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STRATIGRAPHIC SECTIONS IN THE LA VALUTE-CHIARSÒ AREA (MT ZERMULA, CARNIC ALPS, NE ITALY)

SEZIONI STRATIGRAFICHE
NELL'AREA DE LA VALUTE-CHIARSÒ
(M. ZERMULA, ALPI CARNICHE, ITALIA NORD-ORIENTALE)

Abstract - Nineteen stratigraphic sections which age spans from the Late Ordovician to the early Carboniferous were measured by various scientists in the La Valute Chiarsò area, mainly for litho- and bio-stratigraphic purposes. These data, some still unpublished, are here summarized and updated to the more recent zonation schemes, together with those from spot samples collected in the area.

Key words: Pre-Variscan sequence, Lithostratigraphy, Biostratigraphy, Conodonts, Carnic Alps.

Riassunto breve - Diciannove sezioni stratigrafiche di età compresa tra l'Ordoviciano Superiore e il Carbonifero inferiore sono state misurate da vari autori nell'area de La Valute-Chiarsò, principalmente nell'ambito di studi di carattere lito- e bio-stratigrafico. I dati di queste sezioni, alcune delle quali ancora non pubblicate, vengono brevemente presentati, talora aggiornati agli schemi di zonazione recenti.

Parole chiave: Sequenza Pre-Varisica, Litostratigrafia, Biostratigrafia, Conodonti, Alpi Carniche.

Introduction

The Carnic Alps are one of the most investigated area in the world for its well exposed and beautifully preserved Palaeozoic sequence, which has attracted scientists from the middle of the XIX century to present day. More than a thousand of papers are devoted to the geology and palaeontology of the area (CARULLI 2012; <http://www.infoteca.it/mfsn/bibliogeo/>) and a huge number of stratigraphic sections and localities were measured and studied by different authors. Many of these were examined to define the characters of the lithostratigraphic units, constrain their age in terms of duration and transition, and to achieve information on the development of the sedimentary basin of the Carnic Alps during the early Palaeozoic.

This paper is the first of a series of contributions where sections and localities of the various sectors of the Palaeocarnic chain are presented and related together, including data from already published sections, sometimes updated according to recent studies, and new and/or still unpublished data. The aim is to provide a complete overview of all the available data in the different parts of the Carnic Alps. The westernmost flank of Mt Zermula massif, located in the central sector of the Carnic Alps, is here presented. Rocks from Upper Ordovician to Mississippian are here exposed and sev-

eral stratigraphic sections were measured, mainly in La Valute area and along the Chiarsò creek valley (Fig. 1).

Geological Settings

The succession exposed in the western flank of Mt Zermula massif is part of a large, overturned north-east-dipping monocline, folding a previously folded and thrust succession. According to VENTURINI (1990), this structure represents part of the overturned flank of a multi-kilometer scale recumbent south-verging fold formed during the Variscan orogeny. These structures were locally disrupted by at least three Alpine compressional phases (VENTURINI 1990; LÄUFER 1996). The first phase (Chattian-Burdigallian) is coaxial with the Variscan one so that its effects are difficult to distinguish without a post-Variscan cover, but the Tortonian-Messinian and Plio-Pleistocene ones are visible in the study area with dextral E-W to ENE-WSW trending and strike-slip faults (VENTURINI 1990). Although the tectonic overprint is severe, the stratigraphic relations are generally preserved.

Rocks from Late Ordovician to lower Pennsylvanian age are exposed in the study area. They belong to the Valbertad, Uqua, Nölbling, Alticola, Rauchkofel, La Valute, Findenig, Hoher Trieb, Spinotti, Pal Grande

and Hochwipfel formations. For a detailed description of the geology of the area and the lithostratigraphic units exposed refer to CORRADINI et al. (2016; 2020).

Stratigraphic Sections

In the La Valute-Chiarsò area a total of 19 sections were measured, covering an age from Late Ordovician to Mississippian; also, a few spot samples were collected for cartographic and or stratigraphic purposes.

Most of these data were already published in various papers, whereas a few are here newly presented. Being

most of the section constituted by calcareous rocks, conodonts (Fig. 2) were the main fossils investigated, whereas in a few cases of pelitic intervals the occurrence of graptolites provided biostratigraphic data.

The studied sections are presented in stratigraphic order. Beside the precise location, a summary of data and references, the biostratigraphy is adjoined to the more recent zonation schemes. More precisely, the Silurian scheme by CRAMER et al. (2011) was followed, with the emendations by CORRADINI & CORRIGA (2012) and CORRADINI et al. (2015a), as already pointed out by SCHÖNLAUB et al. (2017). However, for the Wenlock the scheme by CORRADINI & SERPAGLI (1999) was

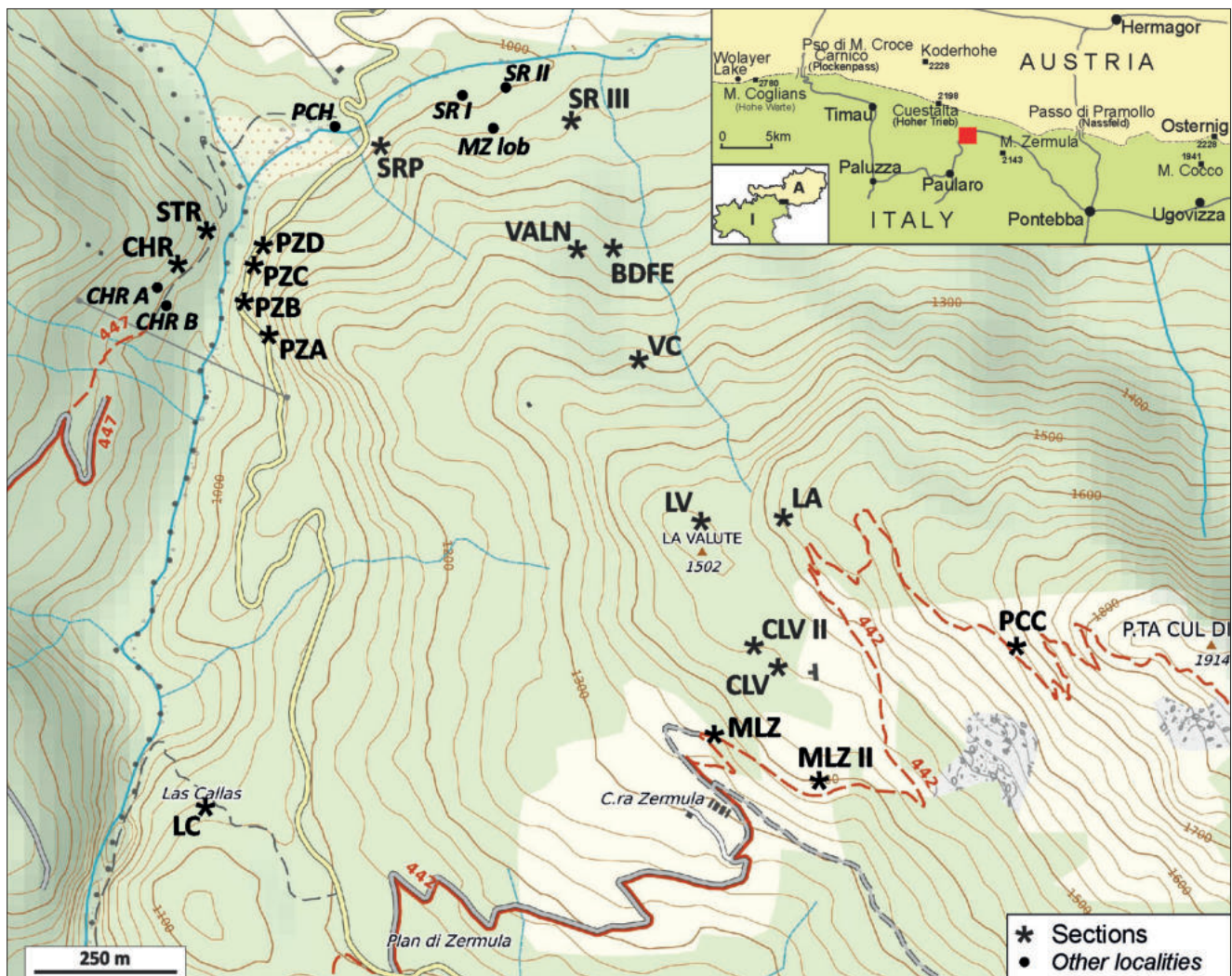


Fig. 1 - Topographic map of the La Valute-Chiarsò area, with location of the stratigraphic sections and localities presented in the paper. Abbreviations: BDFE: Bosc dai Floriz Est; CHR: Chiarsò; CHR A: Chiarsò A; CHR B: Chiarsò B; CLV: Casera la Valute; CLV II: Casera La Valute II; LA: La Valute scogliera; LC: Las Callas; MLZ: Malga Zermula; MLZ II: Malga Zermula II; MZ lob: Monte Zermula loboliti; PCC: Punta Cul di Creta; PCH: Ponte Chiarsò; PZA: Plan di Zermula A; PZB: Plan di Zermula B; PZC: Plan di Zermula C; PZD: Plan di Zermula D; SR I: Stua Ramaz I; SR II: Stua Ramaz II; SR III: Stua Ramaz III; SRP: Stua Ramaz Ponte; STR: Stua Ramaz; VALN: La Valute Nord; VC: La Valute casermetta.

- Carta topografica dell'area de La Valute-Chiarsò con ubicazione delle sezioni e delle altre località presentate. Abbreviazioni: BDFE: Bosc dai Floriz Est; CHR: Chiarsò; CHR A: Chiarsò A; CHR B: Chiarsò B; CLV: Casera la Valute; CLV II: Casera La Valute II; LA: La Valute scogliera; LC: Las Callas; MLZ: Malga Zermula; MLZ II: Malga Zermula II; MZ lob: Monte Zermula loboliti; PCC: Punta Cul di Creta; PCH: Ponte Chiarsò; PZA: Plan di Zermula A; PZB: Plan di Zermula B; PZC: Plan di Zermula C; PZD: Plan di Zermula D; SR I: Stua Ramaz I; SR II: Stua Ramaz II; SR III: Stua Ramaz III; SRP: Stua Ramaz Ponte; STR: Stua Ramaz; VALN: La Valute Nord; VC: La Valute casermetta.

utilized, because in the Carnic Alps it is impossible to follow the very detailed subdivision of the Wenlock by CRAMER et al. (2011). For the Lochkovian the zonation scheme provided for the Carnic Alps and Sardinia by CORRADINI & CORRIGA (2012) is applied. In the rest of the Devonian the zonation schemes by WEDDIGE (1977), BULTYNCK et al. (1988), KLAPPER (1989), KLAPPER & KIRCHGASSER (2016), and SPALLETTA et al. (2017) are used. For the lower Carboniferous, those by CORRADINI et al. (2016), ZHURALEV et al. (2021), SANDBERG et al. (1978) and LANE et al. (1980) are applied.

