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Geology and stratigraphy of the Cason di Lanza area (Mount Zermula, Carnic Alps, Italy)

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Abstract: *In the Cason di Lanza-Mt. Zermula area rocks from Ordovician to Permian are exposed. They belong to the "Variscan sequence" and to the "Permo–Carboniferous sequence" of the Carnic Alps. The structural settings and the stratigraphic sequence of neritic and pelagic deposits are described.*

Introduction

Cason di Lanza Pass is located in the heart of the Carnic Alps, along the mountain road connecting Paularo and Pontebba (Fig. 1). The Carnic Alps are one of the classic areas for the study of the Palaeozoic in Europe (BANDEL, 1972; SCHÖNLAUB, 1979, 1985; SELLI, 1963; VAI, 1976). This area represents the external non- to low-metamorphic portion of the Variscan substratum within the Southern Alps (VAI, 1976; SPALLETTA et al., 1982; BRIME et al., 1998).

Fig. 1: Location map and panoramic view of the Cason di Lanza Pass, taken from the top of Mt. Pizzul. In front right the white cliffs of the Zuc della Guardia, constituted by Devonian reefal carbonates. In the northern side of the valley, behind the hut, mainly Permo–Carboniferous rocks are exposed.

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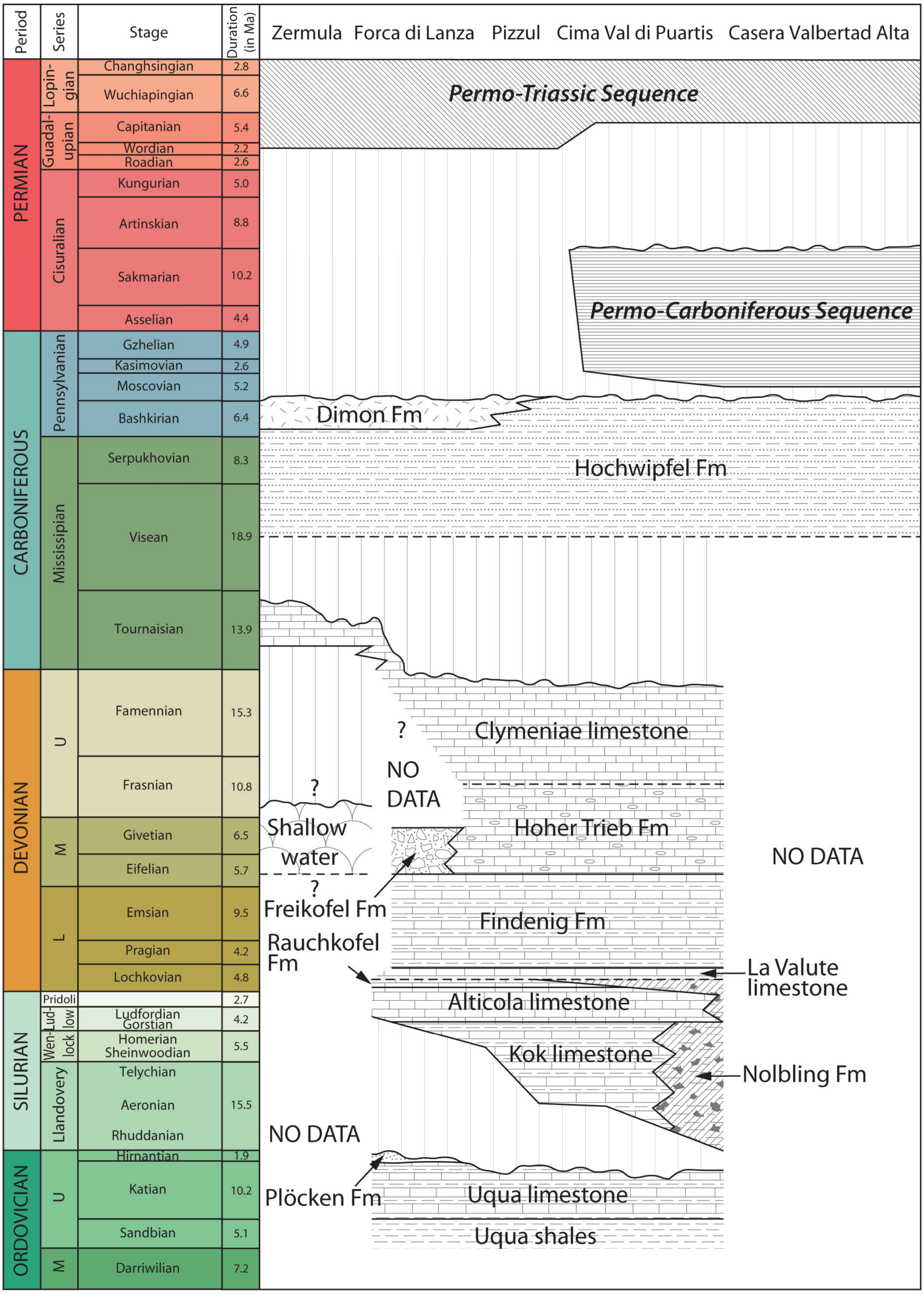

Fig. 2: Simplified stratigraphic sketch of the Cason di Lanza Pass area.

The succession of the Cason di Lanza Pass area ranges from Ordovician to Lower Permian: the Variscan and the Permo–Carboniferous sequences of the Carnic Palaeozoic are widely exposed in an area of a few square kilometers, with the lowermost part of the Permo–Triassic succession being locally exposed. The Variscan sequence includes rocks of Late Ordovician to Early Carboniferous age that were affected by the Variscan orogeny during the Westphalian (VENTURINI, 1990). The Permo–Carboniferous sequence is also known as 'late Hercynian' sequence (VENTURINI, 1990) and ranges from Early Carboniferous to Early Permian. The Permo–Triassic succession is part of the so-called 'Alpine' sequence (VENTURINI, 1990). In the study area only Upper Permian rocks are exposed. The present complex geological setting is due to the Alpine tectonics, both extensional and compresional phases, that involved the whole Carnic area, starting from the Cenozoic.
The morphology of the area conforms to a typical high mountain morphology, controlled by lithology (massive Middle Devonian limestone constituting the highest and sharpest edifices), tectonic, mass wasting and with a glacial imprint.

History of researches

The geology of Mt. Zermula and the Cason di Lanza area was studied since the second half of 19th century. For long time the main goal of scientist was the reconstruction of the stratigraphic sequence of the Carnic Alps, and the age of the calcareous mountain groups was debated on the basis of lithological similitude with the other mountains of the area and recovery of fossil remains from the underlying sediments. In this respect, the calcareous cliffs of Mt Zermula were considered either Carboniferous (i.e.: STUR, 1856; PIRONA, 1861; TARAMELLI, 1878, 1881, 1882; PANTANELLI, 1882), or Triassic (FRECH, 1894). Finally, TARAMELLI (1895), on the basis of the stratigraphy of the area, recognized the Devonian age of Mt. Zermula.
At the beginning of the 20th century the Palaeozoic sequence in the Cason di Lanza area was widely investigated by Michele Gortani and Paolo Vinassa de Regny, who considered the area as part of the "central core of the Carnic Alps", and published tens of papers on various geological and palaeontological topics. Among them, they described the stratigraphic sequence of the area (VINASSA DE REGNY & GORTANI, 1905a, 1908; GORTANI, 1913, 1915, 1920), discriminating for the first time the Silurian shales from the Carboniferous sediments, and published a geological map of the area (VINASSA DE REGNY & GORTANI, 1905a). Furthermore, they described several fossils from the area: various Ordovician groups (VINASSA DE REGNY, 1910) Silurian graptolites (VINASSA DE REGNY, 1907; GORTANI, 1920), Carboniferous plant remains (VINASSA DE REGNY & GORTANI, 1905b) and Permian invertebrates (VINASSA DE REGNY & GORTANI, 1905b).
After a gap of several years, the Cason di Lanza/Zermula area was investigated in the sixties within mapping projects (SELLI, 1963a), with special regards on the Permo–Carboniferous sequence (SELLI, 1963b). At the same time biostratigraphic researches on conodonts were carried out on different intervals of the Variscan sequence: Ordovician (MANZONI, 1965; SERPAGLI & GRECO, 1965; SERPAGLI, 1967) and Upper Devonian/Lower Carboniferous (MANZONI, 1965, 1966; FERRARI & VAI, 1966). Devonian corals were studied by FERRARI (1968).
More recently, the Permo–Carboniferous sequence cropping out north of Cason di Lanza was studied in detail by VENTURINI (1990a, 1990b). The age of the various calcareous units from Ordovician to Lower Carboniferous was studied by means of conodonts in several stratigraphic sections (i.e.: BAGNOLI et al., 1998; PERRI & SPALLETTA, 2001; KAISER, 2005; CORRIGA, 2011; CORRIGA et al., 2011). Finally, fossils belonging to different groups and ages were described: vertebrates (DALLA VECCHIA, 2000), loboliths (CORRADINI et al., 2005), graptolites (PIRAS & SIMONETTO, 2011), corals (KIDO et al., 2011b), and trace fossils (MIETTO et al., 1986).

