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The Pre-Variscan sequence of the Carnic Alps (Austria and Italy)

The Pre-Variscan sequence of the Carnic Alps – an introduction

Carlo Corradini[1], Thomas J. Suttner[2], Annalisa Ferretti[3], Susanne M.L. Pohler[4], Monica Pondrelli[5], Hans-Peter Schönlaub[6], Claudia Spalletta[7] & Corrado Venturini[7]

5 Text-Figures

Carnic Alps
Paleozoic
Stratigraphy
Type locality
Stratotype
Austria
Italy

Contents

Zusammenfassung

Eine überarbeitete Version der stratigraphischen Tabelle für die prä-variszische Abfolge der Karnischen Alpen wird vorgestellt. Die lithostratigrafischen Einheiten jedes hier bearbeiteten Zeitabschnitts wurden revidiert und vereinheitlicht. Anerkannte Einheiten wurden entsprechend formalisiert und auch die Alterseinstufung der lithostratigraphischen Grenzen verbessert. Die Abfolge erstreckt sich vom Mittelordovizium bis in das frühe Pennsylvanium und setzt sich formal aus 36 Formationen zusammen. Diese Arbeit soll als Grundlage für die zukünftige Erforschung der Karnischen Alpen dienen und eine bessere globale Korrelation mit anderen paläogeographischen Gebieten ermöglichen.

Abstract

An updated stratigraphic scheme of the Pre-Variscan sequence of the Carnic Alps is proposed herein. Lithostratigraphic units have been carefully revised and homogenized in each investigated time slice. Recognized units have been formalized accordingly. The data on the age of the boundaries have been improved as well. The succession spans the Middle Ordovician - early Pennsylvanian interval and has been formally divided in 36 formations, providing a sound reference for future geological studies in this part of the Carnic Alps and enabling a more global correlation with other paleogeographical domains.

1 Carlo Corradini: Dipartimento di Scienze Chimiche e Geologiche, Università di Cagliari, via Trentino 51, 09127 Cagliari, Italy. corradin@unica.it
2 Thomas J. Suttner: Institute for Earth Sciences (Geology & Paleontology), NAWI Graz, University of Graz, Heinrichstrasse 26, 8010 Graz, Austria. suttner.thomas@gmail.com
3 Annalisa Ferretti: Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, via Campi 103, 41125 Modena, Italy. ferretti@unimore.it
4 Susanne M.L. Pohler: Institut für Geologie und Mineralogie, Universität zu Köln, Zülpicher Str. 49a, Gebäude 310, 50674 Köln, Germany. dr.s.pohler@gmail.com
5 Monica Pondrelli: International Research School of Planetary Sciences, Università d'Annunzio, viale Pindaro 42, 65127 Pescara, Italy. monica@irsps.unich.it
6 Hans-Peter Schönlaub: Austrian Academy of Sciences, Commission for Geosciences, Dr. Ignaz Seipel-Platz 2, 1010 Vienna, Austria. hp.schoenlaub@aon.at
7 Claudia Spalletta & Corrado Venturini: Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Sezione di Geologia, Alma Mater Studiorum-Università di Bologna, via Zamboni 67, 40126 Bologna, Italy. claudia.spalletta@unibo.it, corrado.venturini@unibo.it

Riassunto

Viene presentato uno schema litostratigrafico aggiornato della sequenza Pre-Varisica delle Alpi Carniche. Tutte le unità litostratigrafiche sono state revisionate, ridescritte e formalizzate ufficialmente. L'età dei limiti formazionali è stata ricalibrata. La successione comprende rocce dall'Ordoviciano Medio alla parte iniziale del Pennsylvaniano, distinte in 36 formazioni, che serviranno da riferimento per gli studi futuri nelle Alpi Carniche e consentiranno una migliore correlazione con altri domini paleogeografici.

Introduction

The Carnic Alps are located along the Italian-Austrian border. This mountain chain reveals one of the best exposed and complete Paleozoic sequences of the world, ranging from the Middle Ordovician to the Upper Permian.