Bosc dai Floriz Est (BDFE)

The Bosc dai Floriz Est (BDFE) section (Figs 3, 4a) is located on the northern slope of La Valute coordinates 46°34'30.012"N - 13°07'11.663"E (base), 46°34'27.625"N - 13°07'12.356"E (top) and altitude of about 1170 m. The section was studied by CORRADINI et al. (2016).

The lower part of the section is represented by 2.20 m of fossiliferous sandstones of the Valbertad Fm., followed by 1.30 m of nodular limestones of the Uqua Fm. barren of fossils. Above a paraconformable contact, the section continues with about 15.5 m of black pelitic shales with intercalation of limestone beds and lenses belonging to the Nölbling Fm.

The scarce conodont fauna collected from the limestone beds and lenses allow to date the Silurian part of the section to the Sheinwoodian and the Homerian, more precisely to the *Oz. s. sagitta* and *Oz. s. rhenana* zones.

La Valute Nord (VALN)

The La Valute Nord (VALN) section (Figs 4b, 5) is located in the northern slope of La Valute, a few dozens of meters west of the BDFE section, at coordinates 46°34'29.947"N - 13°07'09.692"E (base), 46°34'26.572"N - 13°07'09.339"E (top) and altitude between 1140 and 1240 m. The section was presented by CORRADINI et al. (2016), whereas graptolites from the central part were documented by PIRAS et al. (2012).

The section is about 60 m thick, and is made of pelites and limestones of the Nölbling and Alticola formations. The lower part consists of about 45 m of black shales with interbedded levels and lenses of dark cephalopod limestone, belonging to the Nölbling Fm. Limestones are relatively more abundant in the lower and upper part of this interval, whilst black shales are the only lithology present in the central part. A few tectonic disruptions occur in this part of the section, resulting in offset and/or shortening, although it is impossible to evaluate their extent in the field due to poor outcrop conditions. The upper part of the section, above a covered interval of about 10 m, is constituted by 3.2 m of light gray wackestones-packstones of the Alticola Fm.

Well preserved graptolites collected about 20 m from the base of the section allowed to refer these levels to the Sheinwoodian *M. belophorus* Zone (PIRAS et al. 2012); the scarce conodont fauna allows to state a Silurian age for the whole section, although various biozones of Wenlock and Pridoli are documented (Fig. 5). Biostratigraphic data indicate the presence of at least three tectonic repetitions (CORRADINI et al. 2016).

La Valute Casermetta (VC)

The La Valute Casermetta (VC) section (Fig. 4c) is located in the northern slope of La Valute, south of the BDFE section, at coordinates 46°34'25.728"N - 13°07'11.247"E and altitude 1315 m. The section was studied by CORRADINI et al. (2016).

The section is referred to the Nölbling Fm. and is represented by a few meters of strongly tectonized dark cephalopod limestone and pelitic intercalations. Abundant orthoceratid cephalopods occur in a few beds, but the state of preservation is very poor, and the fauna is re-crystallized, preventing taxonomic attribution.

The very poor conodont fauna collected indicates that the section is of Silurian age, preventing any more precise attribution.

Stua Ramaz III (SR III)

The Stua Ramaz III (SR III) section is located about 400 m east of Stua Ramaz bridge along a creek at coordinates 46°34'36.717"N - 13°07'09.646"E and altitude 1040 m.

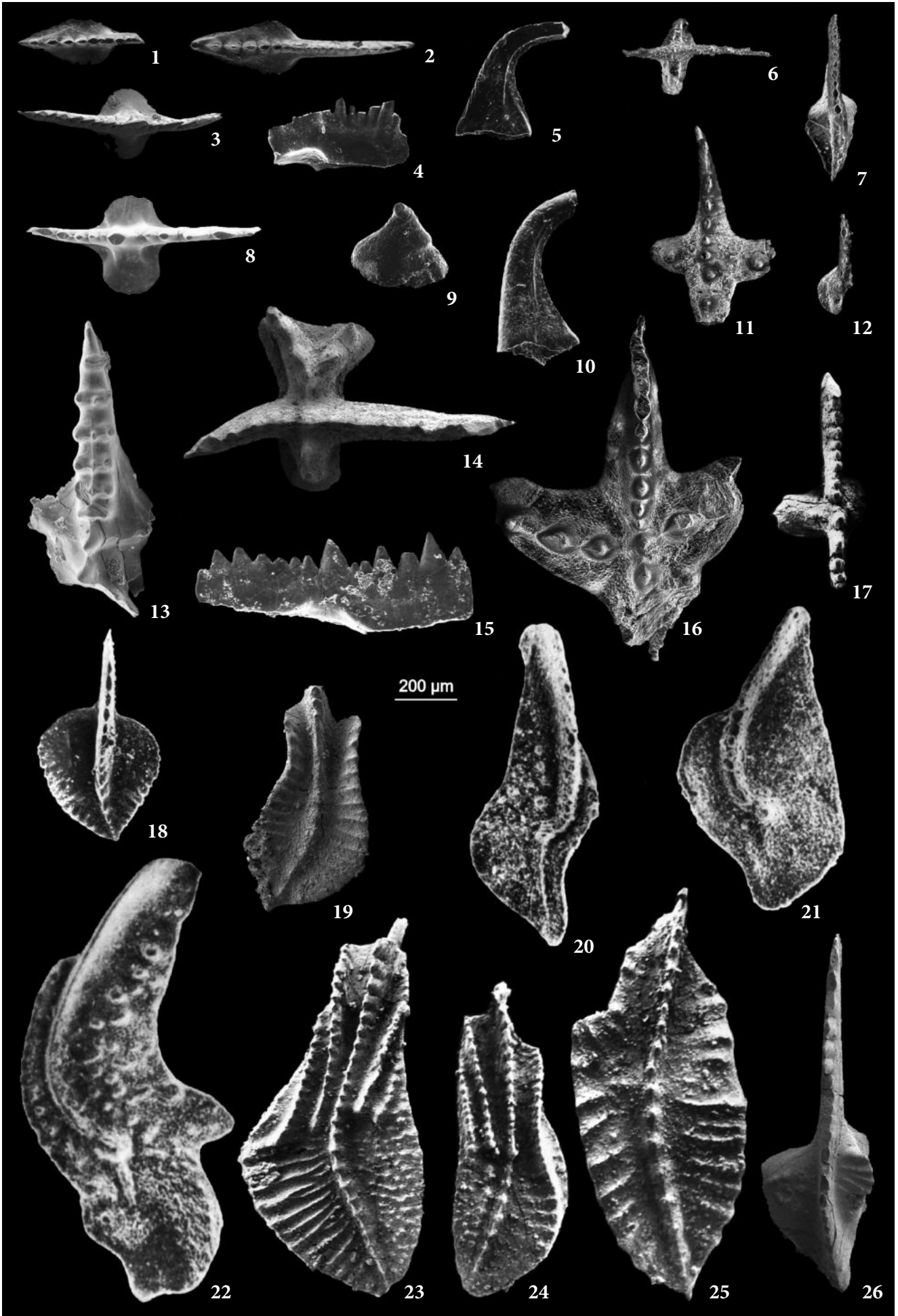
It is a poorly preserved outcrop of pelites and limestone lenses of the Nölbling Fm. All the four samples collected were barren.

Casera La Valute (CLV)

The Casera La Valute (CLV) section (Figs 4e, 6) is located a few dozens of meters west of Casera La Valute, at coordinates 46°34'05.564"N - 13°07'26.225"E and altitude 1455 m. The section was studied by CORRADINI et al. (2016).

About 11 m of limestones and black shales, belonging to the Nölbling and the Alticola formations are here exposed. The lower part of the section is represented by 1.2 m of dark grey limestone with abundant nautiloid cephalopods, and continues with 3.4 m of partly covered black shales of the Nölbling Fm. The upper part consists of well-bedded light grey, at place pinkish, wackestone-packstone of the Alticola Fm.

A scarce conodont fauna allowed to date the Nölbling Fm. to the Gorstian and Ludfordian (*K. crassa* to *Pol. siluricus* zones), and the Alticola Fm. to the Pridoli ("*Oz. eosteinhornensis* s.l. Zone).



Casera La Valute II (CLV II)

The Casera La Valute II (CLV II) section is located just north of the CLV section, at coordinates 46°34'05.732"N - 013°07'24.622"E and altitude 1460 m. It is a very short section measured with the goal to date 45 cm of dark shales and limestones of the Rauchkofel Fm. sandwiched between the uppermost part of the Alticola Fm. and the basal La Valute Fm. Unfortunately, no useful data were obtained.

La Valute Cave (LV)

The La Valute Cave (LV) section (Figs 4d, 7) is located just north of the top of La Valute, a few hundred meters NNW of Casera La Valute, at coordinates 46°34'13.946"N - 13°07'19.782"E and altitude 1475 m.