Geological and structural settings

The Variscan sequence is largely laterally uniform across the Cason di Lanza Pass area with the exception of the Eifelian–Frasnian interval, when the basin was differentiated in a shallow water part, with the deposition of back reef and reef deposits, and a distal part, with pelagic deposits interlayered by gravity driven redeposited material coming from the shallow water units (Fig. 2). During the Westphalian, this sequence was affected by the Variscan orogeny, which in the Carnic Alps resulted in a non to low grade metamorphic thin-skinned fold-and-thrust belt with structures mainly N120°E trending (VENTURINI, 1990a; BRIME et al., 2008). In the Cason di Lanza Pass area a top to the south detachment led to the formation of a pluri-kilometric asymmetric NW-SE trending fold with an

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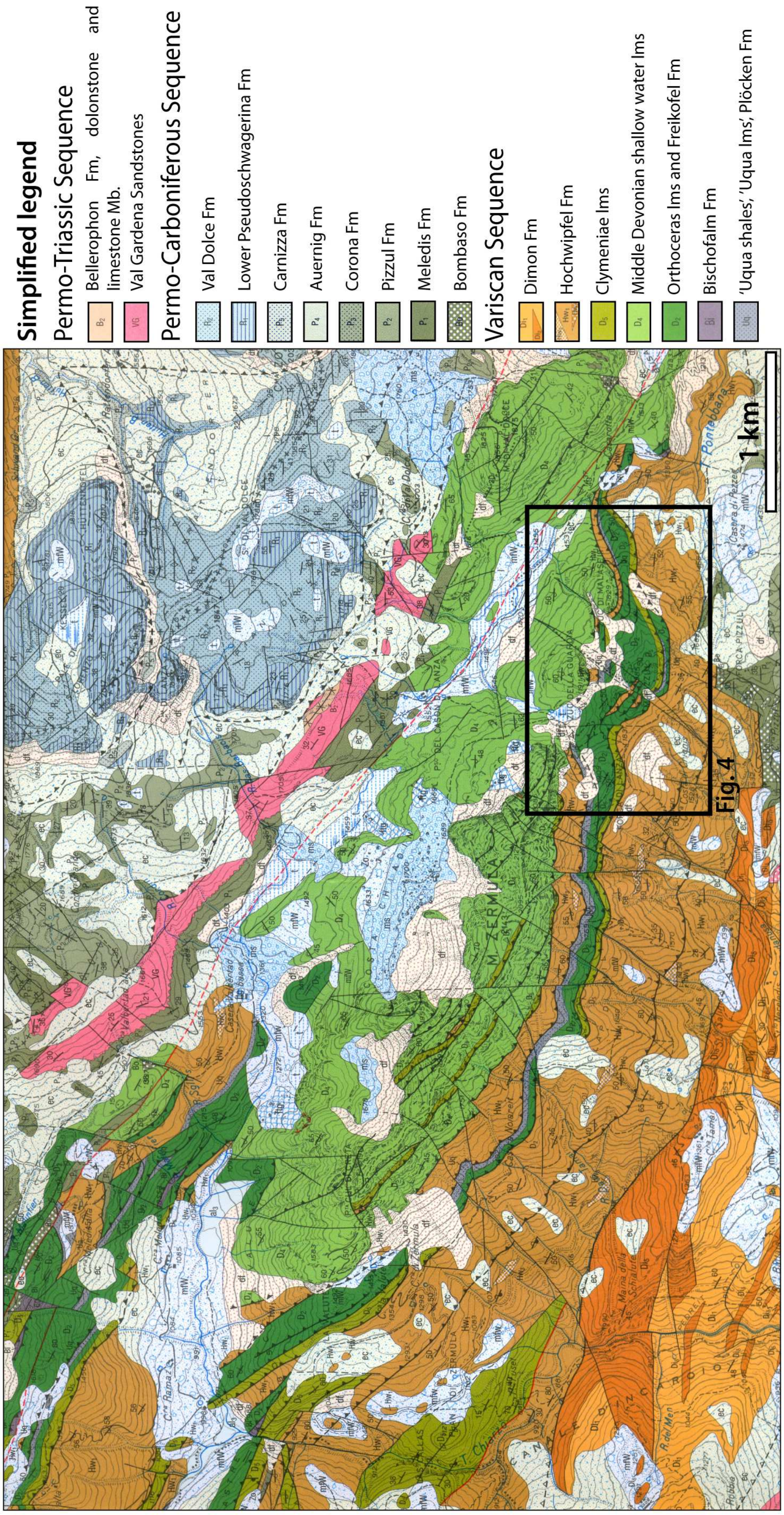

Fig. 3: Simplified geological map of the Cason di Lanza Pass area (after Venturini et al., 2001). See text for the description of the units. Light patterned yellow, blue and red represents Quaternary deposits. The box represents the location of the detailed geological map of Fig. 4.

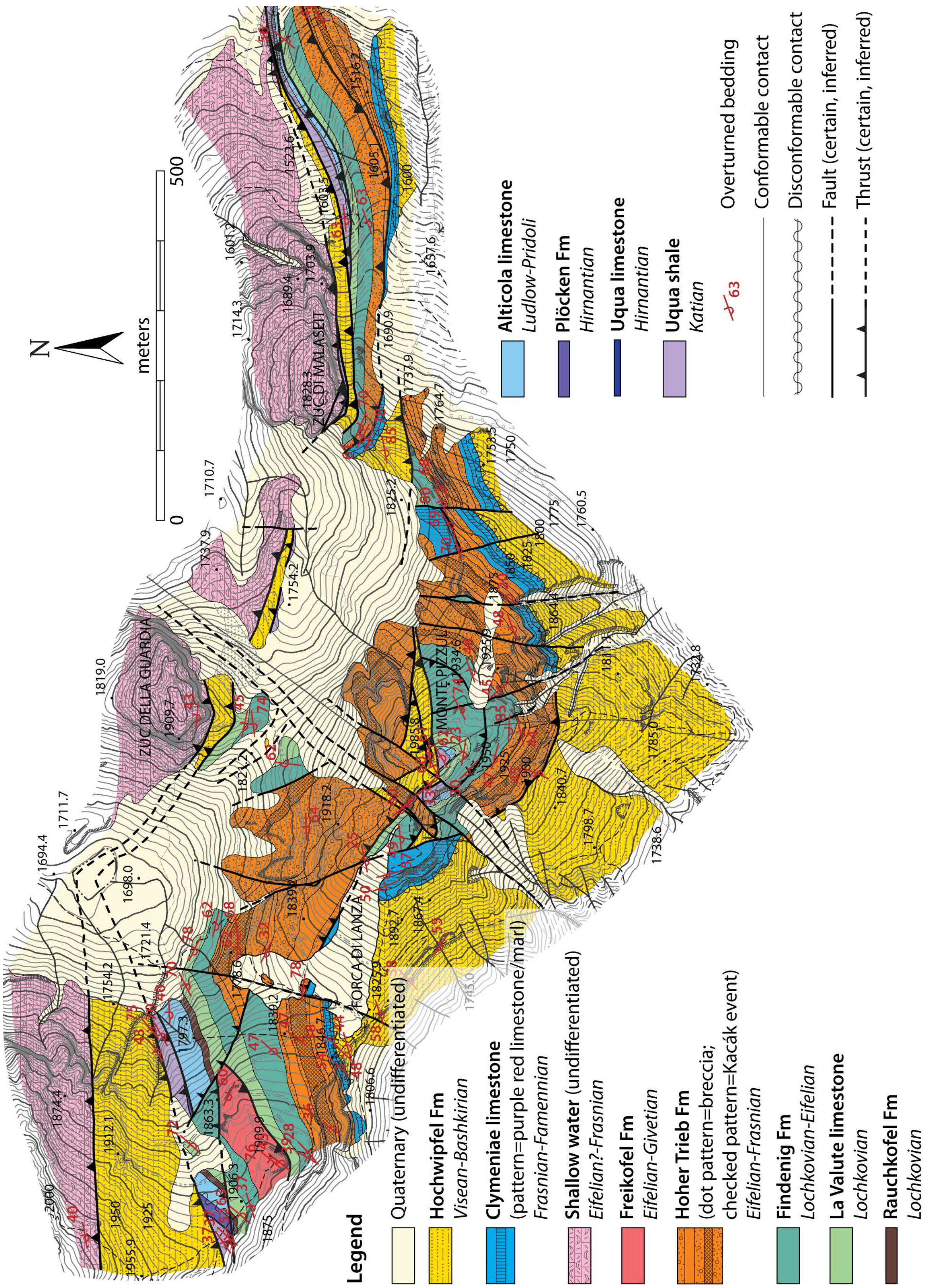

Fig. 4: Detailed geological map of the mount Pizzul area.

overturned flank which includes the Zermula and Pizzul mountains as well as the Malinfier gorge (VENTURINI, 1990a) (Fig. 3). Centrimetric to decametric large parasitic asymmetric folds are superimposed to the pluri-kilometric fold where lithological characters allow such ductile deformation.

The Variscan belt was then subjected to trastensional syn-sedimentary tectonic (VENTURINI, 1990a) which lead to the formation of the Forni Avoltri, Pramollo and Tarvisio basins. The Cason di Lanza area represents the westernmost portion of the Pramollo basin, the largest and better preserved one among these basins. The glacio-eustatic sea level fluctuations superimposed on the higher order tectonically driven subsidence controlled a succession characterized by intercalation of fluvio-deltaic and shallow sea deposition (VENTURINI, 1990a).

The Permo–Carboniferous sequence rests in angular unconformity on top of the Variscan substratum (Punta Cul di Creta, Fig. 3) but in general the contact with the Variscan substratum is of tectonic origin (Fig. 3). The basal part of the Permo–Triassic sequence is also exposed in the study area, resting in disconformity on top of the Permo–Carboniferous sequence in the Casera Valbertad alta area (Fig. 3).

The Carnic area were disrupted by at least three Alpine compressional phases (VENTURINI, 1990a; LÄUFER, 1996), which have been characterized using the stress tensor inversion method from fault striations (PONDRELLI, 1998). The oldest phase of Chattian–Burdigalian age, show a maximum compressional stress roughly coaxial with the Variscan compression in a compressive stress regime. This resulted in enhancing the shortening associated with the structures inherited from the Variscan orogeny (VENTURINI, 1990a; LÄUFER, 1996).

The second alpine phase, of Tortonian–Serravallian age, is characterized by a N-S trending maximum compressional stress, in a compressive stress regime (PONDRELLI, 1998), which resulted in E-W trending south-verging thrusts, NW-SE trending dextral strike-slip faults and NE-SW trending sinistral strike-slip faults. In the study area, E-W trending south verging thrusts lead the shallow water Middle Devonian units of the Mount Zermula, Zuc della Guardia and Zuc di Malaseit to overthrust on top of the Forca di Lanza - Mount Pizzul Upper Ordovician to Lower Carboniferous succession (Figs 3, 4, 5). This thrust tectonically obliterated most of the most proximal slope deposits (Freikofel Fm) which are preserved only in a single outcrop close to the Forca di Lanza (Fig. 4).