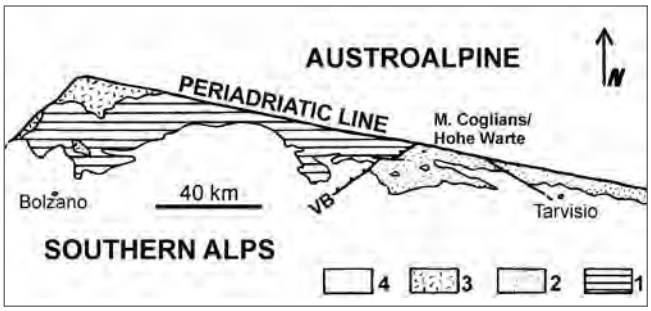
The "Paleocarnic Chain" is considered as a part of the Variscan ancient core of the Eastern Alps in the Southalpine domain, and extends as a narrow strip for more than 100 km in a W-E direction, with a N-S width that rarely exceeds 15 km (Text-Fig. 1). To the North it is bordered by the Gailtail Line, part of the Periadriatic Lineament, separating the Austroalpine domain from the Southalpine domain; towards the South it is unconformably covered by Upper Paleozoic and Triassic successions (VENTURINI & SPALLETTA, 1998; SCHÖNLAUB & FORKE, 2007). The Paleocarnic Chain can be subdivided into two parts (Text-Fig. 2), separated by the Val Bordaglia thrust (BRIME et al., 2008), a prominent NE-SW trending fault: the western zone is made of greenschist facies metamorphic rocks, the eastern zone mainly consists of sedimentary successions (VENTURINI & SPALLETTA, 1998; BRIME et al., 2008) except for the northernmost part where banded limestones occur.

Rocks deposited between the Middle Ordovician and the Late Triassic are exposed in the Carnic Alps. They are subdivided into three sequences: the Pre-Variscan, the Permo-Carboniferous and the Alpine sequences. The Pre-Variscan sequence includes rocks of Middle Ordovician to early Pennsylvanian age that were affected by the Variscan orogeny during the late Bashkirian and Moscovian (VENTURINI, 1990; SCHÖNLAUB & FORKE, 2007). The Permo-Carboniferous sequence ranges from the Pennsylvanian to the Middle Permian. The youngest Paleozoic rocks of the Carnic Alps are documented in the Upper Permian-Triassic succession that is part of the so-called 'Alpine' sequence (VENTURINI, 1990).

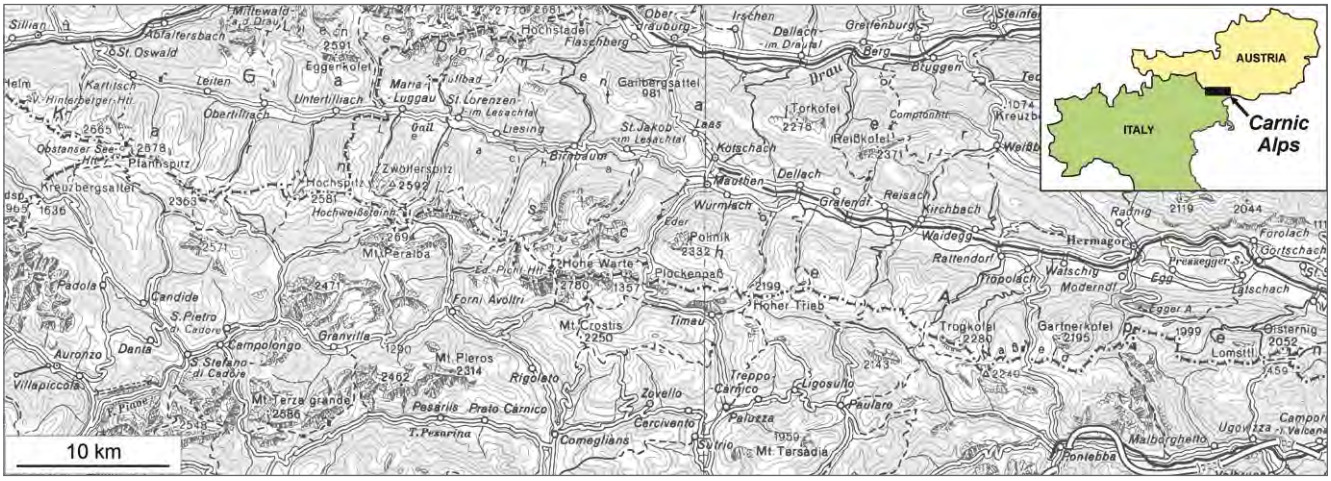
Here we focus on the Pre-Variscan sequence, which has been entirely revised resulting in an updated stratigraphic scheme (Text-Fig. 3) illustrating and formalizing 36 formations.