The section was studied by CORRIGA (2011) and CORRIGA et al. (2011), and conodont fauna was updated by CORRADINI et al. (2016). The LV section is indicated

Fig. 2 - Selected conodonts from the La Valute-Chiarsò area. 1) *Ozarkodina sagitta rhenana* (WALLISER, 1964); upper view of P1 element; Bosc dai Floriz section, sample BDFE 4. 2) *Ozarkodina sagitta sagitta* (WALLISER, 1964); upper view of P1 element; Bosc dai Floriz section, sample BDFE 9. 3) "*Ozarkodina*" *eosteinhornensis* s.l. (WALLISER, 1964); upper view of P1 element; La Valute Nord section, sample VALN 9. 4) *Kockelella ortus sardoa* SERPAGLI & CORRADINI, 1999; lateral view of P1 element; Casera La Valute section, sample CLV 2. 5) *Dapsilodus obliquicostatus* (BRANSON & MEHL, 1933); lateral view; Casera La Valute section, sample CLV 3. 6) *Lanea telleri* (SCHULZE, 1968); upper view of P1 element; La Valute Cave section, sample LV 2. 7) *Flajsella schulzei* (BARDASHEV, 1989); upper view of P1 element; La Valute Cave section, sample LV 1. 8) *Zieglerodina planilingua* (MURPHY & VALENZUELA-RIOS, 1999); upper view of P1 element; Stua Ramaz III locality, MZ-lob block. 9) *Pseudooneotodus beckmanni* (BISCHOFF & SANNEMANN, 1958); lateral view; Casera La Valute section, sample CLV 3. 10) *Panderodus unicostatus* (BRANSON & MEHL, 1933); lateral view; Casera La Valute section, sample CLV 3. 11) *Ancyrodelloides transitans* Bischoff & Sannemann, 1958; upper view of P1 element; Valute Cave section, sample LV 2. 12) *Flajsella streptostygia* VALENZUELA-RIOS & MURPHY, 1997; upper view of P1 element; La Valute Cave section, sample LV 3. 13) *Icriodus hesperius* KLAPPER & MURPHY, 1975; upper view of P1 element; Stua Ramaz III locality, MZ-lob block. 14) *Kockelella variabilis ichnusae* SERPAGLI & CORRADINI, 1998; upper view of P1 element; Stua Ramaz II locality, loose block MZ-BK 2. 15) *Zieglerodina remscheidensis* (ZIEGLER, 1960); lateral view of P1 element; Stua Ramaz III locality, MZ-lob block. 16) *Ancyrodelloides trigonicus* BISCHOFF & SANNEMANN, 1958; upper view of P1 element; Valute Cave section, sample LV 1. 17) *Criteriognathus steinhornensis* (ZIEGLER, 1956); upper view of P1 element; Stua Ramaz section, sample STR 3. 18) *Polygnathus marginivolutus* GEDIK, 1969; upper view of P1 element; Plan di Zermula B section, sample PZB 3. 19) *Polygnathus pseudofoliatius* WITTEKINDT, 1965; upper view of P1 element; Stua Ramaz Ponte section, sample SRP 7. 20) *Palmatolepis marginifera utahensis* ZIEGLER & SANDBERG, 1984; upper view of P1 element; Las Callas section, sample LC 1. 21) *Palmatolepis marginifera marginifera* HELMS, 1959; upper view of P1 element; Las Callas section, sample LC 1. 22) *Palmatolepis rugosa trachytera* ZIEGLER, 1960; upper view of P1 element; Las Callas section, sample LC 3G. 23) *Siphonodella quadruplicata* (BRANSON & MEHL, 1934); upper view of P1 element; Plan di Zermula C section, sample PZC 7. 24) *Siphonodella obsoleta* HASS, 1959; upper view of P1 element; Plan di Zermula C section, sample PZC 8. 25) *Siphonodella lobata* (BRANSON & MEHL, 1934); upper view of P1 element; Plan di Zermula C section, sample PZC 8. 26) *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS, 1970; upper view of P1 element; La Valute scogliera section, sample LA 2.

- Conodonti dell'area La Valute-Chiarsò. 1) *Ozarkodina sagitta rhenana* (WALLISER, 1964); veduta superiore dell'elemento P1; sezione Bosc dai Floriz, campione BDFE 4. 2) *Ozarkodina sagitta sagitta* (WALLISER, 1964); veduta superiore dell'elemento P1; sezione Bosc dai Floriz, campione BDFE 9. 3) "*Ozarkodina*" *eosteinhornensis* s.l. (WALLISER, 1964); veduta superiore dell'elemento P1; sezione La Valute Nord, campione VALN 9. 4) *Kockelella ortus sardoa* SERPAGLI & CORRADINI, 1999; veduta superiore dell'elemento P1; sezione Casera La Valute, campione CLV 2. 5) *Dapsilodus obliquicostatus* (BRANSON & MEHL, 1933); veduta laterale; sezione Casera La Valute, campione CLV 3. 6) *Lanea telleri* (SCHULZE, 1968); veduta superiore dell'elemento P1; sezione La Valute Cave, campione LV 2. 7) *Flajsella schulzei* (BARDASHEV, 1989); veduta superiore dell'elemento P1; sezione La Valute Cave, campione LV 1. 8) *Zieglerodina planilingua* (MURPHY & VALENZUELA-RIOS, 1999); veduta superiore dell'elemento P1; località Stua Ramaz III, campione MZ-lob. 9) *Pseudooneotodus beckmanni* (BISCHOFF & SANNEMANN, 1958); veduta laterale dell'elemento P1; sezione Casera La Valute, campione CLV 3. 10) *Panderodus unicostatus* (BRANSON & MEHL, 1933); veduta laterale; sezione Casera La Valute, campione CLV 3. 11) *Ancyrodelloides transitans* BISCHOFF & SANNEMANN, 1958; veduta superiore dell'elemento P1; sezione Valute Cave, campione LV 2. 12) *Flajsella streptostygia* VALENZUELA-RIOS & MURPHY, 1997; veduta superiore dell'elemento P1; sezione La Valute Cave, campione LV 3. 13) *Icriodus hesperius* KLAPPER & MURPHY, 1975; veduta superiore dell'elemento P1; località Stua Ramaz III, campione MZ-lob. 14) *Kockelella variabilis ichnusae* SERPAGLI & CORRADINI, 1998; veduta superiore dell'elemento P1; località Stua Ramaz II, campione MZ-BK 2. 15) *Zieglerodina remscheidensis* (ZIEGLER, 1960); veduta superiore dell'elemento P1; località Stua Ramaz III, campione MZ-lob. 16) *Ancyrodelloides trigonicus* BISCHOFF & SANNEMANN, 1958; veduta superiore dell'elemento P1; sezione La Valute Cave, campione LV 1. 17) *Criteriognathus steinhornensis* (ZIEGLER, 1956); veduta superiore dell'elemento P1; sezione Stua Ramaz, campione STR 3. 18) *Polygnathus marginivolutus* GEDIK, 1969; veduta superiore dell'elemento P1; sezione Plan di Zermula B, campione PZB 3. 19) *Polygnathus pseudofoliatius* WITTEKINDT, 1965; veduta superiore dell'elemento P1; sezione Stua Ramaz Ponte, campione SRP 7. 20) *Palmatolepis marginifera utahensis* ZIEGLER & SANDBERG, 1984; veduta superiore dell'elemento P1; sezione Las Callas, campione LC 1. 21) *Palmatolepis marginifera marginifera* HELMS, 1959; veduta superiore dell'elemento P1; sezione Las Callas, campione LC 1. 22) *Palmatolepis rugosa trachytera* ZIEGLER, 1960; veduta superiore dell'elemento P1; sezione Las Callas, campione LC 3G. 23) *Siphonodella quadruplicata* (BRANSON & MEHL, 1934); veduta superiore dell'elemento P1; sezione Plan di Zermula C, campione PZC 7. 24) *Siphonodella obsoleta* HASS, 1959; veduta superiore dell'elemento P1; sezione Plan di Zermula C, campione PZC 8. 25) *Siphonodella lobata* (BRANSON & MEHL, 1934); veduta superiore dell'elemento P1; sezione Plan di Zermula C, campione PZC 8. 26) *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS, 1970; veduta superiore dell'elemento P1; sezione La Valute scogliera, campione LA 2.

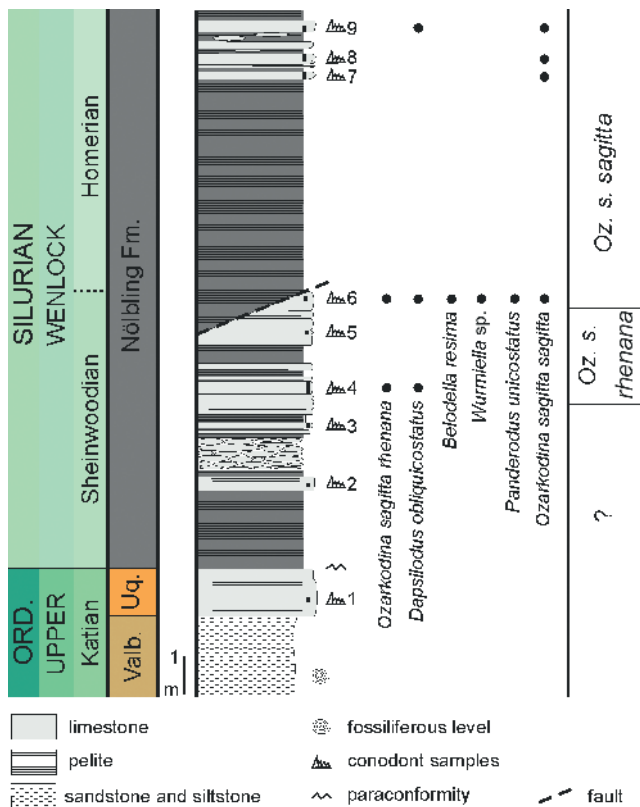


Fig. 3 - Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the Bosc dai Floriz (BDFE) section. Ord. = Ordovician; Uq. = Uqua Fm.; Valb. = Valbertad Fm. Modified after CORRADINI et al. (2016).

- Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione Bosc dai Floriz (BDFE). Ord. = Ordovician; Uq. = Uqua Fm.; Valb. = Valbertad Fm. Modificato da CORRADINI et al. (2016).

as reference section for the upper boundary of the La Valute Fm. (CORRADINI et al. 2015b).

The section was measured inside and outside a First World War cave and consists of 8 m of nodular limestone exposing the gradual transition between the La Valute and the Findenig formations.

A poorly preserved and relatively scarce conodont fauna allowed to date the section to the middle and upper Lochkovian (*Ad. trigonicus* and *M. pandora* β zones), however a younger age cannot be excluded for the Findenig Fm. part of the section.

Stua Ramaz Ponte (SRP)

The Stua Ramaz Ponte (SRP) section is located along a forest road just south of the bridge on Rio di Lanza creek at Stua Ramaz, at coordinates 46°34'36.204"N - 13°06'52.280"E and altitude 975 m. The section was studied by CORRADINI et al. (2016).

