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Maria G. Corriga
Thomas J. Suttner
Carlo Corradini
Erika Kido
Monica Pondrelli
Luca Simonetto

THE AGE OF THE LA VALUTE LIMESTONE-FINDENIG LIMESTONE TRANSITION IN THE LA VALUTE SECTION (MOUNT ZERMULA AREA, CARNIC ALPS)

L'ETÀ DEL PASSAGGIO CALCARE DE LA VALUTE - CALCARE DEL FINDENIG NELLA SEZIONE DE LA VALUTE (MONTE ZERMULA, ALPI CARNICHE)

Riassunto breve - La sezione de La Valute, potente circa 8 metri, è costituita da calcari del Devoniano Inferiore ed espone il limite tra il calcare de La Valute e il calcare del Findenig. Si tratta di depositi pelagici con ricche associazioni di dacryoconaridi, nautiloidi, ostracodi, trilobiti, brachiopodi, articoli di crinoidi e conodonti. Per datare il limite formazionale sono stati studiati quindici campioni a conodonti, che hanno fornito una fauna abbastanza ricca e differenziata; sono stati riconosciuti i generi *Ancyrodelloides*, *Belodella*, *Dvorakia*, *Flajsella*, *Lanea*, *Oulodus*, *Pedavis*, *Pseudooneotodus*, *Wurmiella* e *Zieglerodina*. L'associazione consente il riconoscimento di due biozone a conodonti del Lochkoviano medio-superiore: la Biozona a *trigonicus* (parte alta del calcare de La Valute) e la Biozona a *pandora* β (base del calcare del Findenig): il limite formazionale è situato nella parte inferiore della Biozona a *pandora* β.
Parole chiave: Conodonti, Devoniano Inferiore, Lochkoviano, Alpi Carniche, Italia.

Abstract - *The Lower Devonian sequence at La Valute cave is about 8 meters thick and includes the boundary of La Valute limestone and Findenig limestone. It is represented by pelagic deposits yielding dacryoconarids, nautiloids, ostracods, trilobites, brachiopods, some crinoid stem-plates and conodonts. In order to give an age constrain for the formation-boundary fifteen conodont samples were collected and processed. Apart from some barren samples, a quite diverse Lochkovian fauna is obtained. Conodont genera like* Ancyrodelloides, Belodella, Dvorakia, Flajsella, Lanea, Oulodus, Pedavis, Pseudooneotodus, Wurmiella *and* Zieglerodina *have been identified. Distinctive conodont-assemblages belong to two middle-late Lochkovian biozones, the* trigonicus *Zone (upper part of La Valute limestone) and the* pandora *β Zone (base of Findenig limestone), which allow the allocation of the formation-boundary near the base of the* pandora *β Zone.*
Key words: *Conodonts, Lower Devonian, Lochkovian, Carnic Alps, Italy.*

Introduction

This paper is a contribution to a project run by several Italian and Austrian institutions on formal lithostratigraphy of the pre-Variscan sequence of the Carnic Alps. The Carnic Alps, extending across the border between Austria and Italy, represent the non metamorphic to low metamorphic sector of the Palaeozoic succession of the Southern Alps. The sequence here recorded exposes rocks from Ordovician to Carboniferous age, and has been investigated by several workers from the XIX century on. The huge amount of papers published since then documents different aspects of the Carnic Alps geology (geological mapping, palaeontology, stratigraphy, structural geology, etc.). The single units of this sequence are mainly denominated with informal names, that derivate either from fossils, facies or historical terms. Furthermore, being the region across the state border between Italy and Austria, different terminologies have been adopted on both sides of the mountain chain, which result in a high number of names indicating similar -if not the same- lithological units. Almost none of them have been formalized according to the ICS rules.

The goal of the project on "Formal lithostratigraphic units in the pre-Variscan sequence of the Carnic Alps" is to achieve a common and unified terminology, formally subdividing the lithostratigraphic column in geological units with well-defined stratotypes. In order to reach such a result, all the lithostratigraphic units must be stratigraphically constrained.

Aim of this paper is to precisely date the transition between the La Valute and the Findening limestone at La Valute (Monte Zermula area, Italy). These units crops out extensively in the Lower Devonian succession of the entire Carnic Alps.