Former lithostratigraphic schemes

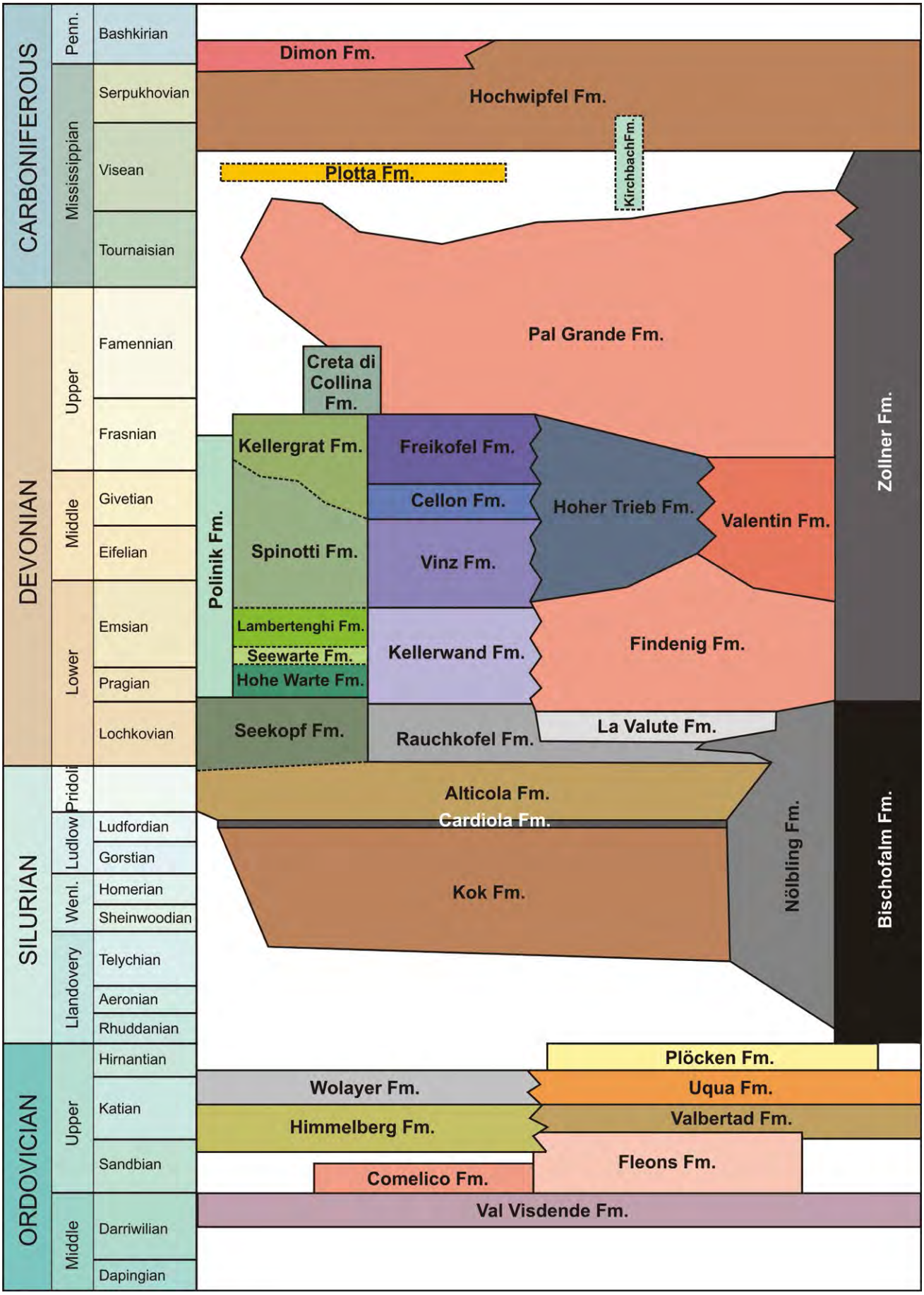
For the Carnic Alps several lithostratigraphic schemes exist, of which the latest versions from Austria and Italy are introduced here in order to show modifications performed in the new chart of the pre-Variscan sequence by the Carnic Alps Working Group. One of the major differences between Austrian and Italian charts is the number of units. While in the Austrian chart 43 units are discriminated (PILLER et al., 2004; HUBMANN et. al, 2014; Text-Fig. 4), the Italian schemes consist of definitely less units which are mainly the expression of well-distinguished larger scale facies (for example see VENTURINI & SPALLETTA, 1998; VENTURINI, 2006, 2009; Text-Fig. 5). Devonian reef and transitional facies, for example, represent one unit each in many Italian



Text-Fig. 2.
Simplified geological map of the Southern Alps showing the partition of the Paleocarnic Chain into a West and a East Zone separated by the Val Bordaglia thrust (after VENTURINI & SPALLETTA, 1998, modified). VB: Val Bordaglia thrust; 1: low to middle grade metamorphic basement; 2: non- to anchi-metamorphic units; 3: Variscan intrusive bodies; 4: post-Paleozoic units.