About 15 m of limestones, strongly affected by ductile folding and slip, with interbedded shales in the upper

part of the outcrop are exposed, belonging to the La Valute, Findenig and Hoher Trieb formations. A fault separates the La Valute Fm. from the Findenig Fm.

The conodont fauna collected from this section is very scarce and poorly preserved and state a generic Middle Devonian age for the Findenig and Hoher Trieb formations.

Stua Ramaz (STR)

The Stua Ramaz (STR) section (Figs 8, 9a) was measured at the beginning of the path n. 447, at coordinates 46°34'36.204"N - 13°06'52.280"E and altitude 1000 m. The section was first studied by VAI (1980), and a biostratigraphic assignment was provided by PERRI & SPALLETTA (1998); CORRADINI & PONDRELLI (2021) summarized the data.

The section consists of about 12.5 m of pink to reddish, locally nodular, tentaculitid limestones with rare shaley interbeds and several grey calcisiltitic to calcarenitic bed. It is the classical exposure of allodapic beds within the Findenig Fm. (VAI 1980). Only 10 of the 14 collected samples yielded conodonts. The scarce fauna allowed to assign the section to the Eifelian-Emsian (*Po. serotinus-Po. partitus* zones) but prevented placing the precise position of the Lower/Middle Devonian boundary.

Malga Zermula II (MLZ II)

The Malga Zermula (MLZ II) section is located along the shortcut of the forest road between Casera Zermula and Casera La Valute about 250 m east of the MLZ section, at coordinates 46°34'00.811"N - 13°07'26.811"E and altitude 1390 m.

This short section exposes a few meters of limestones at the boundary between the Findenig and the Hoher Trieb formations. The four samples collected yielded a very poor and fragmented fauna, preventing a precise age attribution.

Malga Zermula (MLZ)

The Malga Zermula (MLZ) section is located along the forest road between Casera Zermula and Casera La Valute, at coordinates 46°34'01.741"N - 13°07'26.262"E and altitude 1355 m.

This short section was sampled at the top of the limestones of the Hoher Trieb Fm., close to the tectonic contact with the pelites of the Hoher Trieb Fm.

The section is dated to the lower Givetian *Po. timorensis* Zone (CORRADINI et al. 2016).

Punta Cul di Creta (PCC)

The Punta Cul di Creta (PCC) section is located along the path n. 442 to Cul di Creta and Mt Zermula

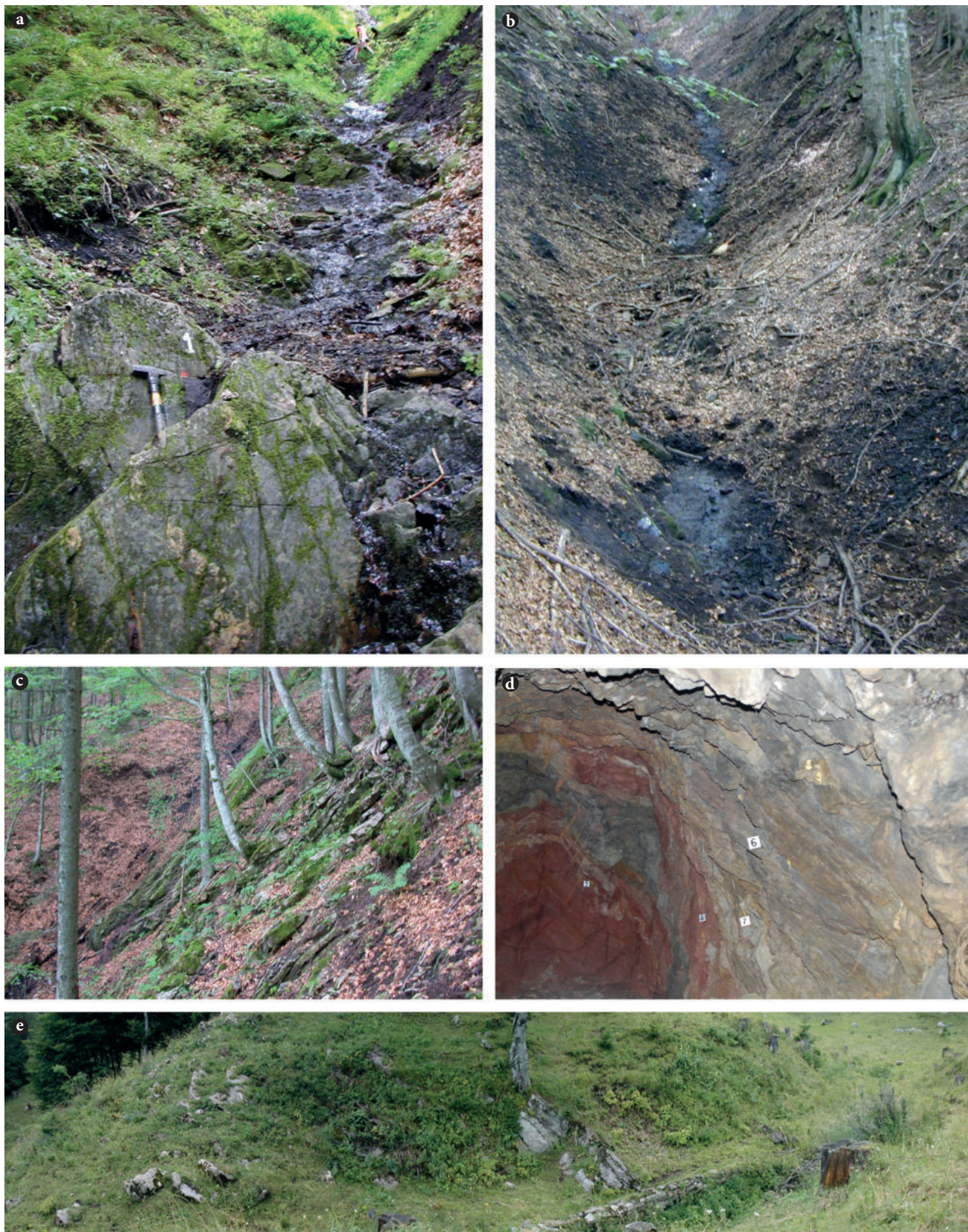
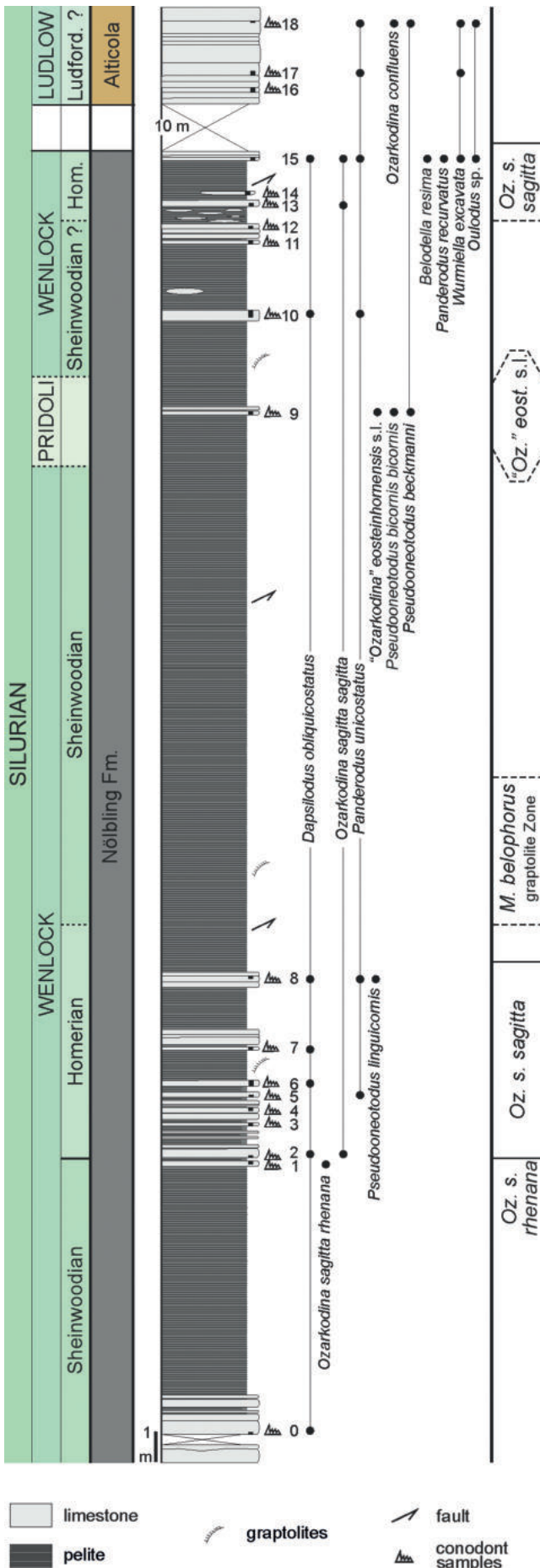


Fig. 4 - Views of selected stratigraphic sections in the La Valute area. a) Bosc dai Floriz (BDFE) section. b) the lower part of the La Valute Nord (VALN) section. c) La Valute Casermetta (VC) section. d) the transition between La Valute and Findenig formations in La Valute Cave (LV) section. e) Casera La Valute (CLV) section.
 - Viste di alcune sezioni stratigrafiche nell'area de La Valute. a) Bosc dai Floriz (BDFE). b) la parte inferiore della sezione La Valute Nord (VALN). c) La Valute Casermetta (VC). d) la transizione tra le formazioni de La Valute e del Findenig nella La Valute Cave (LV). e) Casera La Valute (CLV).



at coordinates 46°34'09.250"N - 13°07'44.588"E and altitude 1660 m.

The section was measured in a well bedded sector of the Spinotti Fm. Unfortunately, the 10 samples collected yielded only one fragmented ramiform element, preventing any age attribution. The microfacies analysis of thin sections shows that these rocks are rich in benthic forams but it was possible to assign them only at generic level to *Parathurammia*.