The Lochkovian of the Carnic Alps

The Lower Devonian of the Carnic Alps starts with the Rauchkofel Formation. However two different lithological units are assigned to this name: pelagic dark limestones and interbedded shales ("pelagic Rauchkofel Fm.") and very shallow water fossiliferous sediments ("neritic Rauchkofel Fm."). The first facies is widely distributed in the Carnic region, whereas the latter is more limited to the Lake Wolayer area.

The Rauchkofel Fm. is overlain by well-bedded light gray/ocraceus limestone, slightly nodular at places; this unit is named La Valute limestone here and is equivalent to the Boden Limestone of the Wolayer area (Kreutzer 1992). Fossils are scarce. The La Valute limestone grades upward into the purple red nodular Findenig limestone.

In the deeper part of the basin the sequence consists of black argillite shales distinguished into two units on the basis of rocks interbedded within the shales: the Nölbling Formation, with levels of limestone, and the Bischofalm Formation, with lydites. Graptolites are the only fossils abundant in both these units.

Geological settings of La Valute Area

The La Valute area is characterized by severe thin-skinned tectonic deformation (Vai 1976; Schönlaub, 1985; Venturini 1990). The area is in fact located in the lowermost part of a several kilometer large fold driven by a roughly NE dipping, top to the south detachment thrust of Variscan age (Venturini 1990). As a consequence, the stratigraphic succession is overturned. This large fold is disrupted by roughly WNW-ESE trending north dipping inverse faults and thrusts of Variscan as well as Chattian-Burdigalian ages. All these lineaments were reactivated as dextral strike-slip faults during the Serravallian-Tortonian and Plio-Pleistocene compressional phases (Venturini 1990).

The studied section is part of a stratigraphic succession that starts with few meters of fossiliferous Uqua shales of Upper Ordovician age. On top of this unit, it is locally present up to a meter of nodular mudstone-wackestone of the Uqua limestone.

The Silurian deposition starts in disconformity on top of the Ordovician sediments and consists of the so-called "Findenig facies", representing mostly pelagic deposits (Wenzel 1997). A few tenths of meters of black graptolitic shales alternating with mudstone to wackestone of the Nölbling Formation were here deposited from the Wenlock to the late Ludlow. These sediments are covered by less than ten meters of light red wackestone to packstone of the Alticola limestone, which in the study area is limited to Pridoli. The sequence continues with a few decimeters of the pelagic Rauchkofel Formation, consisting of dark gray to black shales and wackestone.

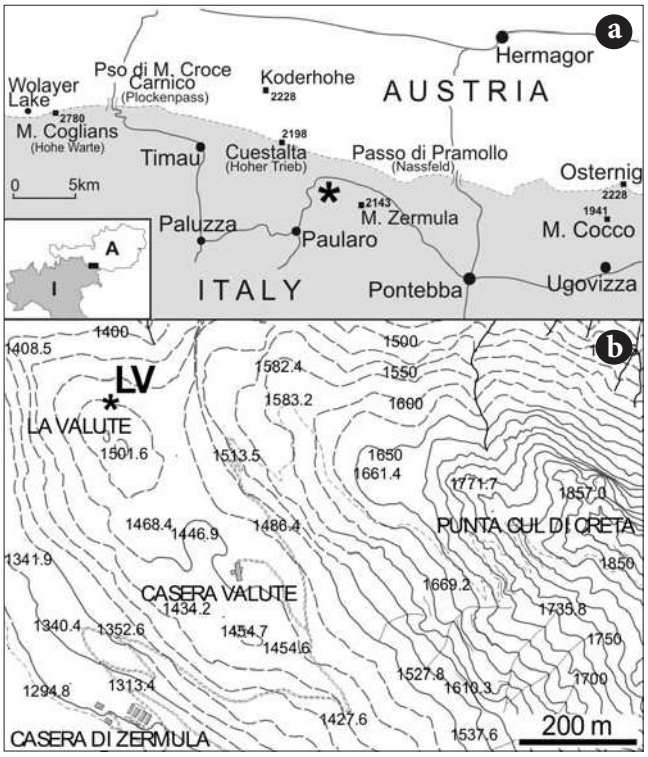


Fig. 1 - Location map. a) Schematic map of the Carnic region, with location of the La Valute area (asterisk). b) Topographic map of the western part of Mt. Zermula massif, with location of the La Valute section.
- *Ubicazione dell'area studiata. a) Mappa schematica delle Alpi Carniche, con indicazione dell'area de La Valute (asterisco). b) Carta topografica della parte occidentale del Monte Zermula, con ubicazione della sezione de La Valute.*

The Devonian facies in this area consist of prevalent pelagic to gravity-driven deposits sourcing from the shallow water facies. The Lower Devonian consists of the La Valute and Findenig limestones. The La Valute limestone is a light brown to light gray mudstone to wackestone in centimeter to decimeter thick layers. The transition to the Findenig limestone is marked by a change to a purple red color and by an increase of marl content. Both units were deposited in an open sea depositional environment.