Text-Fig. 1.
Location of the Carnic Alps. Topographic map 1:200,000, rescaled.



Text-Fig. 3.
General lithostratigraphic scheme of the Pre-Variscan sequence of the Carnic Alps (columns left-right: System/Period, Series/Epoch, Stage/Age).

charts while Austrian workers subdivided the shallow marine, reef-related facies into 11 formations and the transitional zone (proximal ramp) into 4 formations. It should be noted that in Italy an official denomination for these subdivisions did not exist. Therefore, in different papers the subdivisions of the Pre-Variscan sequence were indicated with various names, even when the criteria of subdivision were often similar.

However, nearly none of the units, neither of Austrian, nor of Italian schemes, is formally established and some of them are now regarded as not justified and either erased from the actual chart or integrated into other formations of similar lithological characters. Units of former charts that have undergone change are briefly characterized below.

Austrian Scheme

In the Austrian Stratigraphic Chart 2004 (ASC 2004; PILLER et al., 2004) an Uggwa Limestone and an Uggwa Shale are depicted: herein, the Uggwa Shale is renamed into Valbertad Formation, while Uggwa Limestone remained in the present chart, however, formalized with the Italian name as Uqua Formation. Previously, the Silurian Bischofalm Formation in the new chart was subdivided into four units (Bischofalm Quartzite, Lower, Middle and Upper Bischofalm Shale). The former Megaerella Limestone is included partly into the Alticola Formation and partly into the Seekopf Formation. That decision was taken, because of its lithological character that, apart from the occurrence of *Rhynchonella megaera*, is very similar to aforementioned units. Early Devonian units were confused on the Austrian Stratigraphic Chart 2004. Originally, a neritic and pelagic Rauchkofel Limestone existed (KREUTZER, 1992), which continued in deeper marine settings laterally. Those deposits were called Boden Limestone (in the ASC 2004 wrongly indicated as shallow marine unit). Only the pelagic Rauchkofel Limestone is formalized now as Rauchkofel Formation. In order to discriminate the neritic from the pelagic Rauchkofel Limestone, neritic deposits are renamed into Seekopf Formation. The Boden Limestone had to be renamed, because "Boden" as part of Rauchkofel Boden is no valid geographic name. Outcrops of equivalent deposits are found around La Valute and consequently the unit is named La Valute Formation. Gamskofel (typological error in the ASC 2004: Gamskogel Limestone) and Feldkogel limestones were fused and renamed into Polinik Formation, where a major part of the sequence of laminated limestones is cropping out. The Eiskar Limestone is regarded as lithological variation of the Spinotti and Kellergrat formations and therefore partly included in either of the latter units. Following the recommendations of the International Commission on Stratigraphy (ICS) the Kellergrat Reef Limestone and the Plotta Lydite are formalized as Kellergrat Formation and Plotta Formation respectively. For Kollinkofel Limestone the Italian name is accepted and the unit is called Creta di Collina Formation. Marinelli Limestone and Kronhof Limestone are regarded as lithological variation of the Pal Grande Formation (previously Pal Limestone) and therefore integrated into the latter unit. New data on the age and a better understanding of the geometry in the field of the Plotta, Kirchbach, Hochwipfel and Dimon formations led to updating the position of their boundaries in the stratigraphic scheme.

Italian Schemes

As already pointed out before, an official subdivision of the Pre-Variscan chain in lithostratigraphic units did not exist in Italy. In rough approximation the older schemes used are less subdivided than the Austrian one, since they were mainly based on grouping similar facies. This resulted by the fact that, when the effort to produce modern geological maps in the Carnic Alps was performed, it was chosen to avoid a detailed distinction of lithostratigraphic units in a so complicated mountain area. For this reason the necessity to group the units in facies associations arose. Also the names used were not applied unequivocally, and the same unit was named differently in different papers. As an example, compare the names used for the shallow water facies association in three more recent schemes: "Shallow water lms" (VENTURINI & SPALLETTA, 1998), "Calcari di piattaforma" (VENTURINI, 2006), "Calcari del M. Coglians" (VENTURINI, 2009).