Plan di Zermula D (PZD)

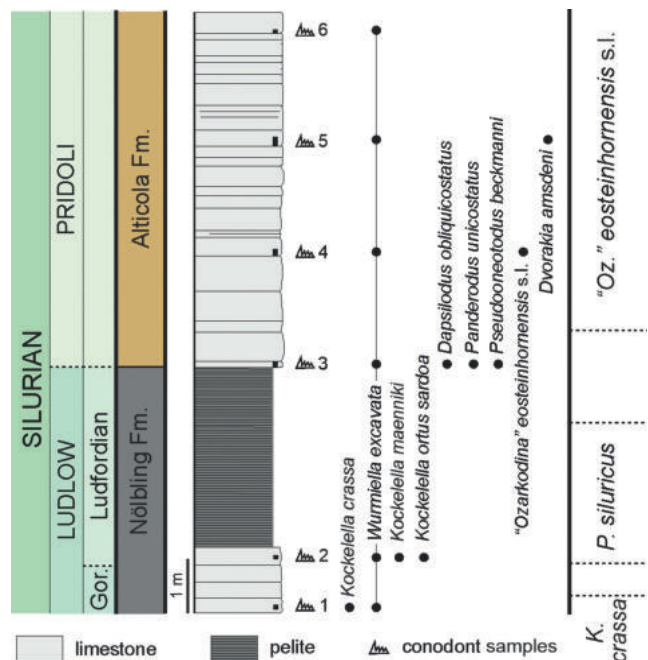
The Plan di Zermula D (PZD) section was measured along the road connecting Paularo to Passo del Cason di Lanza, where an abandoned small quarry can be

Fig. 5 - (left) Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the La Valute Nord (VALN) section. Ludl. = Ludlow; Príd. = Prídolí; east. = eosteinhornensis. Modified after CORRADINI et al. (2016).

- (sinistra) Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione La Valute Nord (VALN). Ludl. = Ludlow; Príd. = Prídolí; east. = eosteinhornensis. Modificato da CORRADINI et al. (2016).

Fig. 6 - (below) Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the Casera La Valute (CLV) section. Gor. = Gorstian. Modified after CORRADINI et al. (2016).

- (sotto) Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione Casera La Valute (CLV). Modificato da CORRADINI et al. (2016).



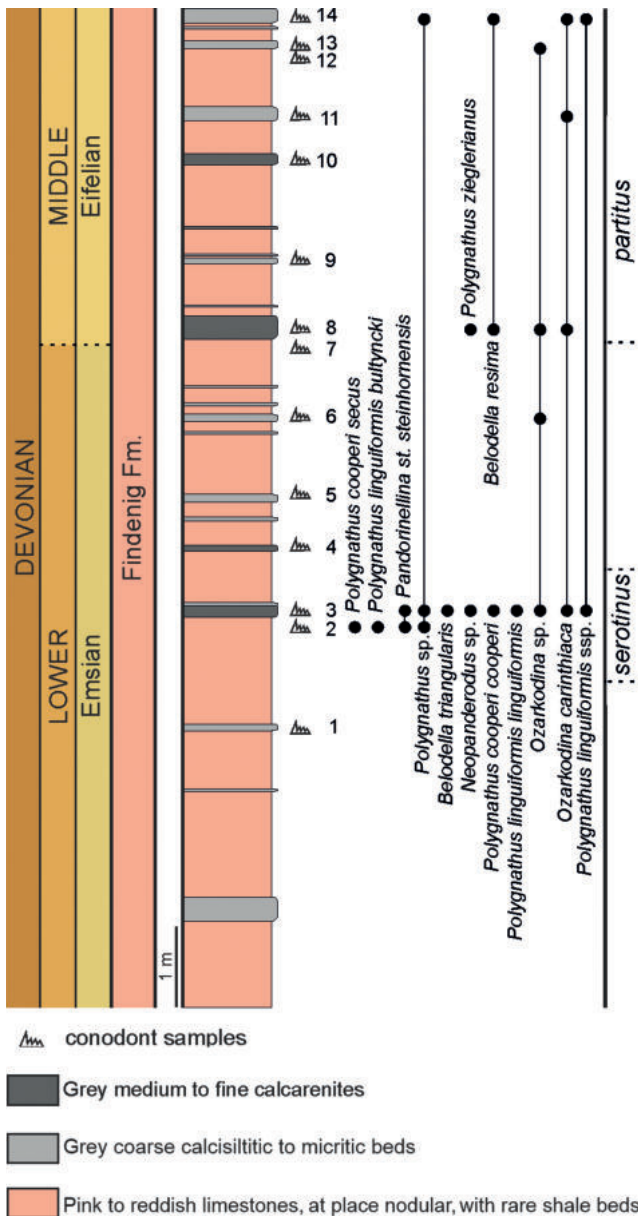
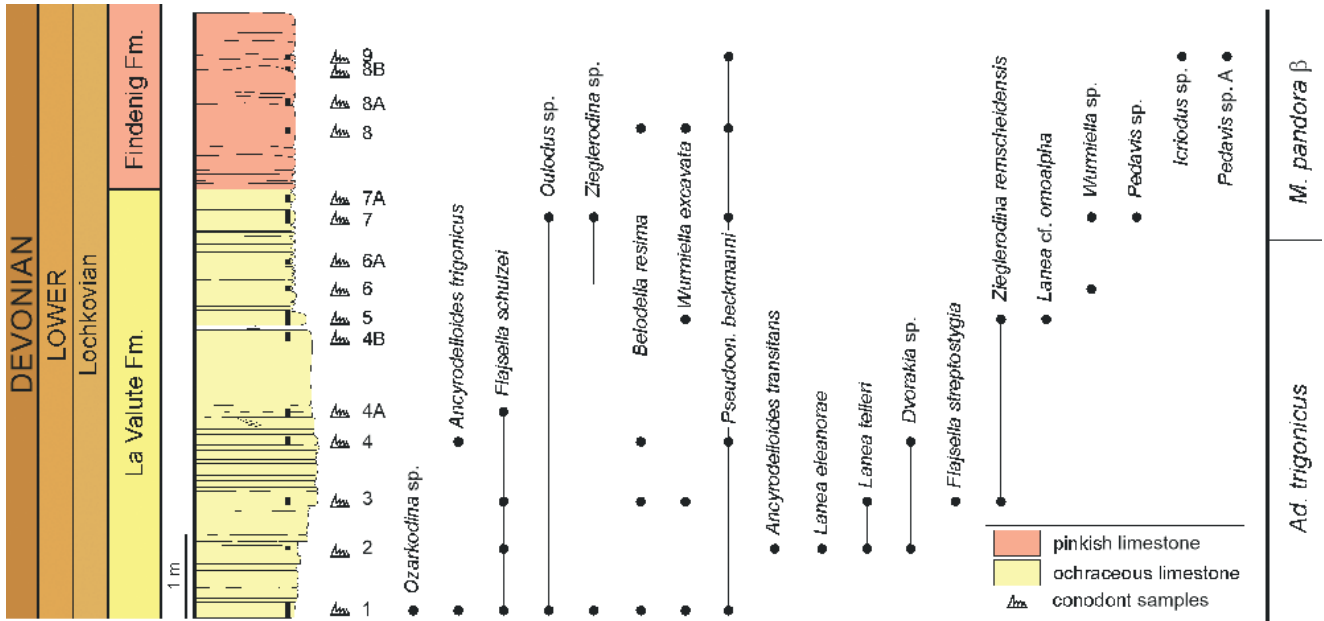


Fig. 7 - Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the La Valute Cave (LV) section. Modified after CORRADINI et al. (2016).

- *Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione La Valute Cave (LV). Modificato da CORRADINI et al. (2016).*

Fig. 8 - (left) Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the Stua Ramaz (STR) section. Column redrawn and modified after VAI (1980).

- *(sinistra) Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione Stua Ramaz (STR). Colonna stratigrafica ridisegnata e modificata da VAI (1980).*

used as parking place just north of the steep cliff above Rio Chiarsò canyon, at coordinates 46°34'32.104"N - 13°06'42.481"E and altitude 1015 m.

It is a short, strongly tectonized section, still in study, sampled with the goal to date a thin dark pelitic level within the limestones of the Pal Grande Fm. Preliminary data indicates that the section spans from the upper Frasnian to the lowermost Famennian: therefore, the pelites may represent one event of the polyphase Kellwasser crisis.

Las Callas (LC)

The Las Callas (LC) section (Figs 9b, 10) was measured in an abandoned limestone quarry close to the path from Plan di Zermula to Las Callas canyon, at coordinates 46°33'58.851"N - 13°06'39.969"E and altitude 1050 m. The section was studied by PERRI & SPALLETTA (1990), who also described in detail the conodont fauna.