The third alpine phase, of Plio–Pleistocene age, is characterized by a NE-SW trending maximum compressional stress, in a strike-slip stress regime (PONDRELLI, 1998), which resulted in a dextral strike-slip reactivation of many E-W and N120°E trending Variscan and Alpine structures. In the study area, this phase is expressed by the N120°E trending dextral strike-slip Cason di Lanza line (Fig. 3), inherited from a syn-sedimentary Permo–Carboniferous fault (VENTURINI, 1990a), which offset the Variscan pluri-kilometric anticline, placing in contact the Variscan and the Permo–Carboniferous sequences (VENTURINI, 1990a). The overturned part of the Variscan anticline rests to the south of the fault, while the part with the ‘normal’ way up is located to the north.

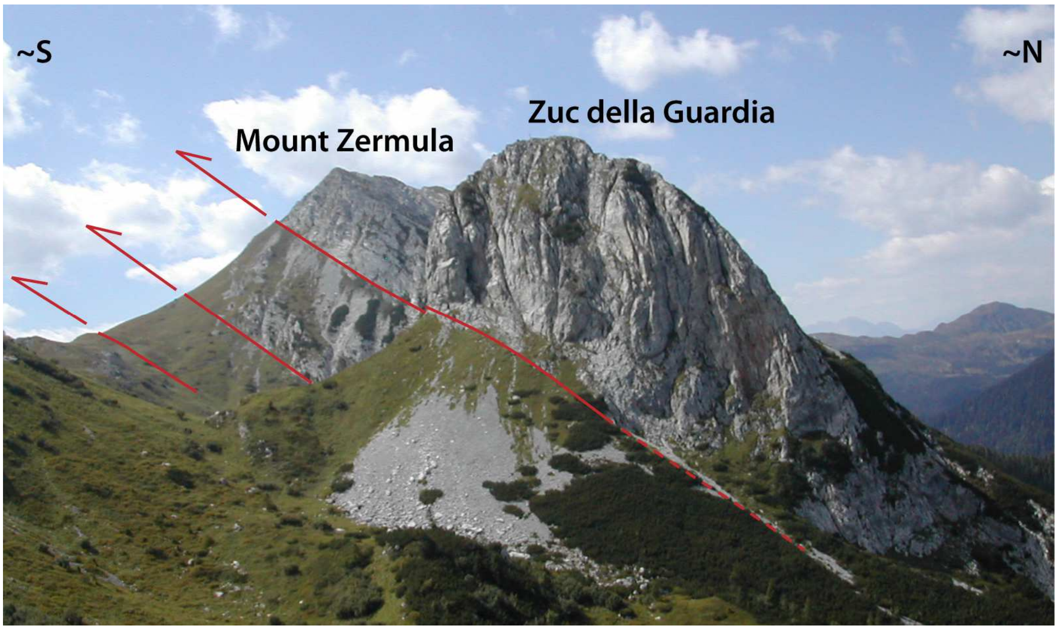

Fig. 5: Roughly east-west trending north dipping Alpine thrust of Tortonian–Serravallian age affecting the Variscan sequence.

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Stratigraphy

As already stated before, in the Cason di Lanza area rocks from Ordovician to Permian are exposed. It is remarkable that in a small area the whole Carnic Palaeozoic sequence is observable. However, some units crop out widely, whereas others are limited to a few small localities. In a rough approximation, Devonian rocks are by long the most abundant and differentiated, including facies deposits from very shallow waters to the basin. Carboniferous rocks are abundant, too, mainly North of Cason di Lanza pass. Palaeozoic rocks oif different ages are less widespread, but good outcrops or sections are present.

Ordovician

The oldest rocks in the area are of Ordovician age and belong to the "Uqua shales", which consists of shales, siltstones, sandstones and rare conglomerates. Fossil content is generally high and usually distributed in distinct layers. The unit can be observed in a few small outcrops in the Cadin di Lanza and at Mt. Pizzul (Figs 3, 4), where one of the most fossiliferous Ordovician localities of the Carnic Alps is exposed (Fig. 6). Here brachiopods, trilobites and bryozoans are abundant; cystoids, crinoids and gastropods are rare.
The sequence continues with a few meters of nodular limestones ("Uqua limestones"), and calcareous sandstones (Ploecken Fm). Both these units are poorly exposed at Forca di Lanza.

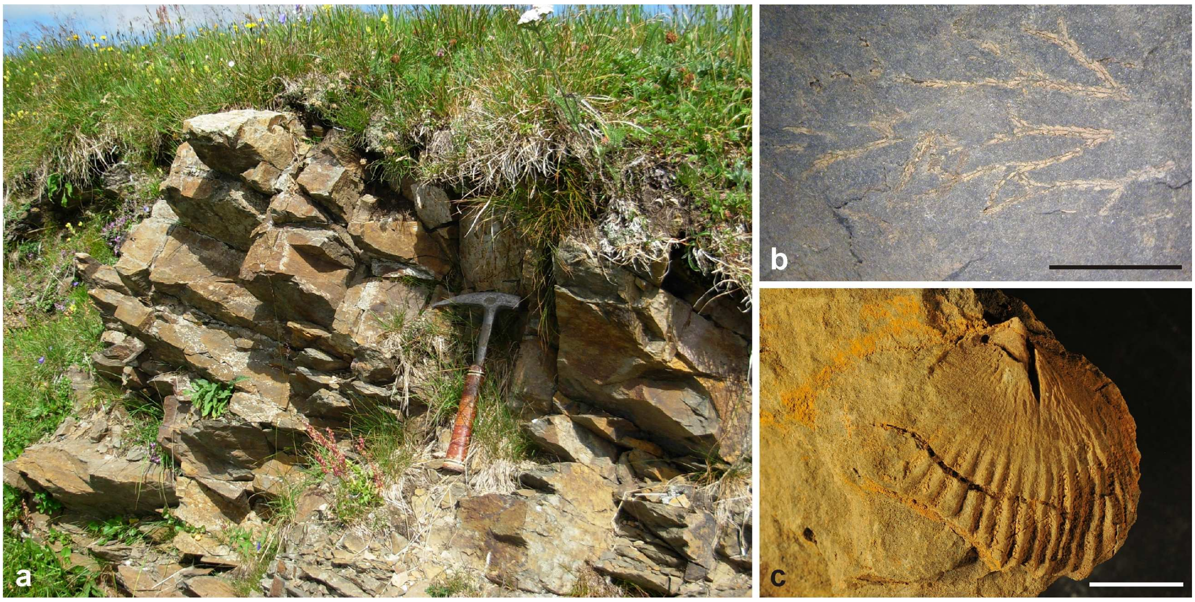


Fig. 6: The "Uqua shales" outcrop at the top of Mt. Pizzul. (a) Detail of the outcrop. (b) undetermined bryozoans. (c) brachiopod. Scale bar = 1 cm.

A good locality to observe the Ordovician sequence is the Valbertad section (BAGNOLI et al., 1998), about 3 Km west of Cason di Lanza (Fig. 7). It exposes both the "Uqua shales" (36 m) and the "Uqua limestones" (2 m). The former is more shaley and less sandy than in the type Uqua locality and outcrops of Cadin di Lanza and Mt. Pizzul. It contains a diverse shelly fauna of Sandbian–Katian age. Disarticulated brachiopod valves (especially large *Porambonites*) and bryozoans are concentrated in lenticular layers through the entire section. Trilobites are rarely present only in the lower part; cystoids are more abundant in the middle part of the section. In addition, the Valbertad section provided the first evidence of Edrioasteroidea in the Ordovician of the Carnic Alps (BAGNOLI et al., 1998). Figured bioturbations and fossil traces are also present.
At about 25 m from the base of the investigated part of the section, centimetric nodular micrite lenses appear in concentrated intervals alternating with sandstones. The uppermost 2 m of the section are represented by the nodular micritic calcareous member of the Uqua Fm ("Uqua limestones"). The rich conodont fauna allowed to refer these beds to the upper Katian–Hirnantian (*A. ordovicicus* Zone; BAGNOLI *et al*., 1998). Well-preserved brachiopods, phosphatic sclerites of the problematic palaeoscolecid *Milaculum*, ostracodes and sponge spiculae were also recovered from the conodont fraction.

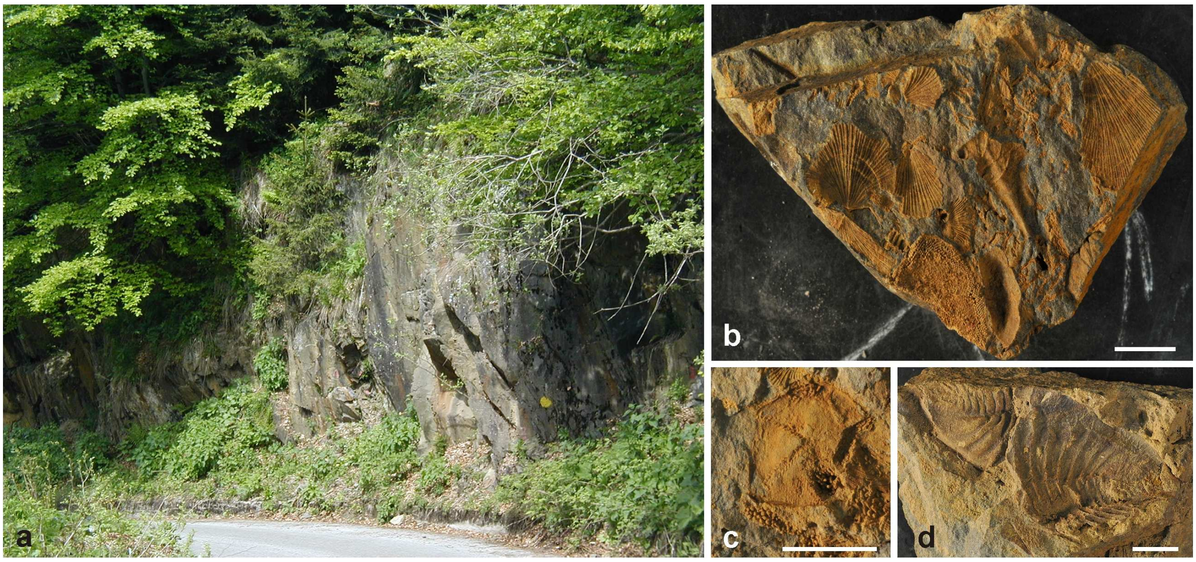


Fig. 7: The Upper Ordovician Valbertad section. (a) Panoramic view of the section. (b) slab with brachiopods and bryozoans. (c) cystoid plate. d: trilobite fragments. Scale bar = 1 cm.