Sometimes, authors applied a more strict distinction of units (comparable with the Austrian scheme), but used different formation-names (cf. CORRIGA et al., 2012 for the Lochkovian).

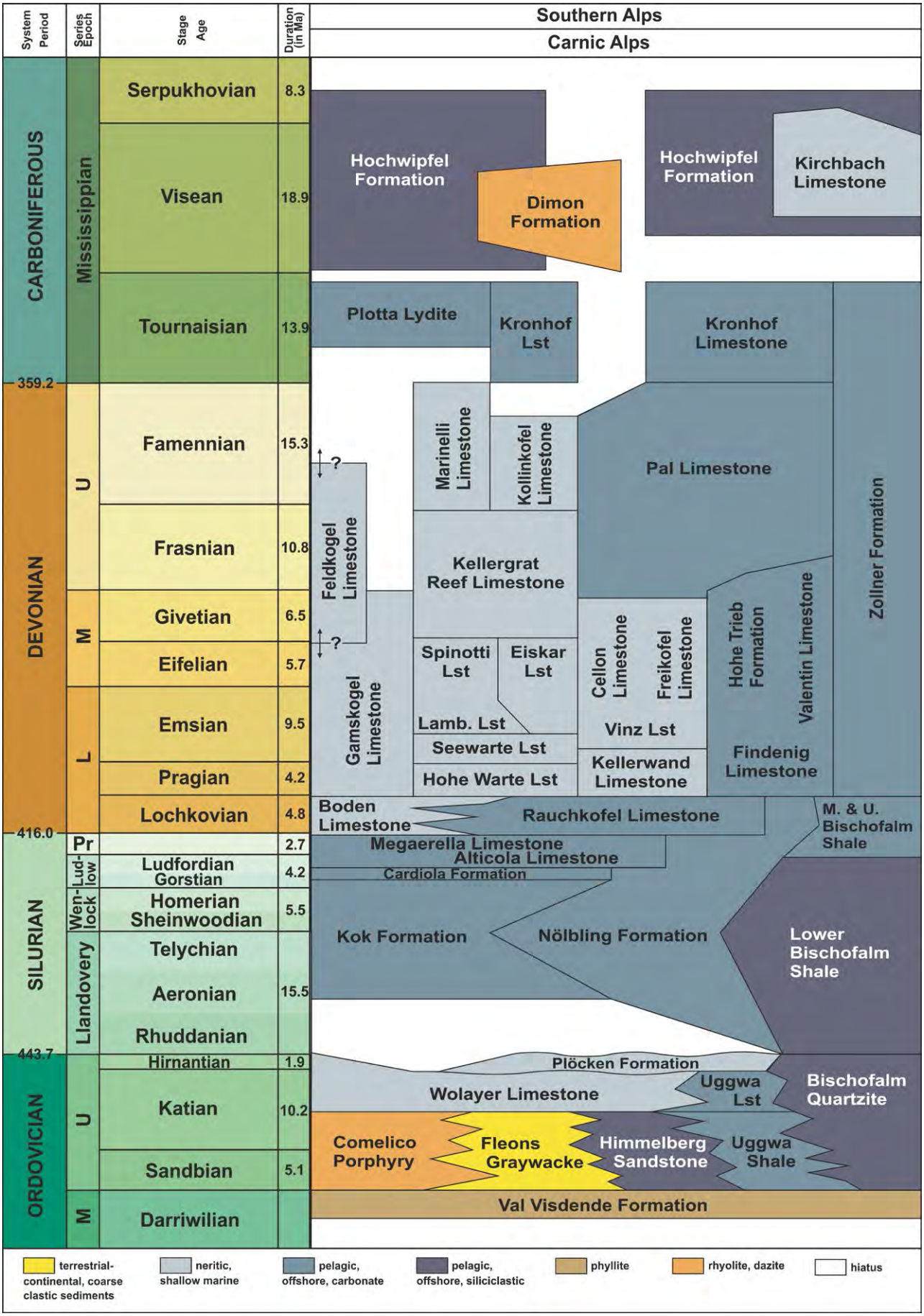
In most Italian schemes the Ordovician was grouped into a comprehensive "Uqua Formation", including both, the shaley and the calcareous facies. The Silurian was subdivided into a mainly calcareous facies ("*Orthoceras* Lms.") and a mainly shaley facies; this subdivision was sometimes extended to the Lochkovian, whereas in other schemes some "platy limestones" were discriminated here. The Devonian consisted of four facies belts: the shallow, transitional and the calcareous and clastic pelagic zones (the latter is sometimes named Zollner Formation); the first three facies belts were followed by a pelagic cephalopod limestone (equivalent of the present Pal Grande Formation). The Hochwipfel Formation and the Dimon Formation represented the clastic, volcanic and volcaniclastic rocks of the Carboniferous, respectively.