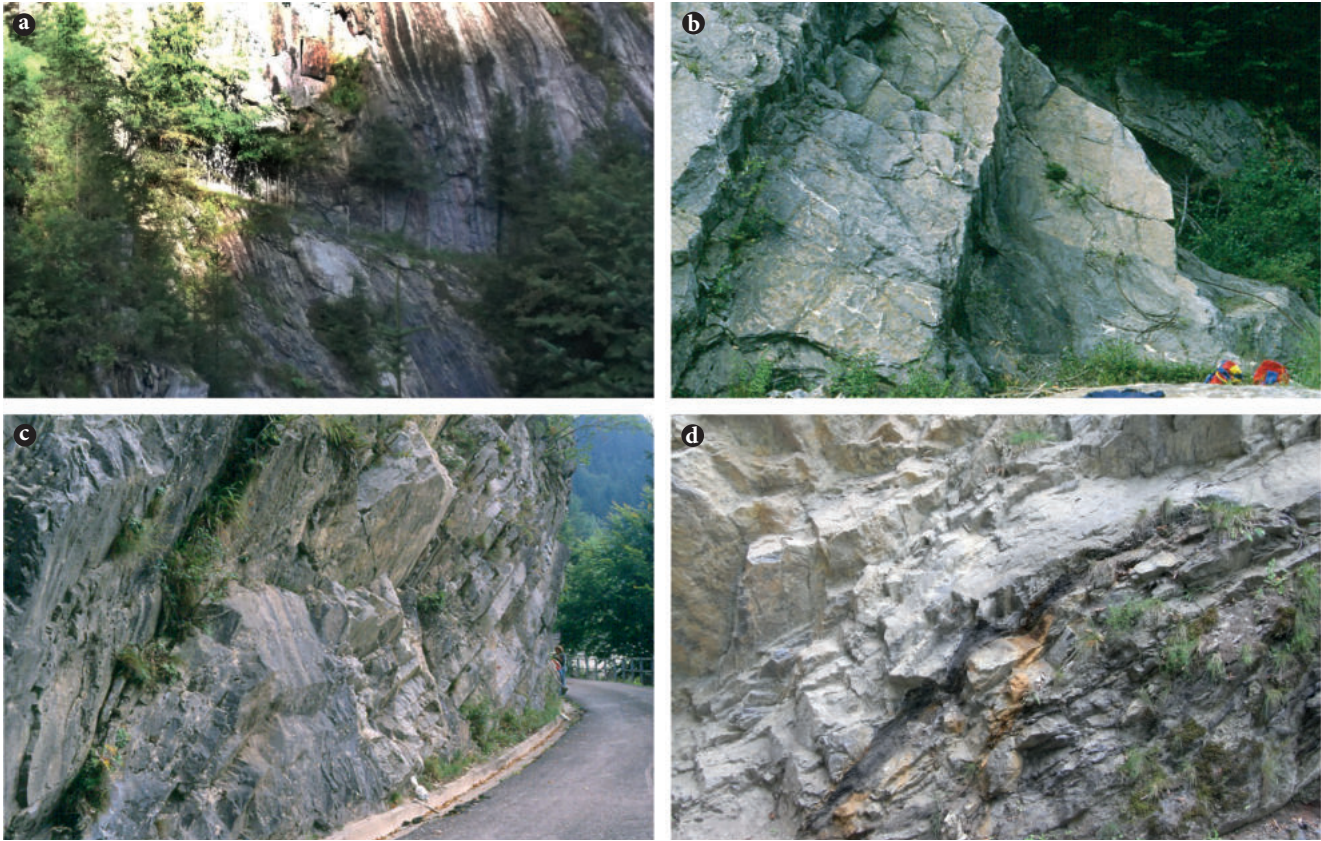


Fig. 9 - Views of selected stratigraphic sections in the Chiarsò creek area. a) Stua Ramaz (STR) section: the section was measured along the path. b) Las Callas (LC) section. c) Plan di Zermula B (PZB) section. d) Plan di Zermula A (PZA) section.

- Viste di alcune sezioni stratigrafiche nell'area del torrente Chiarsò. a) Stua Ramaz (STR): la sezione è stata misurata lungo il sentiero. b) Las Callas (LC). c) Plan di Zermula B (PZB). d) Plan di Zermula A (PZA).

The section exposes about 16 m of grey micritic fossiliferous limestone of the Pal Grande Fm. organized in planar to slightly wavy beds up to 4 cm thick. A slump, more than 1 metre thick is present in the lower part of the section.

The section can be referred to the middle Famennian thanks to the rich and well-preserved conodont fauna allowing the discrimination of three consecutive zones of the SPALLETTA et al. (2017) scheme: *Pa. m. utahensis*, *Sc. vel. velifer* and *Pa. trachytera* zones.

Plan di Zermula B (PZB)

The Plan di Zermula B (PZB) section (Fig. 8c) was measured along the road connecting Paularo to Passo del Cason di Lanza, at coordinates $46^{\circ}34'28.306''\text{N}$ - $13^{\circ}06'40.173''\text{E}$ and altitude 1010 m.

The section exposes a few meters of limestones interrupted by several faults. Conodont data allow to discriminate several Famennian zones from the *Pa. m. utahensis* to the *Pa. gr. expansa*.

Chiarsò (CHR)

The Chiarsò (CHR) section (Fig. 11) is located along of the path n. 447 a few dozens of meters south of STR

section, at coordinates $46^{\circ}34'30.182''\text{N}$ - $13^{\circ}06'35.803''\text{E}$ and altitude 1025 m.

The section exposes a few meters of subvertical beds of limestones rich in ammonoids, belonging to the Pal Grande Fm. A rich and well-preserved conodont fauna allows to assign the whole section to the middle Famennian *Ps. granulosis* Zone.

Plan di Zermula A (PZA)

The Plan di Zermula A (PZA) section (Figs 9d, 12) was measured along the road connecting Paularo to Passo del Cason di Lanza, at coordinates $46^{\circ}34'26.327''\text{N}$ - $13^{\circ}06'41.878''\text{E}$ and altitude 1010 m. It is a famous section, as it is one of the four sections in the Carnic Alps where the Devonian/Carboniferous boundary is exposed.

The section was first described by VENTURINI & SPALLETTA (1990); a detailed conodont biostratigraphy was provided by PERRI & SPALLETTA (2001), KAISER (2005), KAISER et al. (2009) and SPALLETTA et al. (2021); geochemistry and selected mineral components were studied by KAISER (2005), KAISER et al. (2008; 2009), PISARZOWSKA et al. (2020) and RAKOCIŃSKI et al. (2020). Finally, the data were briefly summarized by CORRADINI & PONDRELLI (2021).

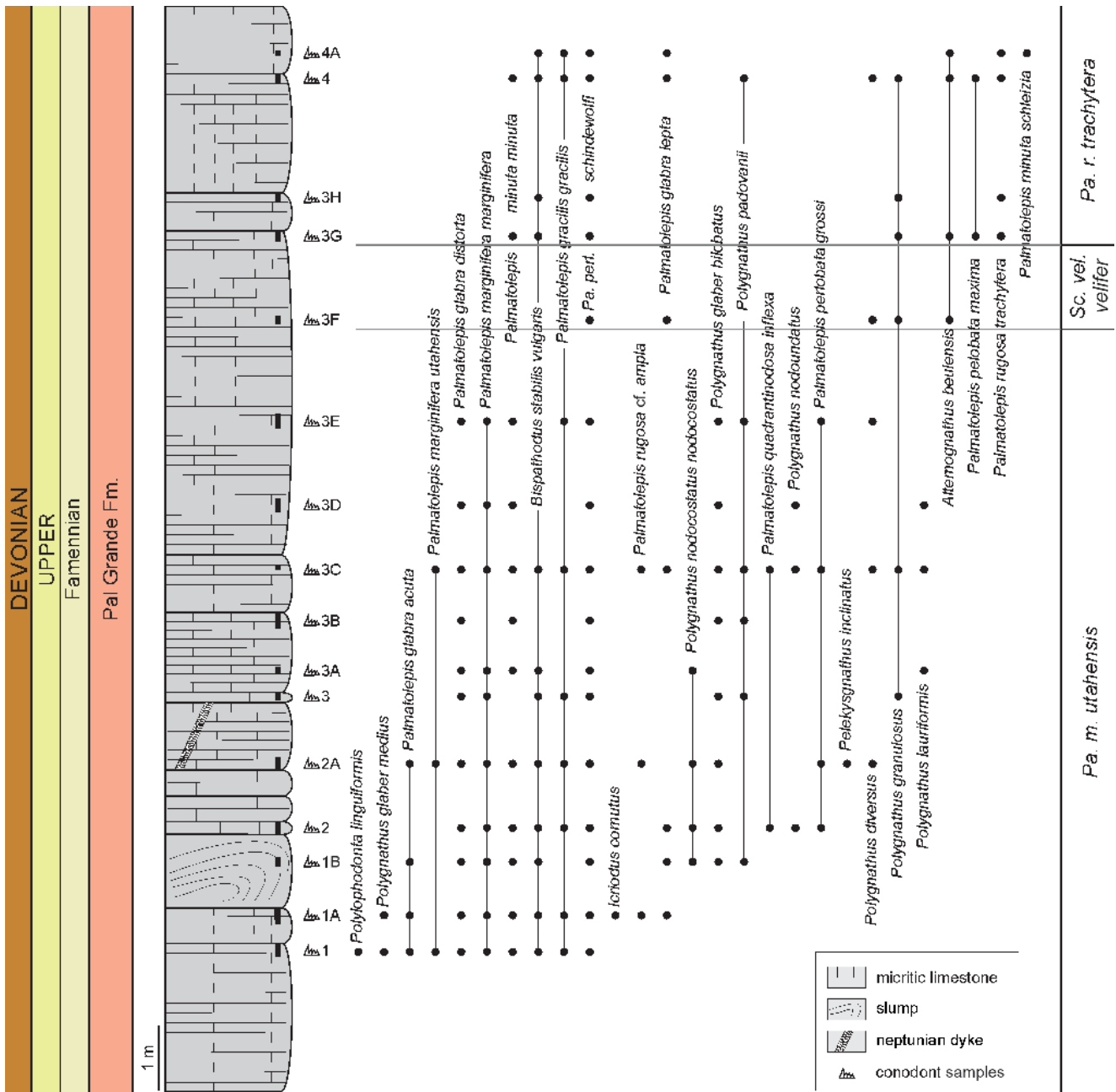


Fig. 10 - Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the Las Callas (LC) section. Redrawn and modified after PERRI & SPALLETTA (1990).
 - Cronostratigrafia (Sistema, Serie, Piano), litostrotigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione Las Callas (LC). Ridisegnata e modificata da PERRI & SPALLETTA (1990).

The section is overturned and exposes a few meters of well bedded limestones of the Pal Grande Fm. The limestone sedimentation is interrupted by a 10-20 cm thick black shale level, interpreted as an equivalent of the Hangenberg Black Shales (PERRI & SPALLETTA 2001). The limestones are conformably followed by a few dozens of cm of cherts of the Zollner Fm. and by pelites of the Hochwipfel Fm.

The age of the PZA section spans from the late Famennian to the early Tournaisian (*Pa. gr. expansa* to *Si. quadruplicata* zones), even if a few lower Carboniferous zones are missing, likely due to tectonic elision.

Plan di Zermula C (PZC)

The Plan di Zermula C (PZC) section was measured along the road connecting Paularo to Passo del Cason di Lanza a few dozens of meters north of the PZA section, at coordinates 46°34'31.015"N - 13°06'41.164"E and altitude 1010 m. The section was studied by PERRI & SPALLETTA (2001).