Silurian

Silurian rocks in the Cason di Lanza area are poorly exposed and only a few small outcrops are known. Both, shaley and calcareous facies are observable.

Silurian black shales with graptolites are mainly present in the northern flank of the Rio di Lanza valley in the area of Casera Meledis, about 4 Km west of Lanza pass (Fig. 3). Graptolites from a few outcrops, currently almost hidden by soil and vegetation, were described by VINASSA DE REGNY & GORTANI (1905a), VINASSA DE REGNY (1906) and GORTANI (1923); recently PIRAS & SIMONETTO (2011) revised the classical "Casera Meledis" section (Fig. 8): "it is a very small outcrop, almost hidden in the wood, where abundant shale debris occur on the path and a few beds are exposed after digging a short trench" (PIRAS & SIMONETTO, 2011: p. 14), along the path CAI 449a between Casera Meledis bassa and Casera Meledis alta. The authors reported seven graptolite taxa from the lower Llandovery *triangulatus* Zone.

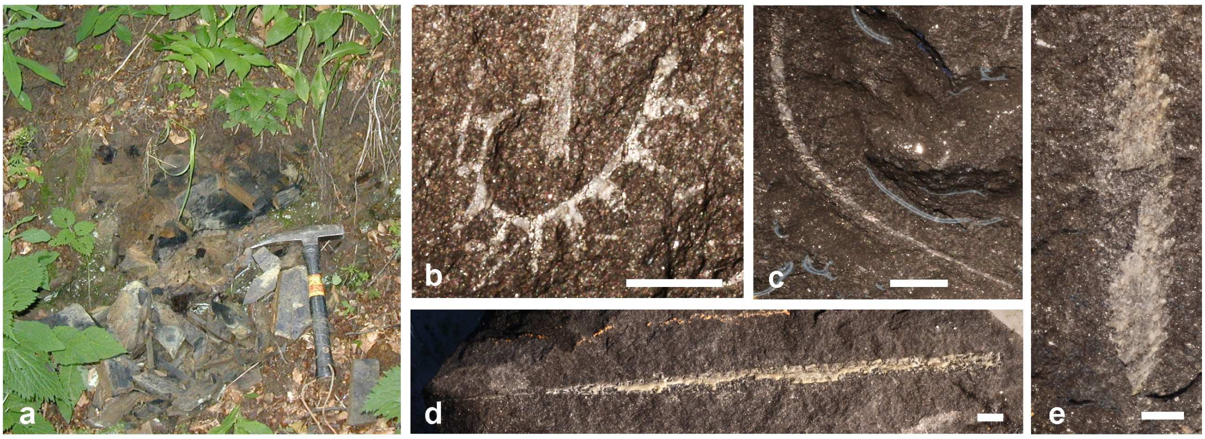


Fig. 8: View of the outcrop and graptolites from the Casera Meledis section. (a) close view of the outcrop. (b) *Demirastrites triangulatus* (HARKNESS, 1851). (c) *Monograptus revolutus* KURCK, 1882. (d) *Rhaphidograptus thoernquisti* (ELLES & WOOD, 1906). (e) *Parapetalolithus palmeus* (BARRANDE, 1850). Scale bar = 2 mm.

Extended outcrops of Silurian black shales and interbedded limestones (Nölbling Fm) in the La Valute area, the northwestern part of Mt. Zermula massif have been dated by conodonts to the Wenlock (*rhenana* and *sagitta* zones) (Fig. 3).

The "*Orthoceras* limestones" are exposed only in a few minor outcrops in the Mt. Pizzul area (Fig. 4). The best section is located at Cadin di Lanza (Cadin II section), where a few meters of *Alticola* limestone crop out (Fig. 9). It is a light grey-brownish, well bedded, micritic limestones, with orthoceratids. The section has been dated by means of conodonts to the Pridoli (CARTA, 2011).

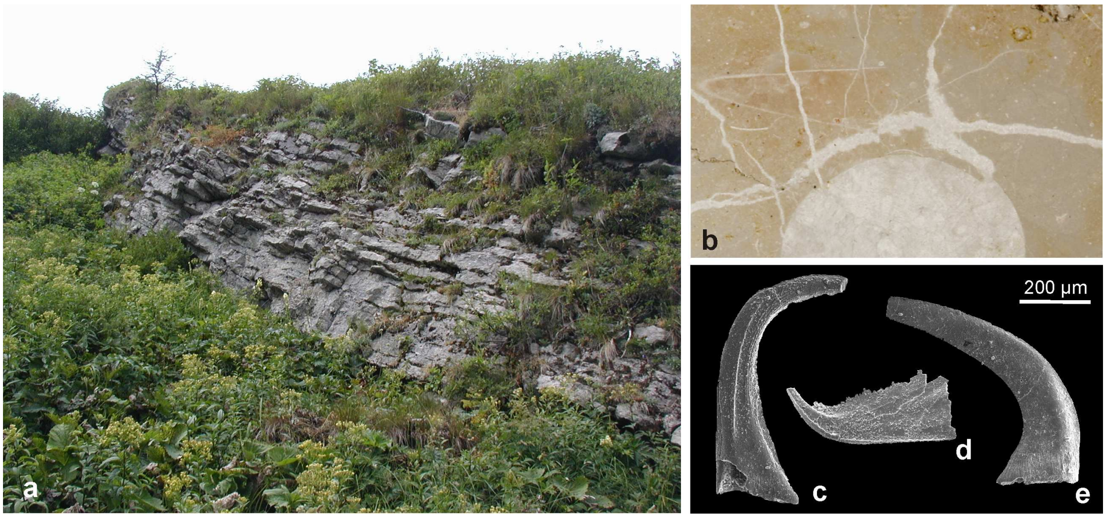


Fig. 9: The Cadin II section. (a) Panoramic view of the section. (b) microfacies with orthoceratid nautiloids. (c)-(e) conodonts; (c) *Panderodus unicostatus* (BRANSON & MEHL, 1933); (d) *Belodella resima* (PHILIP, 1965); (e) *Panderodus recurvatus* (RHODES, 1953).

Lower Devonian

Lower Devonian deposits are abundant and widespread in the Cason di Lanza area, where four lithostratigraphic units are discriminated: Rauchkofel Fm, Nölbling Fm, La Valute limestone and Findenig Fm. All these units are well exposed in Cadin di Lanza- Mt. Pizzul area, just south of the pass, and/or in the Rio Malinfier-La Valute area, a few Km on the west (Figs 3-4).

Fig. 10: Loboliths from the Rauchkofel Fm in the Cadin di Lanza area. (a) slab with four loboliths and a few stem fragments (Museo Friulano di Storia Naturale). (b) slab in Cadin di Lanza area with several small loboliths (arrows) and crinoidal and cephalopod remains. (c) level with loboliths in the Rio Malinfier West section. (d) detail of photo (c).

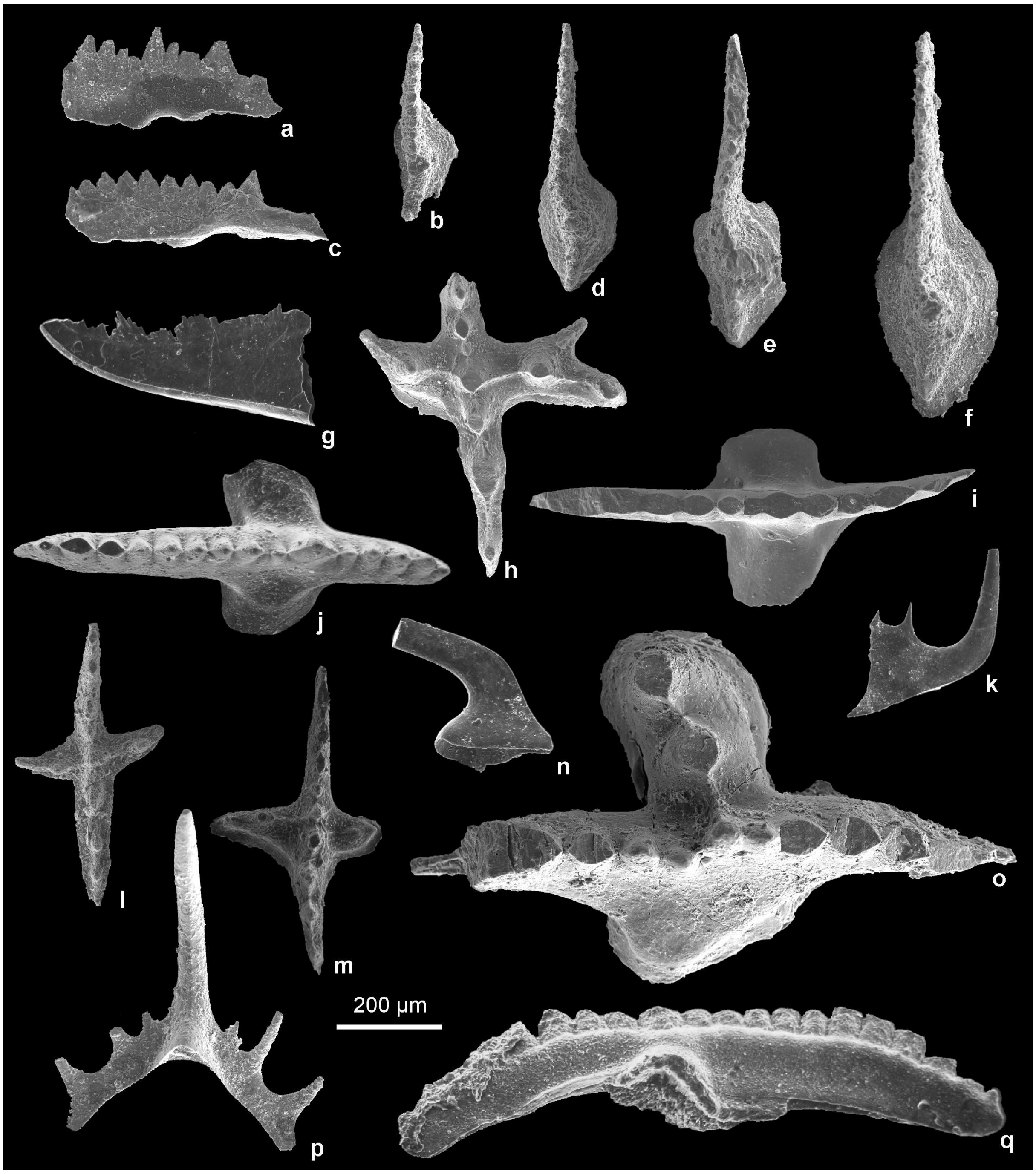
The Rauchkofel Fm is represented by few meters of dark wackestones to packstones with black shales interbedded. The fossil fauna is dominated by orthocerathid cephalopods, crinoids and conodonts; graptolites, brachiopods, bivalves are also present; loboliths (Fig. 10) mark a level just above the Silurian/Devonian boundary (CORRADINI et al., 2005; CORRIGA, 2011).
The Nölbling Fm ranges from lower Silurian to Lochkovian and consists of black shales, with mudstone and wackestone lenses interbedded. Pyritized fossils (Fig. 11) and rare conodonts are present in the carbonatic levels, and in some places graptolites can be obtained from the shales. This unit reaches its maximum thickness (about 40 meters) in the Valute area; however, likely tectonic duplication may have occurred. The upper part of the unit and the boundary with the overlying La Valute limestone is exposed in the Rio Malinfier section (Fig. 11).

