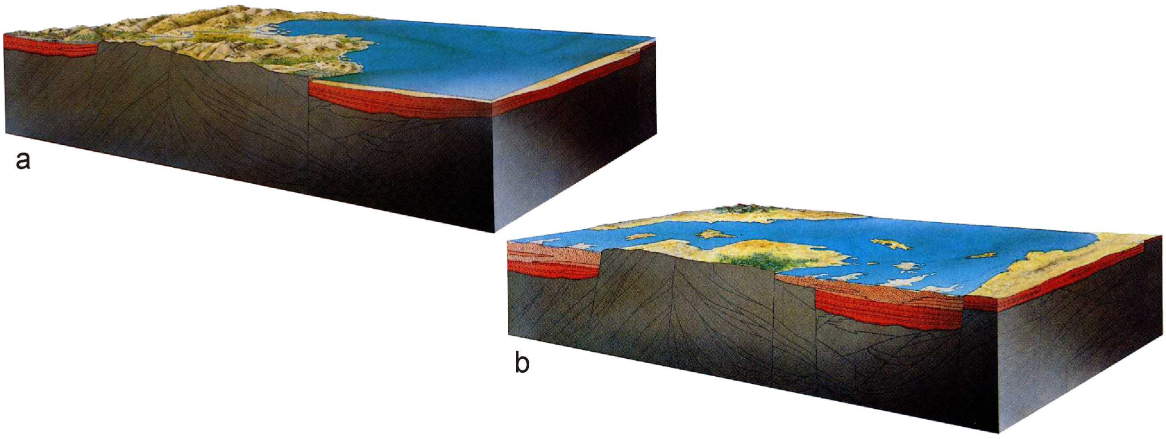

Fig. 6: Evolution of the Carnic basin from Late Carboniferous to Early Permian.

Across the Carboniferous–Permian boundary and in the Lower Permian (Fig. 6b), calcareous facies are dominant; the three formations (Schulterkofel Fm, Val Dolce Fm and Zweikofel Fm), grouped in the Rattendorf Group (VENTURINI, 1990) indicate a general transgression with more stable marine conditions. The transgressive trend continues throughout the Lower Permian, and ends with the Trogkofel Group (VENTURINI, 1990) (Trogkofel Fm, FORKE et al., 2006), characterized by reefs up to 400 metres thick.
Within the Middle Permian, a transpressional tectonic phase causes extensive emersion and karstification. In the Upper Permian an extensional phase starts, controlling the deposition of a sequence of continental ruditic deposits (Tarvisio Breccia and Sesto Conglomerates) followed by marine to terrigenous (Val Gardena Sandstones), and finally evaporitic, lagoonal and shallow marine water (*Bellerophon* Fm). This sequence was deposited in an environment characterised by alluvial fans (Tarvisio Breccia and Sesto Conglomerates), alternating with alluvial plains with irregular braided rivers deposited a thick sequence of pelites and sandstones (Val Gardena Sandstones). The *Bellerophon* Fm, marking the end of the Carnic Palaeozoic, indicates a slow rise in sea level, and is characterized by gypsum, rauhwackes and evaporitic dolostone in the lower part of the succession and by dolostone and black limestone in the upper part.

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