Review of the Pre-Variscan sequence

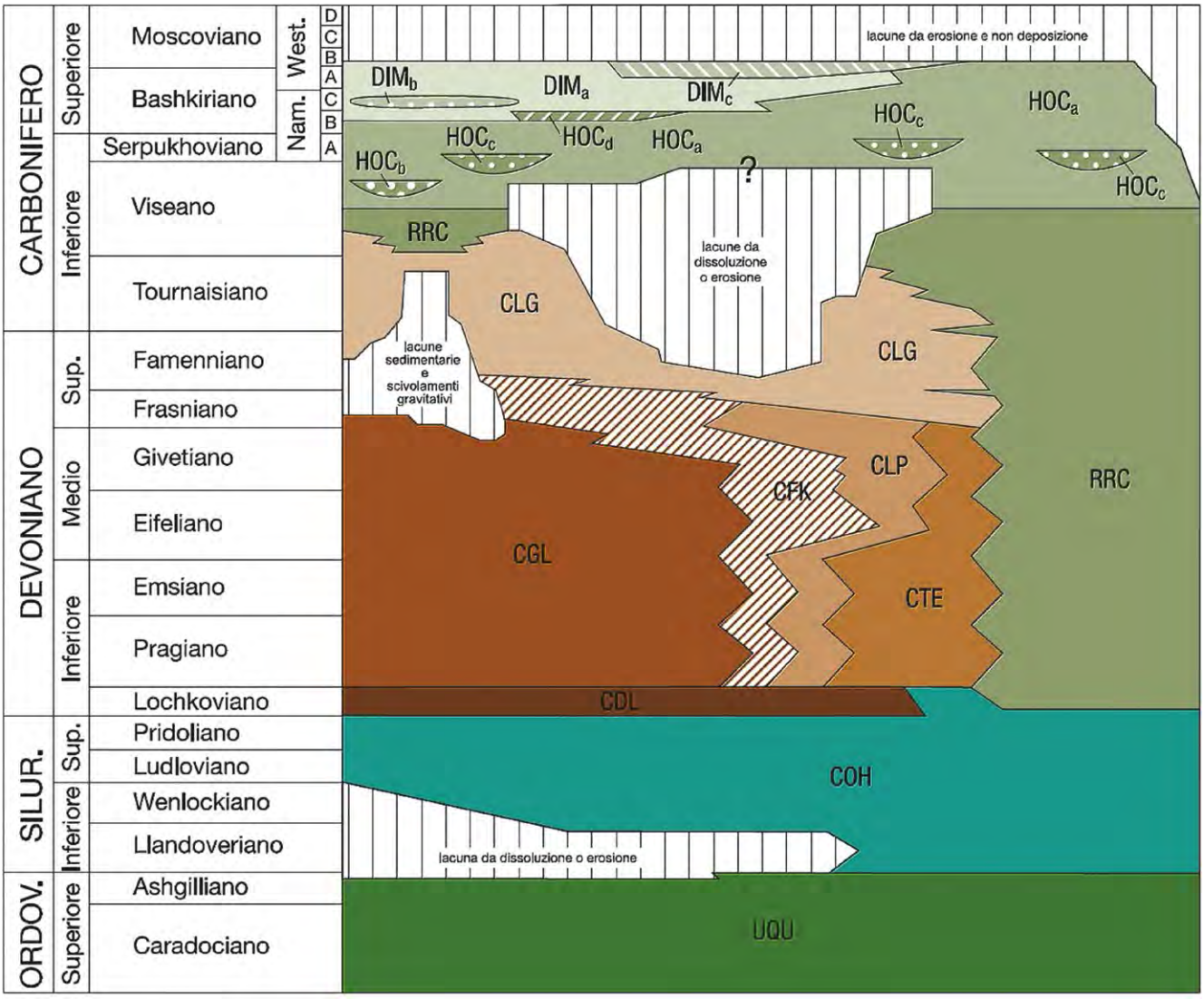
Ordovician

The oldest rocks of the Carnic Alps are Middle Ordovician in age and crop out west of the Val Bordaglia Line. They are represented by phyllitic schists and quartzites, with subordinate conglomeratic layers (Val Visdende Formation), followed by porphyroids (Comelico Formation) and volcaniclastic sediments (Fleons Formation).