It a short, strongly tectonized, folded and faulted section of micritic limestones of the Pal Grande Fm., overlaid by a few cm of cherts and pelites of the Hochwipfel Fm. According to a relatively well-preserved conodont

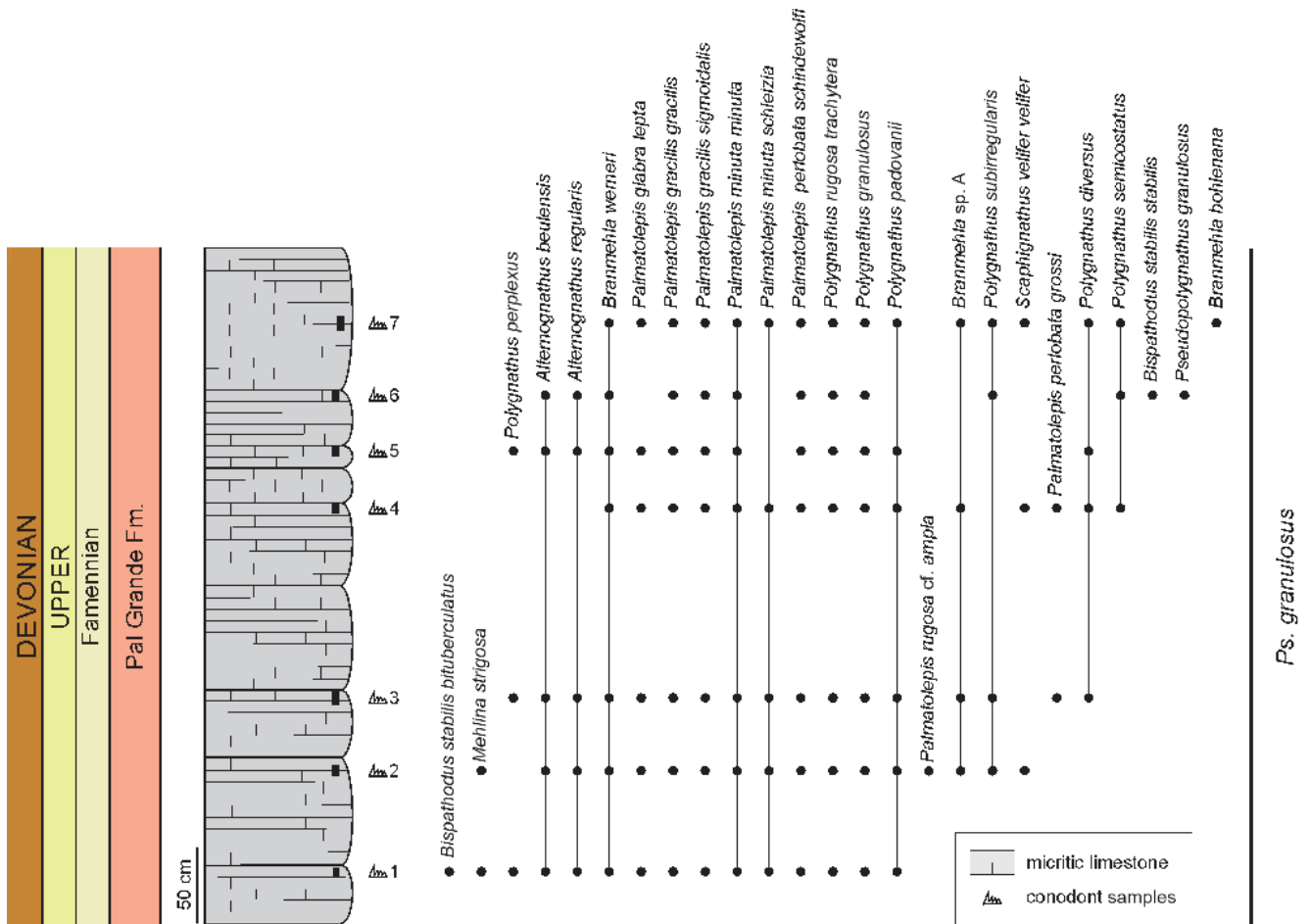


Fig. 11 - Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the Chiarsò (CHR) section.

- Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione Chiarsò (CHR).

fauna, the section is dated to the early Tournaisian *Pr. kockeli* and *Si. quadruplicata* Zones. It should be noted that a few zones, from the *Si. bransoni* to *Si. wilberti*, are missing due to a tectonic elision.

La Valute scogliera (LA)

The La Valute scogliera (LA) section was measured about 150 m east of La Valute top, at coordinates 46°34'16.897"N - 13°07'25.175"E and altitude 1525 m. A few meters of limestones of the Pal Grande Fm. crop out disconformably overlying the shallow water ?Middle Devonian rocks. The data from this locality were reported by CORRADINI et al. (2016).

The section yields a rich but in general poorly preserved upper Tournaisian fauna that can be referred to the upper part of the *anchoralis-latus* Zone.

Other localities

Stua Ramaz I (SR I) - The Stua Ramaz I outcrop is located about 150 m east of Stua Ramaz bridge at co-

ordinates 46°34'40.248"N - 13°06'53.921"E and altitude 1000 m. A few graptolites were collected from a poorly exposed outcrop of the Nölbling Fm., allowing to state a Telychian-early Sheinwoodian age for the locality.

Stua Ramaz II (SR II) - The Stua Ramaz II locality is about 250 m east of Stua Ramaz bridge at coordinates 46°34'41.247"N - 13°06'56.275"E and altitude 1000 m. A few lenses of limestone within poorly preserved shales of the Nölbling Fm. are exposed. Cardiolid bivalves and orthoceratid cephalopods occur, and a conodont sample yielded a fauna of the Ludfordian *A. ploeckensis* Zone (CORRADINI et al. 2016).

Monte Zermula loboliti (MZ lob) - The locality MZ lob is located about 250 m east of Stua Ramaz bridge along a creek at coordinates 46°34'39.788"N - 13°06'55.785"E and altitude 1020 m. Here a few loose blocks of the Rauchkofel Fm., bearing beautifully preserved lobolites of the pelagic crinoid of family Scyphocrinitidae were found (CORRADINI et al. 2005; 2020). The rich conodont fauna collected allowed to assign the locality to the lowermost Lochkovian *Icr. hesperius* Zone.

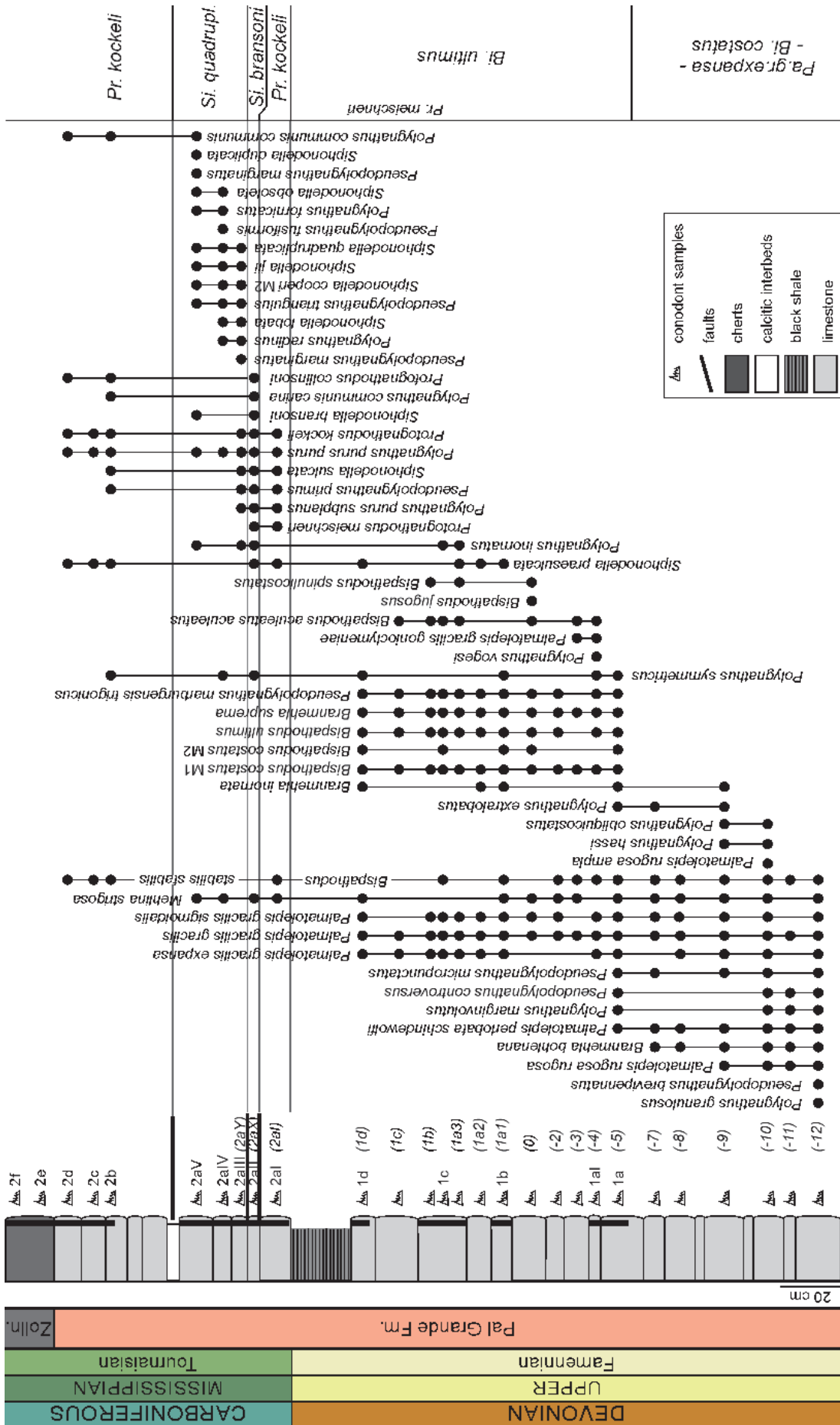


Fig. 12 - Chronostratigraphy (System, Series, Stage), lithostratigraphy, stratigraphic column, conodont samples, distribution of conodonts, and biostratigraphy of the Plan di Zermula A (PZA) section. Conodont data after PERRI & SPALLETTA (1990), KAISER et al. (2009) and SPALLETTA et al. (2021).
 - Cronostratigrafia (Sistema, Serie, Piano), litostratigrafia, colonna stratigrafica, campioni a conodonti, distribuzione dei conodonti e biostratigrafia della sezione Plan di Zermula A (PZA). Dati a conodonti da PERRI & SPALLETTA (1990), KAISER et al. (2009) e SPALLETTA et al. (2021).