Fig. 11: (a) The Nölbling Fm-La Valute limestone transition in the Rio Malinfier section. (b)-(c) pyritized fossils from the Nölbling Fm, Rio Malinfier area; (b) gastropod; (c) pygidium of an encrinurid trilobite. Scale bar = 5 mm.

The La Valute limestone is represented by about twenty meters of centimetric thick light grey-ochre nodular mudstones and wackestones with orthoceratids and conodonts. The upper part of the unit grades into the overlying Findenig Fm. This latter unit is about 25 meters thick and consists of centimetric thick layers of nodular purple red mudstones and wackestones with marl millimetric thick intercalations. Locally, for example in the Malinfier gorge, centimetric thick levels of gray packstones occur suggesting gravity driven redeposition from the shallower part of the basin (BANDEL, 1972, 1974; VAI, 1980).
A detailed stratigraphy of the Lower Devonian of the area has been obtained by means of conodonts (Fig. 12) in several sections of the area (CORRIGA, 2011; CORRIGA et al., 2011, and unpubl. data).

All these units are well exposed in the Rio Malinfier area. The Rio Malinfier West section (CORRIGA, 2011) is about 100 m thick and, besides being overturned and affected by a few folds and faults, expose rocks from the *Alticola* lms to the Findenig Fm (Fig. 13).

Fig. 12: Selected Lower Devonian conodonts from Cason di Lanza area. Section abbreviations: CAD III= Cadin di Lanza III; RM = Rio Malinfier; RMW = Rio Malinfier West. (a) *Ozarkodina malladai* VALENZUELA-RIOS, 1994, P1 element, lateral view, sample RMW 4A (*transitans* Zone). (b) *Flajsella streptostygia* VALENZUELA-RIOS & MURPHY, 1997, P1 element, upper view, sample RMW 5 (*trigonicus* Zone). (c) *Flajsella schulzei* (BARDASHEV, 1989), P1 element, lateral view, sample RMW 4X (*eleanorae* Zone). (d) *Flajsella schulzei* (BARDASHEV, 1989), P1 element, upper view, sample RMW 4C (*trigonicus* Zone). *continued next page*



(e) *Flajsella sigmostygia* VALENZUELA-RIOS, 1997, P1 element, upper view, sample RMW 4C (*trigonicus* Zone). (f) *Flajsella stygia* (FLAJS, 1967), P1 element, upper view, sample RMW 4C (*trigonicus* Zone). (g) *Belodella resima* (PHILIP, 1965), S0 element, lateral view, sample RMW 8 (*hesperius* Zone). (h) *Ancyrodelloides murphyi* VALENZUELA-RIOS, 1994, P1 element, upper view sample CAD III (*trigonicus* Zone). (i) *Lanea omoalpha* MURPHY & VALENZUELA-RIOS, 1999, P1 element, upper view, sample RMW 1X (*carlsi* Zone); (j) *Ozarkodina planilingua* MURPHY & VALENZUELA-RIOS, 1999, P1 element, upper view, sample RMW 4 (*carlsi* Zone). (k) *Icriodus hesperius* (KLAPPER & MURPHY, 1975), Sc element, lateral view, sample RMW 8 (*hesperius* Zone). (l) *Ancyrodelloides transitans* (BISCHOFF & SANNEMANN, 1958), P1 element, upper view, sample RMW 5 (*trigonicus* Zone). (m) *Lanea telleri* (SCHULZE, 1968), P1 element, upper view, sample RMW 5 (*trigonicus* Zone). (n) *Dvorakia amsdeni* BARRICK & KLAPPER, 1983, S1 element, lateral view, sample RMW 8 (*hesperius* Zone). (o) *Ancyrodelloides carlsi* (BOERSMA, 1973), P1 element, upper view, sample RM 1 (*transitans* Zone). (p) *Oulodus spicula* MAWSON, 1986, S0 element, lateral view, sample RMW 5 (*trigonicus* Zone). (q) *Wurmiella wurmi* (BISCHOFF & SANNEMANN, 1958), P1 element, lateral view, sample RMW 4 (*carlsi* Zone).

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Fig. 13: Sketched stratigraphic log and selected views of the Rio Malinfier West section (modified after CORRIGA, 2011). Red numbers indicate conodont samples. The section is overturned. (a) panoramic view of the upper half of the section. (b) detail of the base of the section. (c) the slightly tectonized boundary between the *Alticola* lms and the Rauchkofel Fm in the central part of the section. (d) the La Valute limestone. (e) the gradual transition between the La Valute limestone and the Findenig Fm in the upper part of the section.

Middle Devonian: the reef and related facies

Starting from the Emsian this part of the Carnic basin begins to differentiate into a proximal part with extensive carbonatic build ups and related depositional environments and a deeper part characterized by deposition in calm waters. In the fore-reef area, thick bodies of gravitative driven material grade in the deeper parts of the basin. The main diffusion of bioherms and reefs is recorded during the Middle Devonian and the reefal facies persisted to be the most prominent carbonatic deposit up to the first part of the Late Devonian (Frasnian).

The white calcareous cliffs of Mt. Zermula and Zuc della Guardia (Fig. 14), that dominate Cason di Lanza Pass on the south, and Mt. Cavallo di Pontebba a few Km eastward consist of shallow water deposits (Fig. 3). Other major Devonian reefs are located at Mt. Coglians and Mt. Osternig, but small outcrops are scattered all along the whole chain: as a results, in the Carnic Alps the most extended Devonian reefs of Europe are preserved. The reefal facies constitute the majority of carbonatic rocks deposited in the Carnic domain during the Middle Devonian, and are about 1000 m thick at Mt. Coglians.

Fig. 14: The white rocks forming the cliffs of northern flank of Mt. Zermula (right), Zuc della Guardia (centre) and Zuc di Malaseit (left) and are constituted by Middle Devonian reefal carbonates.

Reefs are mainly represented by massive, poorly bedded limestone with a facies being characterized by high diversity. In the Carnic Alps the reefal facies yields stromatoporoids, tabulates, rugose corals, brachiopods, crinoids, gastropods, ostracods, bivalves, cephalopods, trilobites, algae, calcispheres, and foraminifers.

Additionally, all types of facies connected to the reef environment are preserved in the Devonian of the Carnic Alps. Fore-reef and slope deposits consist of prevailing carbonatic rudites and calcarenites with abundant reefal bioclastic content. A variety of back-reef, lagoon and tidal-flat facies characterized by their sedimentological features and fossils are also well represented (Fig. 15).

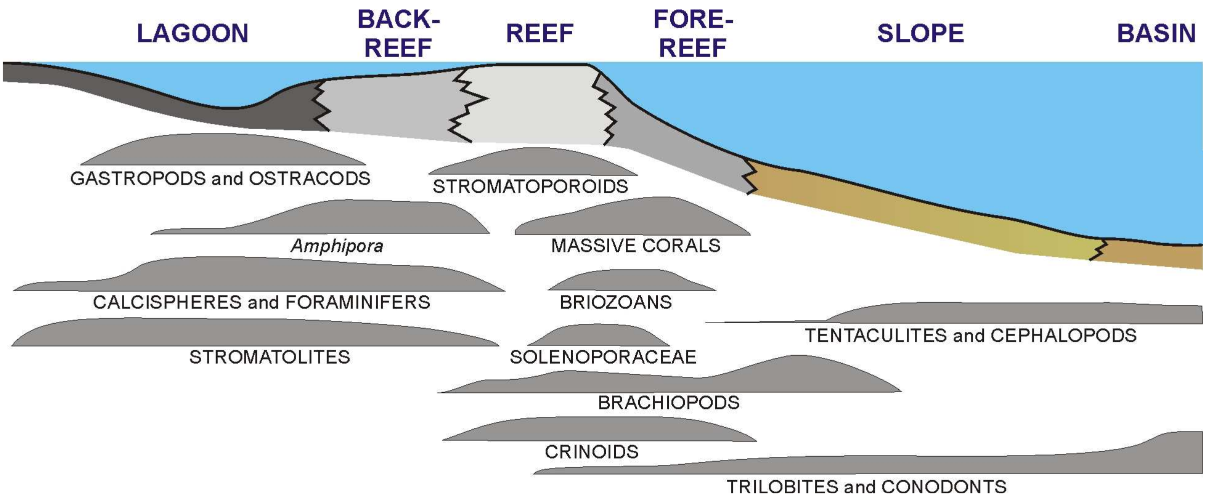

Fig. 15: The distribution of main fossil groups in the Middle Devonian of the Carnic Alps (modified after VAI et al., 2002).

The back reef (Amphipora lms)

On the southern side of the Cason di Lanza pass, right below the reefal cliffs of Mt. Zermula and Mt. Zuc della Guardia, sediments from the calm lagoonal back-reef environment crop out. They are better exposed around the old military house at the Cason di Lanza pass (Fig. 16).