With the exception of local fossil occurrences in the Fleons Formation, the most ancient fossiliferous rocks of the Carnic Alps belong to the Valbertad Formation (Katian). They are represented by up to 100 m of shallow-water pelites, sandstones and rare conglomerates deposited at medium-high southern latitudes. Fossils, mainly bryozoans, brachiopods, echinoderms, trilobites and gastropods, are abundant. In the central part of the basin a coarser grained sandstone unit (Himmelberg Formation) crops out. The basal clastic sequence is followed by a pelmatozoan parautochthonous limestone (Wolayer Formation) in the central part of the chain and by the coeval slightly deeper-water limestones of the Uqua Formation. Both units are late Katian in age, although an extension to the



Text-Fig. 4.
Lithostratigraphy of the Carnic Alps in the Austrian Stratigraphic Chart (after PILLER et al., 2004).



Text-Fig. 5.
The stratigraphic chart of the Variscan sequence used for Sheet 31 "Ampezzo" of the Italian Geological Map (after VENTURINI, 2009). Abbreviations: CDL: Calcari del Rauchkofel; CFK: Calciruditi del Freikofel; CGL: Calcari del M. Coglians; CLG: Calcari di Pramosio; CLP: Calcareniti di Pal Grande; COH: Calcari ad *Orthoceras* e Argilliti a Graptoliti; CTE: Calcari di Cuestalta; DIM_{a-c}: Formazione del Dimon; HOC_{a-d}: Formazione del Hochwipfel; RRC: Radiolariti del Rio Chianaletta; UQU: Formazione dell'Uqua (columns left-right: System/Period, Series/Epoch, Stage/Age).

basal Hirnantian cannot be excluded. The global glacially-induced regression of the Hirnantian is documented by the calcareous sandstone of the Plöcken Formation, providing evidence of the Hirnantian $\delta^{13}C$ excursion (SCHÖNLAUB et al., 2011). It resulted in erosion and local non-deposition, as also indicated by Silurian strata resting disconformably upon the Upper Ordovician sequence (SCHÖNLAUB & HISTON, 1999; BRETT et al., 2009; HAMMARLUND et al., 2012; PONDRELLI et al., 2015).

Silurian

Silurian deposits are irregularly distributed within the Carnic Chain, and range from shallow water bioclastic limestones to nautiloid-bearing limestones, interbedded shales and limestones to deep-shelf or basinal black graptolitic shales and cherts ("lydites"). The overall thickness does not exceed 60 m. The Silurian transgression started at the base of the Llandovery, and, due to the disconformity separating the Ordovician and the Silurian, sediments of unknown thickness are locally missing, which correspond to several conodont zones of Llandovery to Ludlow age (SCHÖNLAUB & HISTON, 1999; BRETT et al., 2009; ŠTORCH & SCHÖNLAUB, 2012; CORRADINI et al., 2015).

The Silurian of the Carnic Alps is subdivided into four lithological facies representing different depths of deposition and hydrodynamic conditions (SCHÖNLAUB, 1979, 1980; WENZEL, 1997). The Wolayer facies is characterized by proximal sediments, while the Bischofalm facies corresponds to 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 central sectors of the chain, as follows: Wolayer-, Plöcken-, Findenig- and Bischofalm facies. The depositional features suggest an overall transgressional regime from Llandovery to Ludlow. Uniform limestone sedimentation within the Pridoli suggests that more stable conditions developed (SCHÖNLAUB, 1997).

In terms of lithostratigraphy, three calcareous units are vertically developed in the proximal parts of the basin: the Kok Formation (Telychian-lower Ludfordian), the Cardiola Formation (Ludfordian) and the Alticola Formation (upper Ludfordian-basal Lochkovian). These units mostly correspond to the "*Orthoceras* limestones" of earlier authors, and are represented by bioclastic wackestone-packstones. The colour gradually turns from brownish and dark gray in the lower Silurian levels, often reflecting a high iron content, to dark then light gray and pink in the Pridoli (Ferretti, 2005; Ferretti et al., 2012; Histon, 2012a, b). Nautiloid cephalopods are very abundant. Trilobites, bivalves and conodonts are common; crinoids, gastropods, ostracods, brachiopods and chitinozoans are present as well (Brett et al., 2009; Corradini et al., 2010, 2015; Histon, 2012b).