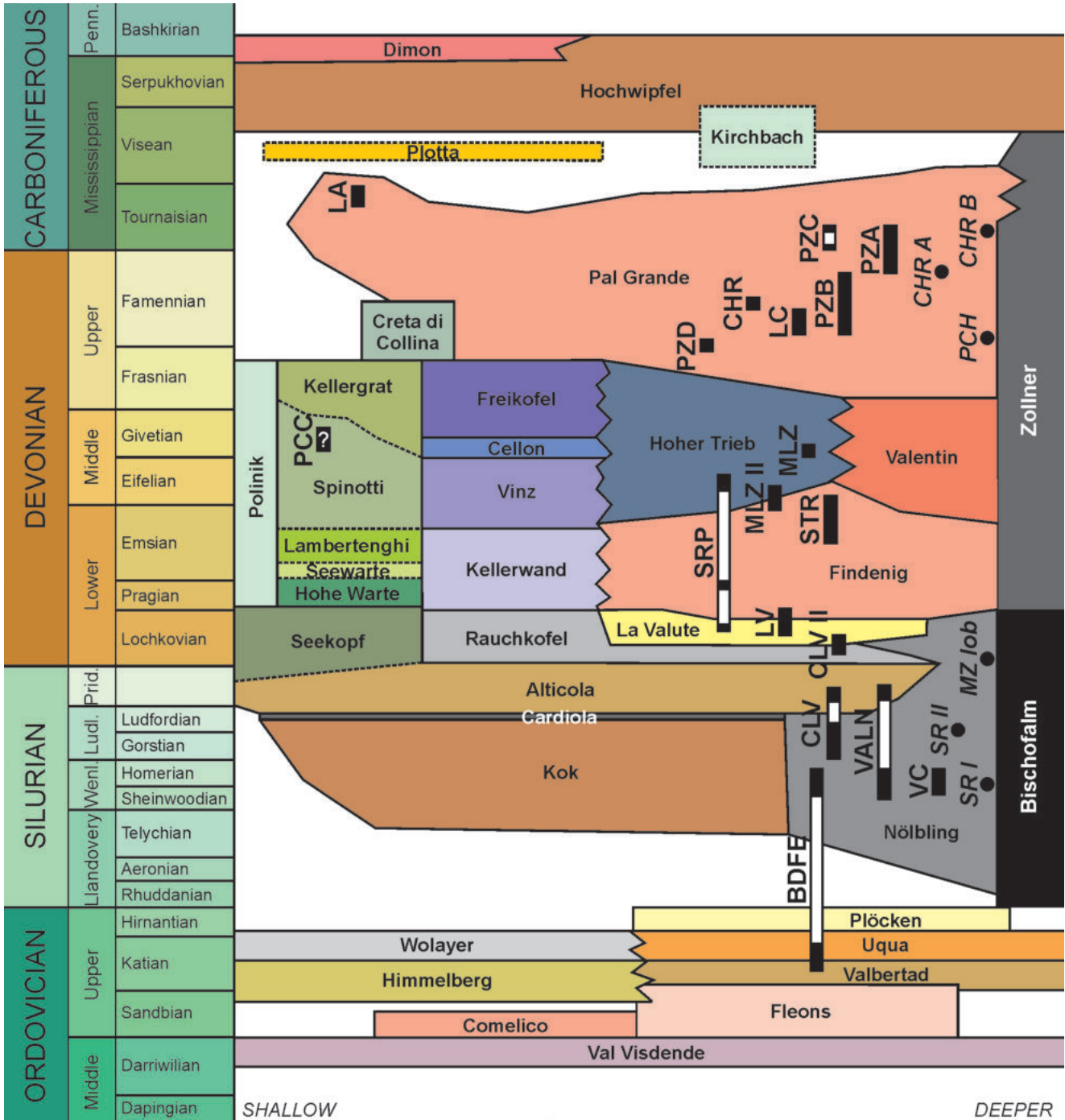


Fig. 13 - Chronostratigraphic age of the sections and other localities studied in the La Valute-Chiarsò area plotted in the litho-stratigraphic scheme of the Carnic Alps, modified after CORRADINI et al. (2015c). Black rectangles: documented intervals in the sections; white rectangles: hiatuses in the sections; circles: spot samples. Abbreviations: BDFE: Bosc dai Floriz Est; CHR: Chiarsò; CHR A: Chiarsò A; CHR B: Chiarsò B; CLV: Casera la Valute; CLV II: Casera La Valute II; LA: La Valute scogliera; LC: Las Callas; MLZ: Malga Zermula; MLZ II: Malga Zermula II; MZ lob: Monte Zermula loboliti; PCC: Punta Cul di Creta; PCH: Ponte Chiarsò; PZA: Plan di Zermula A; PZB: Plan di Zermula B; PZC: Plan di Zermula C; PZD: Plan di Zermula D; SR I: Stua Ramaz I; SR II: Stua Ramaz II; SR III: Stua Ramaz III; SRP: Stua Ramaz Ponte; STR: Stua Ramaz; VALN: La Valute Nord; VC: La Valute casermetta.

- Schema lithostratigrafico della sequenza Pre-Varisca delle Alpi Carniche, modificato da CORRADINI et al. (2015c) con indicata la posizione cronostratigrafica delle sezioni e altre località studiate nell'area La Valute-Chiarsò. Rettangoli neri: intervalli documentati nelle sezioni; rettangoli bianchi: hiatus nelle sezioni; cerchi: campioni isolati. Abbreviazioni: BDFE: Bosc dai Floriz Est; CHR: Chiarsò; CHR A: Chiarsò A; CHR B: Chiarsò B; CLV: Casera la Valute; CLV II: Casera La Valute II; LA: La Valute scogliera; LC: Las Callas; MLZ: Malga Zermula; MLZ II: Malga Zermula II; MZ lob: Monte Zermula loboliti; PCC: Punta Cul di Creta; PCH: Ponte Chiarsò; PZA: Plan di Zermula A; PZB: Plan di Zermula B; PZC: Plan di Zermula C; PZD: Plan di Zermula D; SR I: Stua Ramaz I; SR II: Stua Ramaz II; SR III: Stua Ramaz III; SRP: Stua Ramaz Ponte; STR: Stua Ramaz; VALN: La Valute Nord; VC: La Valute casermetta.

Ponte Chiarsò (PCH) - A single sample was picked in a strongly tectonized outcrop of Pal Grande Fm., a few dozens of meters downstream Stua Ramaz bridge at coordinates 46°34'38.106"N - 13°06'48.851"E and altitude 960 m. It yielded a fragmentary conodont association of earliest Famennian age.

Chiarsò A (CHR A) and Chiarsò B (CHR B) - Two isolated samples were collected on the right side of Chiarsò creek along path 447, a few meters south of section CHR, at coordinates 46°34'29.724"N - 13°06'34.832"E and 46°34'29.561"N - 13°06'35.217"E, respectively. They were named CHR A and CHR B, and both yielded a rich and well-preserved conodont fauna. Sample CHR A is attributed to the uppermost Famennian *Bi. ultimus* Zone, and sample CHR B to the lower Tournaisian *Si. wilberti* Zone.

Discussion and conclusion

The nineteen stratigraphic sections measured in the La Valute-Chiarsò area and the additional spot samples provide information to reconstruct in detail the geology and the stratigraphy of the area (Fig. 13). In the study area an almost complete sequence from the Katian (Upper Ordovician) to the Tournaisian (lower Carboniferous) is exposed. Two different successions crop out in the eastern and western part of the study area and are separated by a regional overthrust (CORRADINI et al. 2016; 2020).

In the eastern part shallow water Devonian rocks of the Spinotti Fm., presumably of Givetian age, are exposed. This unit is unconformably overlain by a few meters of pelagic limestone of the Pal Grande Fm. dated to the latest Tournaisian in the La Valute Scogliera section. A similar hiatus above the shallow water reefal rocks is documented in other areas of the Carnic Alps (e.g., Mt Coglians area, SCHÖNLAUB & KREUTZER 1993).

In the western area a pelagic sequence is exposed. At first approximation the older terms (Upper Ordovician to Middle Devonian) are exposed in La Valute area, whereas the younger units crop out along the Rio Chiarsò valley. In the studied sections the Ordovician is documented only at the base of the Bosc dai Floriz section. Most of the Silurian is represented by black pelites and interbedded dark limestones of the Nölbling Fm. of Sheinwoodian to Gorstian age (Casera La Valute and La Valute Nord sections), whereas only the Pridoli can be surely recognized in rocks of the Alticola Fm. (e.g., Casera La Valute and La Valute Nord sections). The Lower and Middle Devonian is represented by the classical pelagic sequence with locally interbedded gravitative-driven deposits represented by the Rauchkofel, La Valute, Findenig and Hoher Trieb: the age of these units in the study area was documented in the Casera

La Valute II, La Valute, Stua Ramaz Ponte, Stua Ramaz, Malga Zermula and Malga Zermula II sections. The Upper Devonian and the Tournaisian are represented by the pelagic cephalopod limestones of the Pal Grande Fm., documented in several sections along the Chiarsò river (Chiarsò, Las Callas, Plan di Zermula A, Plan di Zermula B, Plan di Zermula C and Plan di Zermula D).

Manuscript received on 24.V.2023, accepted on 07.VIII.2023.

Acknowledgement

Several friends and colleagues helped us during the field campaigns in the area: we do not make a list of them, in order to not forget somebody, but all are deeply acknowledged. We warmly thank the people of Cason di Lanza for their hospitality and support during several years of researches in the area. A special memory for Silvio: our hearts will always have a special place for you. Our friend, colleague and co-author Luca Simonetto passed away during the preparation of this paper, we completed it in loving memory of him.

This paper is a contribution to IGCP Project n. 652 "Reading geologic time in Paleozoic sedimentary rocks" and to PRIN 2022 Project 2022ZH5RWP "DEtailing thE Palaeogeography of Southern PALaeoeurope by meanS of biosTratigraphic correlation and basin development in the Palaeozoic to early Mesozoic time-frame: case histories from the Italian record (DEEP PAST)".

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