These rocks of Givetian (Middle Devonian) age are known as “Amphipora limestones” and are constituted of “prairies” of *Amphipora ramosa*, trapping carbonatic mud. Additionally it yields rugose corals predominately of the genus *Dendrostella*. Within the unit darker levels with the brachiopod *Stringocephalus burtinii* are present here and there. This taxon confirms the Givetian age of the outcrop. In other areas of the Carnic Chain this unit spans a wider time interval (Eifelian–Frasnian, Middle–Upper Devonian) and its thickness reaches 200-400 meters.

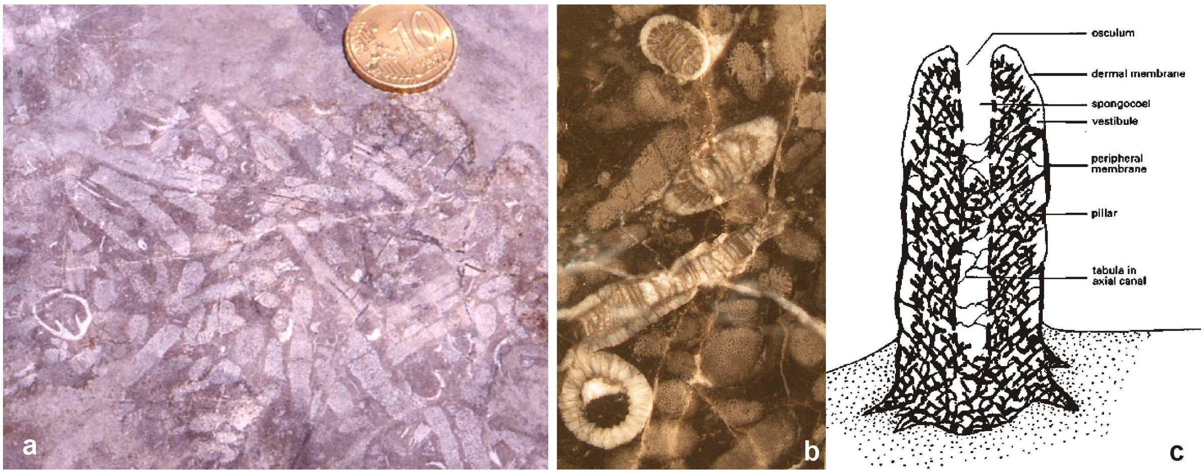

Fig. 16: (a) The *Amphipora* lms at Cason di Lanza Pass. (b) polished slab. (c) reconstruction of *Amphipora ramosa* as a small sponge rooted in the substrate (after STEARN, 1997).

The Genus *Amphipora* is known from Emsian to early Famennian, with the most widespread distribution in Middle Devonian time. The amphiporoid animal was a small, cylindrical, branching, calcified sponge (STEARN, 1997). The stems are rods of a few millimeters in diameter and are composed of skeletal elements of fibrous calcite defining an irregular network of hard tissue in which concentric elements are obscure, and radial elements are hard to distinguish. The labyrintine canals between the elements open on the periphery in apertures of irregular shape or are covered there by a thin hard tissue membrane. The peripheral membrane may be present on only some of the stems or only on some parts of individual stems. A prominent axial canal crossed by dissepiments may or may not be present. Some specimens are branched, other remain as single tubes. Taxonomically, Amphiporidae (Silurian–Permian) are considered a family of the Class Stromatoporoidea, but their phylogenetic relationships with others representatives of the group are still unclear (STEARN, 1997).

Amphipora lived in shallow, calm waters. The stem was anchored inefficiently by irregular outgrowths at the base or cemented into the substrate; the latter hypothesis seems to be more probable (STEARN, 1997).

The fore reef (Hoher Trieb Fm and Freikofel Fm)

Fore reef units consist of slope deposits distally interlayered with pelagic deposits. In the Cason di Lanza Pass area a proximal (Freikofel Fm) and a distal (Hoher Trieb Fm) unit can be distinguished (Figs 2, 4) (PONDRELLI et al., 2011).

In the study area the Freikofel Fm crops out only at one single locality west of Forca di Lanza (Fig. 17) and is about 20 meters thick, resting with an erosional base on top of the Findening limestone, while the upper limit is tectonically erased (Figs 4, 5). It is made of meter thick floatstone and rudstone layers interlayered with decimetric thick grainstones to packstones often showing parting lineations, suggesting deposition in an upper flow regime. The layers base is either erosional or sharp. Erosional surfaces are common within the breccia levels. Locally both facies show normal grading, which suggest deposition from waning flows. Freikofel Fm has been interpreted as result of gravity driven deposition. It has been dated by conodonts to the Eifelian, possibly heteropic with the Cellon Fm found in the western part of the Carnic Alps (KREUTZER, 1990).

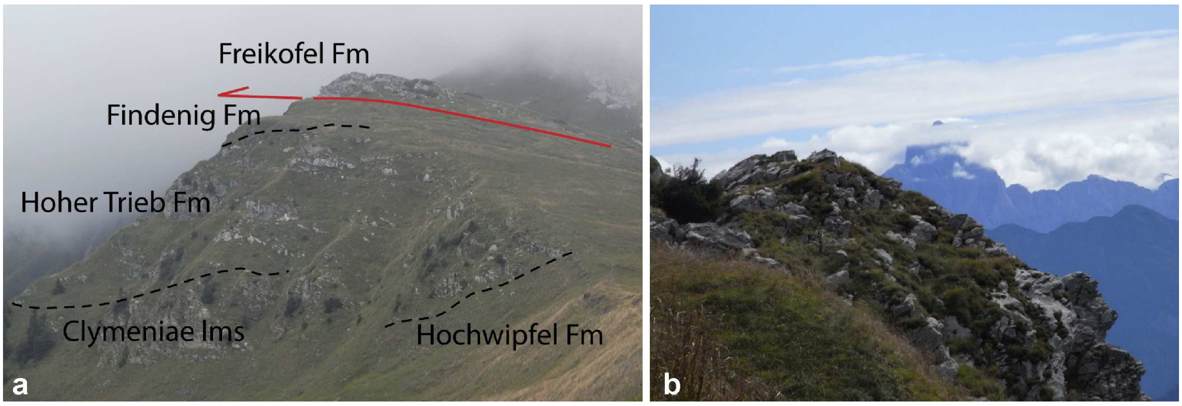

Fig. 17: (a) Panoramic view of the Forca di Lanza section. (b) the Freikofel Fm in the Forca di Lanza section.

The Hoher Trieb Fm crops our extensively along the study area, from the Cima Val di Puartis in the north to La Valute, Forca di Lanza, Mt. Pizzul and Zuc di Malaseit in the south (Fig. 4). The overall thickness can be estimated around 45 meters. It rests on top of the Findening limestone and it is covered by the deposits of the Clymeniae limestone (Figs 2, 4). This unit consists of interlayered meter thick floatstone, centimetric and decimetric thick grainstone and packstone, centimetric thick black radiolarite and shales and rare sandstones. Breccia layers are characterized by the presence of silicified remains of corals (e.g. *Dendrostella* sp., *Grypophyllum* sp. and *Cyathophyllum* sp.) resedimented from the shallow water (Fig. 18). Grainstone and packstone are often laminated and normally graded, suggesting deposition from a waning flow. A black shales episode have been hypothesize to mark the Kačák Event (KIDO et al., 2011a, 2011c; PONDRELLI et al., 2011). This unit is interpreted as transitional from slope to pelagic deposits. According to conodont data, the Hoher Trieb Fm spans an interval from Eifelian through Frasnian, and is partly heteropic with the Freikofel Fm.

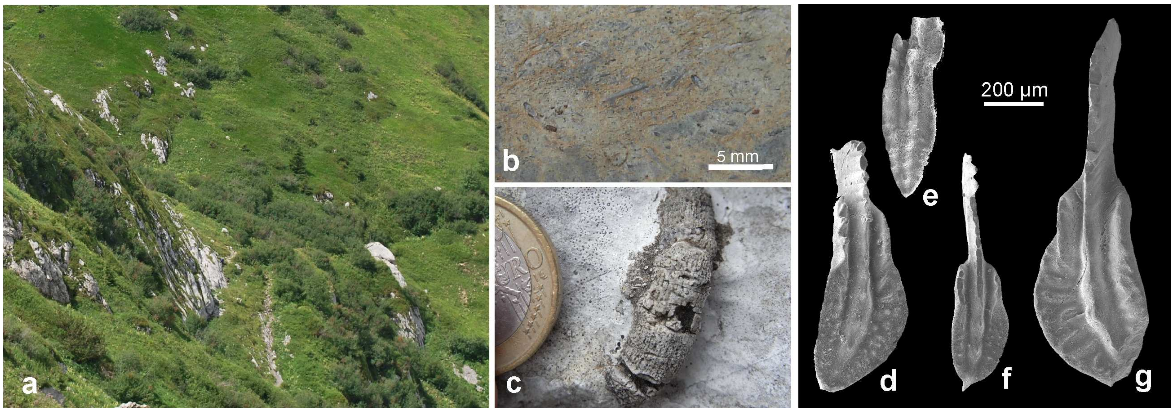

Fig. 18: The Hoher Trieb Fm in the Cadin di Lanza Parete (CAD P) section. (a) panoramic view of the section. (b) tentaculitic limestone. (c) a silicified coral in the outcrop. (d)-(g) conodonts. (d) *Polygnathus eiflius* BISCHOFF & ZIEGLER, 1957. (e) *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON, 1970. (f) *Polygnathus xylus ensensis* ZIEGLER & KLAPPER, 1976. (g) *Polygnathus pseudofoliatus* WITTEKINDT, 1966.

Upper Devonian and lowermost Carboniferous: the "Clymeniae limestones"

During the Frasnian the Carnic basin underwent extensional tectonic pulses and the reefal facies collapsed and drowned (VENTURINI et al., 2009 and reference herein). The Upper Devonian is almost exclusively represented by "Clymeniae limestones" (Fig. 2): pelagic massive and/or nodular limestones with ammonoid remains and conodonts, and rare small trilobites, bivalves, vertebrate microremains (fish teeth and scales) and brachiopods.

In the Cason di Lanza area this unit is poorly exposed, being present only in a few strongly tectonized outcrops at Forca di Lanza and on the western slope of Mt. Pizzul (Fig. 4). Here several metres of nodular grey-pinkish limestone with some more massive levels interbedded have been dated to the upper Frasnian–lower Famennian (Lower *rhenana*-Upper *marginifera* Zone); the colour turns to dark red in the upper part of the sections (Fig. 19).