In the deeper part of the basin, the Bischofalm Formation was deposited. It is a tripartite succession, up to 60 m thick, of black siliceous shales, with cherts interbedded (1), clayish alum shales (2), and black graptolitic shales (3) which mainly were deposited in a euxinic environment. Graptolites are generally abundant (Schönlaub, 1997). Intermediate sedimentary conditions between calcareous and shaley facies are represented by the Nölbling Formation, composed of alternating black graptolitic shales, marls and limestone beds (Schönlaub, 1997).

Devonian

During the Lochkovian (Lower Devonian) the Carnic basin started to differentiate (Kreutzer, 1990, 1992; Schönlaub, 1992; Kreutzer et al., 1997; Hubmann et al., 2003; Suttner, 2007; Corriga et al., 2012). The Seekopf Formation was deposited in moderately shallow water, and the Rauchkofel Formation and La Valute Formation on the outer platform. In the deeper parts of the basin the Nölbling Formation and the Bischofalm Formation continued up to the top of the Lochkovian (*M. hercynicus* graptolite Zone).

Starting from 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: 15). From the Pragian to the lower Frasnian, within short distances a strongly varying facies pattern developed, indicating a progressive but highly diverse deepening of the basin. More than 1000 m of reef and near-reef limestones (Hohe Warte Formation, Seewarte Formation, Lambertenghi Formation, Spinotti Formation, Kellergrat Formation) and various intertidal lagoonal deposits (Polinik Formation) are time equivalent to less than 100 m of pelagic limestones (Findenig Formation and Valentin Formation). In the intermediate fore-reef areas thick piles of mainly gravity-driven deposits accumulated (Kellerwand Formation, Vinz Formation, Cellon Formation, Freikofel Formation). Pelites and cherts were deposited in the deeper part of the basin (Zollner Formation). Between the fore-reef and the deeper part of the basin gravity driven deposits alternate with pelagic limestones and black shales (Hoher Trieb Formation).

Reefs reached their maximum extension during the Givetian and early Frasnian, when the Carnic Alps were at a latitude of about 30° south (Schönlaub, 1992). Four major reef areas developed, now represented by the cliffs of Mt. Coglians/Hohe Warte, Mt. Zermula, Mt. Cavallo/Roßkofel and Mt. Oisternig, beside several minor buildups. The fossil content is very rich, having: stromatoporoids, tabulate and rugose corals, brachiopods, crinoids, gastropods, ostracods, bivalves, cephalopods, trilobites, algae, calcispheres and foraminifers (Kreutzer, 1990, 1992; Rantitsch, 1992; Schönlaub, 1992; Kreutzer et al., 1997).

Devonian / Carboniferous

During the early Frasnian, extensional tectonic activity caused a collapse of the basin and consequently reefs rapidly drowned and reefal organisms disappeared. Starting from the upper Frasnian (Upper *rhenana* conodont Zone) a uniform pelagic environment developed, which continued up to the lowermost Visean (Schönlaub, 1969; Schönlaub & Kreutzer, 1993; Perri & Spalletta, 1998): the pelagic Pal Grande Formation is represented by a grayish, pinkish, reddish wackestone with cephalopods. Locally, cherty sediments (Plotta Formation) capped the Pal Grande Formation.

Carboniferous

Starting from the upper Visean, up to 1000 m of arenaceous pelitic turbidites of the Hochwipfel Formation were deposited. It is interpreted as a Variscan flysch sequence (Vai, 1963; Spalletta & Venturini, 1988 and references therein). These deposits indicate a Variscan active plate margin in a collisional regime following the extensional tectonics during the Devonian and the Mississippian (Schönlaub & Histon, 1999) evolving from a strike-slip context (Spalletta & Venturini, 1988; Vai, 1998). The Hochwipfel Formation consists of quartz-sandstones and grayish shales, turbidites, with intercalations of mudstones, chaotic debris flows and chert and limestone breccias. Locally, plant remains and rare trace fossils can be found (Amerom et al., 1984; Amerom & Schönlaub, 1992). Short local episodes of carbonatic deposition during the Early Visean to the Serpukhovian boundary are represented by the Kirchbach Formation. In the upper part of the Mississippian, basic volcanites and volcaniclastic deposits (Dimon Formation) occur. They are related to crustal thinning associated to a rifting episode (Vai, 1976; Rossi & Vai, 1986; Läufer et al., 1993, 2001). These conditions continued up to the Late Bashkirian (Pennsylvanian), when the Hercynian orogeny in the Carnic area marked the end of the deposition of the Pre-Variscan sequence (Venturini, 1991).

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