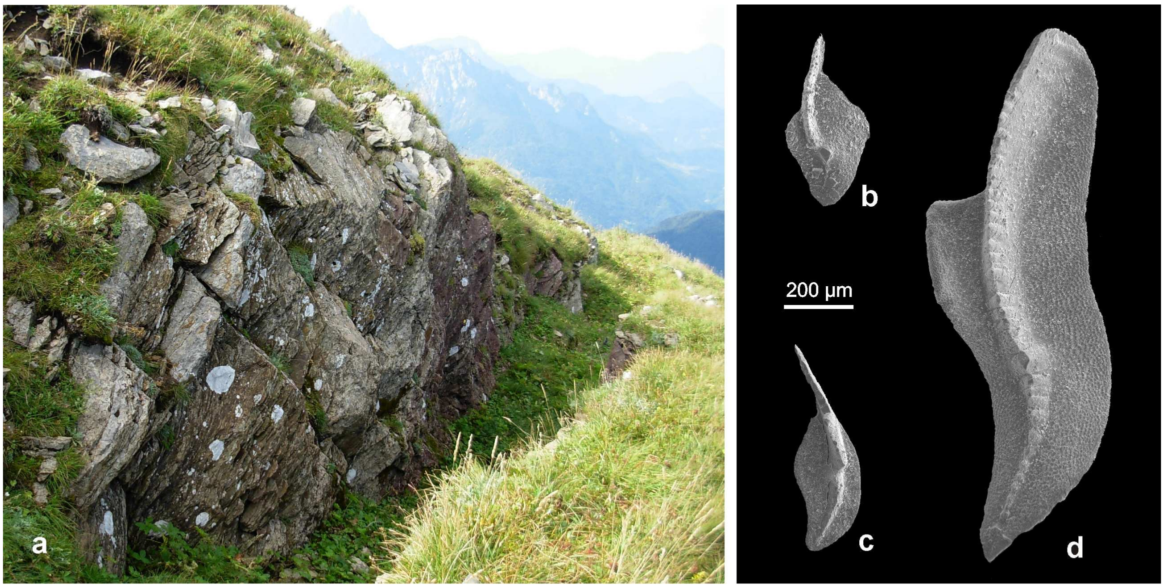

Fig. 19: The Clymeniae limestone in the Pizzul West section. (a) panoramic view of the section. (b)-(d) conodonts from sample PZW 5. (b) *Palmatolepis rhomboidea* SANNEMANN, 1955. (c) *Palmatolepis minuta minuta* BRANSON & MEHL, 1934. (d) *Palmatolepis glabra glabra* ULRICH & BASSLER, 1926.

Massive grey micritic limestones are exposed on the western slope of Mt. Zermula massif, a few km west of Cason di Lanza Pass. These limestones are part of the overturned flank of the Mt. Zermula kilometric antiform (Figs 3, 4). The tectonic style is complicated by the presence of many Variscan and Alpine faults, mainly paralleling the bedding planes, producing elisions and/or tectonic duplications

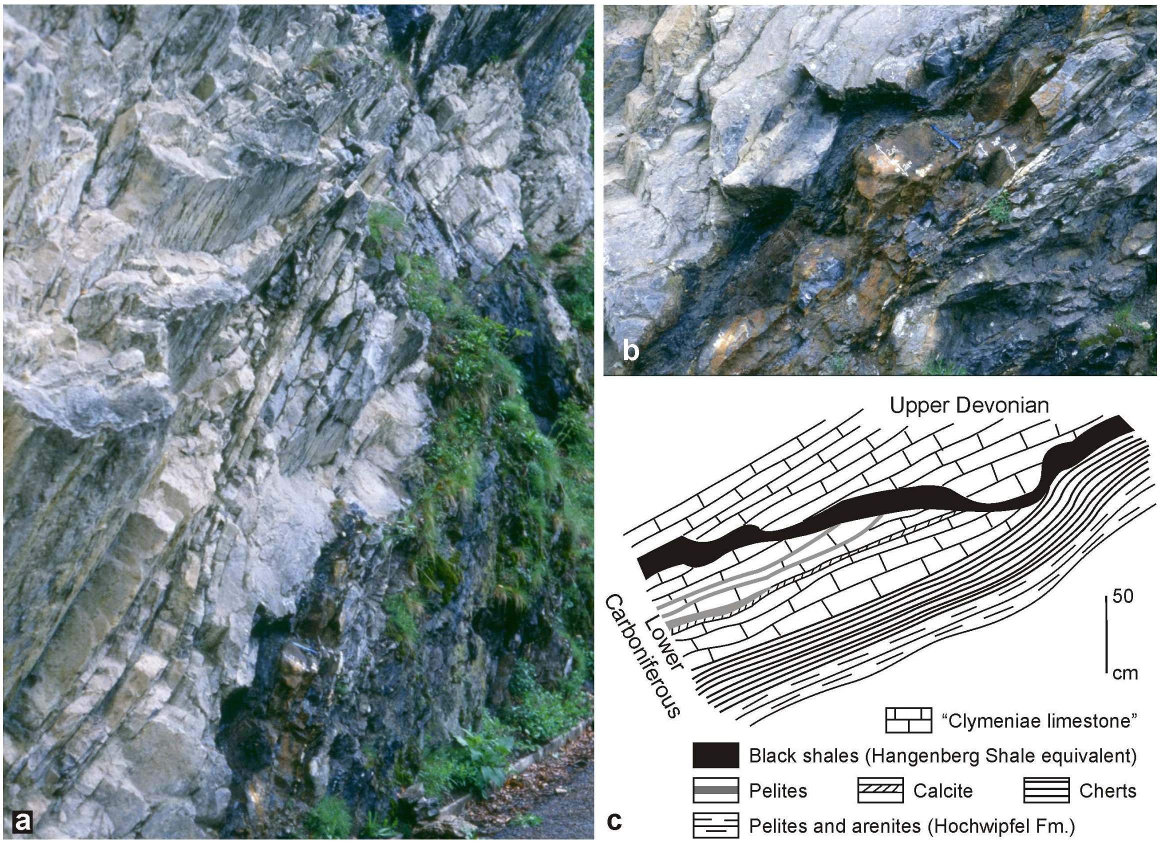

Fig. 20: The Plan di Zermula A section. (a) panoramic view. (b) close view of the Hangenberg Shale equivalent, between the Devonian and Carboniferous beds. (c) sketched drawing of the Plan di Zermula A section (after PERRI & SPALLETTA, 2001, modified).

of a part of the sequence. Here, near the top of the limestone beds, a stratigraphic section across the Devonian/Carboniferous boundary was measured and sampled (PERRI & SPALLETTA, 2001; KAISER, 2005; KAISER et al., 2009). In this section the boundary beds are represented by a level of black shales about 15 cm thick, likely corresponding to the globally known Hangenberg Shale (Fig. 20). According to conodont data, the last limestone level, just below the black shales, belongs to the Lower *praesulcata* Zone, and the first carbonatic level above the shales to the *sulcata* Zone (PERRI & SPALLETTA, 2001; KAISER et al., 2009).

Lower Carboniferous: the "Hercynian flysch"

In the Lower Carboniferous the Carnic basin was affected by strike-slip tectonics releted to the dextral offset of the Insubric Palaeoline. The action of this transtensional to transpressional tectonics lead to the drowinig of some sector of the basin, while other areas were uplifted in some case to emersion. Gravitative driven accumulation of breccias, conglomerates, sandstones and pelites occurred in the depocenters, forming a thick turbiditic sequence (Hochwipfel Fm). Later, where the intensification of transtensional movements lead to break up of the crust and opening of a narrow oceanic basin, these sediments were in place overlaid, and laterally interlayered, by basic volcanic and volcanoclastic deposits (Dimon Fm) (Fig. 2).

In the Cason di Lanza Pass area the Hochwipfel Fm is exposed mainly at Cadin di Lanza, along one of the major Variscan overthrusts (Figs 3, 4). It is represented by thin bedded sandstones and pelites showing normal grading and ripple cross lamination at some places, which suggest a deposition as distal turbidites.

Permo–Carboniferous sequence

North of Cason di Lanza, deposits of the Permo–Carboniferous sequence are extensively exposed. They belong to the western part of the Pramollo Basin. The Carboniferous terms are represented by alternations of fluvio-deltaic and marine deposits, whereas in the Lower Permian units the marine calcareous facies are dominant. For a complete discussion of the Permo–Carboniferous sequence, refer to VENTURINI (1990a) and SCHÖNLAUB et al. (2007).

In the Cason di Lanza area the better exposed Permo–Carboniferous sediments belongs to the Meledis Fm (Upper Carboniferous) and to the Val Dolce Fm (Lower Permian), but other units are also exposed here and there.

The Upper Carboniferous Meledis Fm

The Meledis Fm is widely exposed north of the Cason di Lanza Line, and is mainly represented by fluvio-deltaic quartzitic conglomerates and transitional and shallow marine pelites and sandstones. A fossil flora is abundant in pelitic levels, where also rare insect remains can be found; abundant ichnofossils (mainly *Zoophycus* and *Cosmoraphae*) occur in some sandstone levels (Fig. 21).

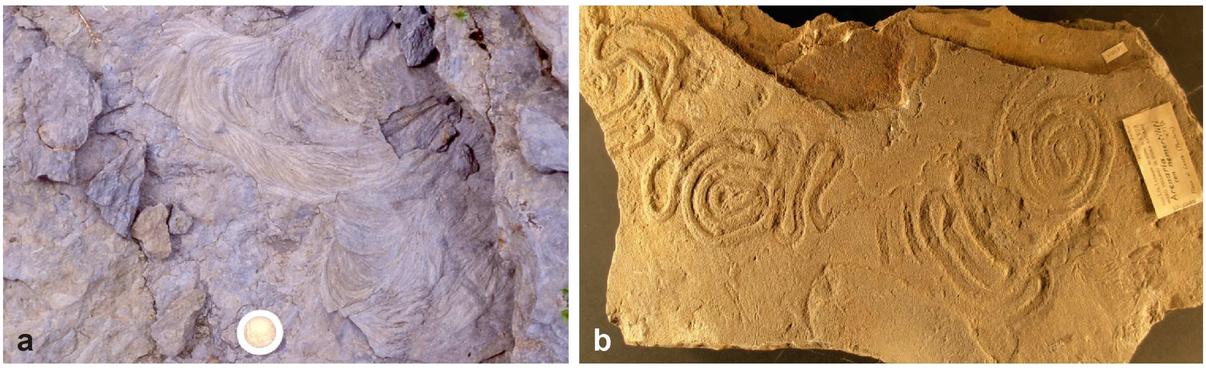

Fig. 21: Trace fossils from the Meledis Fm in Cason di Lanza area. (a) *Zoophycus*. (b) ?*Cosmoraphae.*

One of the most classical localities for Carboniferous flora is located a few hundred meters from Cason di Lanza hut. In the Rio del Museo section (Fig. 22) the main terrigenous lithotypes of the Meledis Fm can be observed; the section is tectonically cut at the base, near the confluence with Lanza Creek, by the Cason di Lanza Line, and is interrupted at the top by a tectonic contact with the red sandstones of the Val Gardena Formation (Upper Permian). The rich fossil flora is preserved in a pelitic interval just above a thick quartzitic conglomerate bed, interpreted as a channel deposits

(VENTURINI, 1990a). The association is mainly represented by "ferns" (e.g. *Alethopteris*, *Callipteridium*, *Linopteris* and *Pecopteris*) and equisetaleans (e.g. *Annularia*, *Sphenophyllum* and *Calamites*).

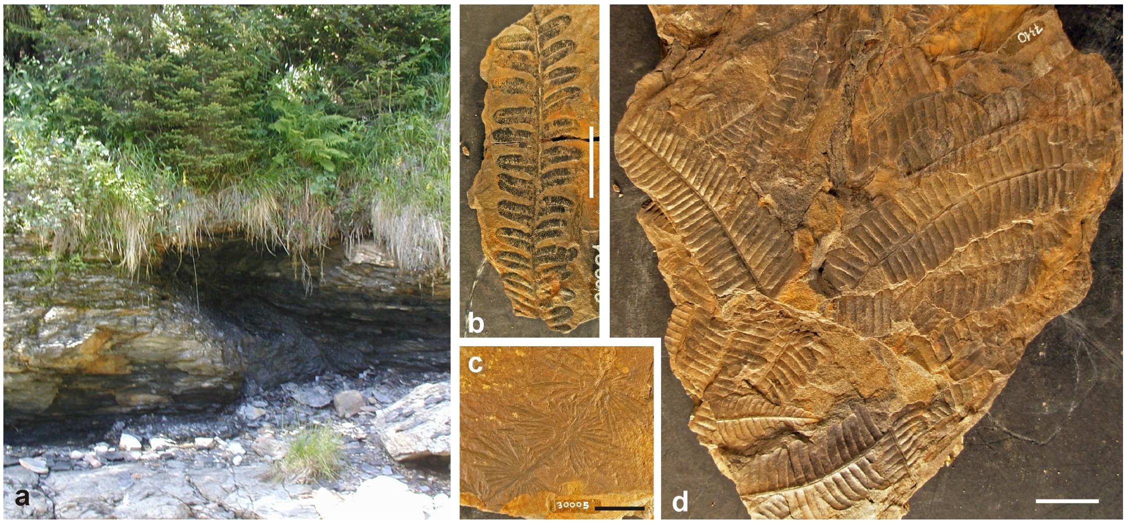

Fig. 22: The Carboniferous plants locality in Rio del Museo. (a) view of the outcrop. (b) *Alethopteris* sp. (c) *Annularia stellata*. (d) large slab with several *Callipteridium* sp. leaves. Scale bar = 2 cm.

The Lower Permian Val Dolce Fm

The Val Dolce Fm crops out extensively more to the North, close to the Italy/Austria border. It is mainly constituted by grey and red shales with sandstones, quartz-conglomerates and calcarenites. In the pelitic levels of Piani di Lanza area a rich invertebrate fauna, dominated by brachiopods is present (Fig. 23); ammonoids (*Imitoceras*), orthocerid nautiloids, bivalves, gastropods, solitary corals, bryozoans and rare trilobites are also present.

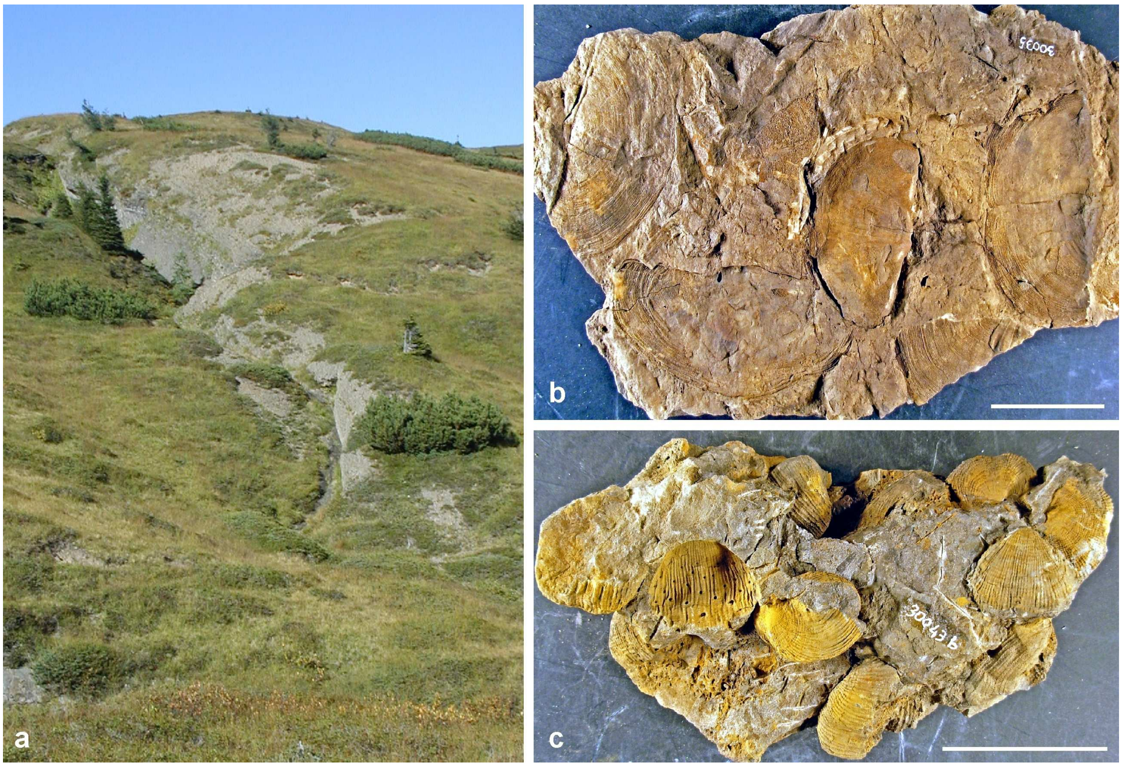

Fig. 23: (a) The brachiopod locality in the Val Dolce Fm at Piani di Lanza. (b) *Isogramma* sp. (c) slab with several *Linoproductus* and other brachiopods. Scale bar = 5 cm.

Other Carboniferous and Lower Permian units

The other units of the Permo–Carboniferous sequence are less widespread in the area, and are exposed mainly in the Piani di Lanza and Val Dolce areas, and at Mt. Creta d'Aip/Trogkofel.

From these units a few vertebrate remains (Fig. 24) have been found: a late Carboniferous footprint, tentatively attributed to ichnogenus ?*Limnopus* by MIETTO et al. (1986), and two teeth of petalodontiform condrychtians (DALLA VECCHIA, 2000).

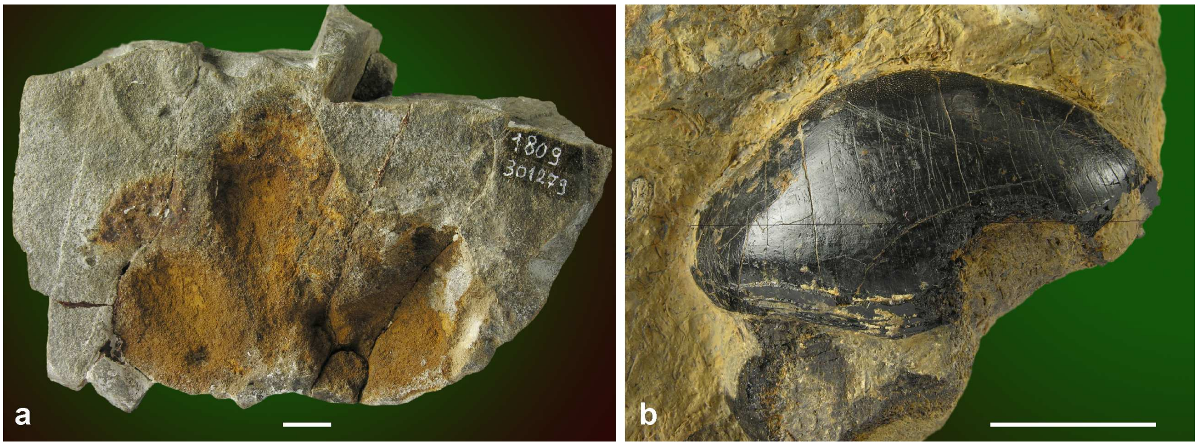

Fig. 24: Evidence of vertebrates from the Lower Permian of Cason di Lanza area. Scale bar = 1 cm. (a) tetrapod footprint belonging to ichnogenus ?*Limnopus*. (b) tooth of the condrychtian *Petalodus ohioensis*.

The Permo–Triassic sequence

The older units of the Permo–Triassic sequence are exposed in the Cason di Lanza area: the Val Gardena Sandstone and the Bellerophon Fm.

The better exposed unit is the Val Gardena Sandstones, which mark the beginning of the Alpine stratigraphic-structural cycle, and is constituted by reddish sandstones unconformably lying on top of the Permo–Carboniferous deposits (Fig. 2). A small outcrop of the dark dolostones and limestones of the Bellerophon Fm is also present within a small anticline in Piani di Lanza locality.

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