During the Middle Devonian, the pelagic purple red facies become interlayered with lithoclastic limestone, which consist of thin and medium grained turbidites in centimeter to decimeter thick layers and matrix supported breccia in meter thick layers probably deposited as debris flows and radiolarite thin bedded black layers. This unit is called Hoher Trieb limestone, and is here about 40 meters thick (Selli 1963; Schönlaub 1985).

The carbonate succession is closed by the Clymeniae limestone of Late Devonian-Early Carboniferous age, which consists of grey to red mudstone to wackestone pelagic limestone.

The unconformable transition to the siliciclastic turbidites of the Hochwipfel Formation caps the succession and marks the beginning of the Variscan tectogenesis.

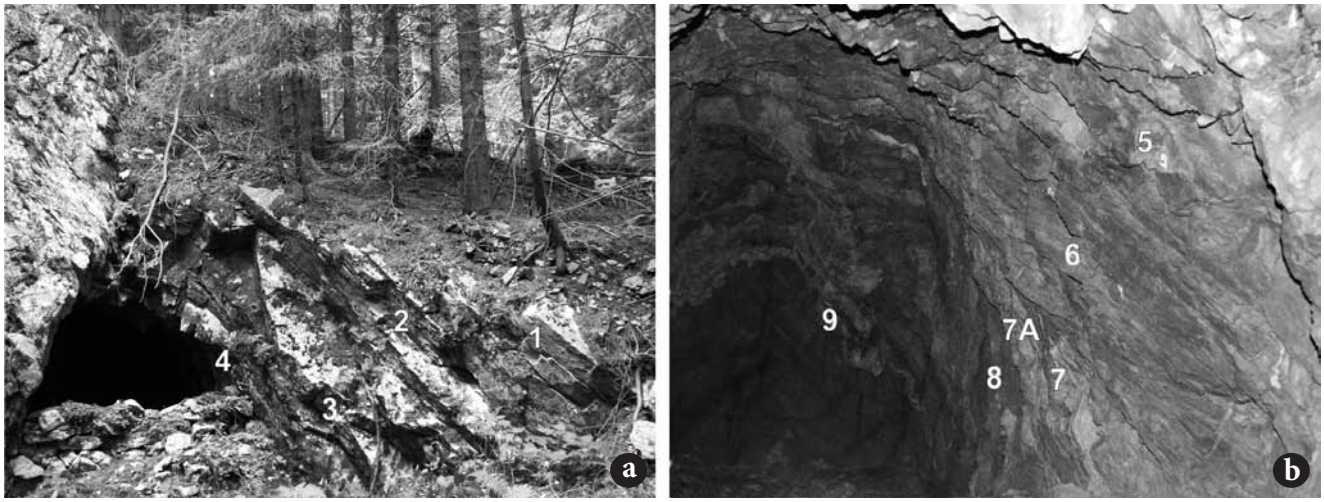


Fig. 2 - Views of La Valute section. a) The lower part of the section, sampled outside the cave in the La Valute limestone; b) views of the cave with location of selected samples. The La Valute limestone-Findenig limestone transition is located between samples 7A and 8. For graphical reason, not all the samples are indicated.
- *Vedute della sezione de La Valute. a) La parte inferiore della sezione, campionata nel calcare de La Valute al di fuori della grotta; b) veduta della grotta con indicazione della posizione di alcuni campioni. La transizione tra il calcare de La Valute e i calcari del Findenig è situata tra i campioni 7A e 8. Per motivi grafici non sono stati riportati tutti i campioni.*

Description of section and facies

The La Valute section is located just north of the top of La Valute, the northwestern part of Mt. Zermula massif, a few hundred meters NW of Casera La Valute (fig. 1). More precisely, the section is measured at coordinates N 46°34'18" E 13°7'18", inside and outside a First World War cave (fig. 2). The section is about 8 m thick and consists of well bedded gray limestone in the lower 5 m which changes to purple red wavy bedded to nodular limestone with increased deposition of clay in the upper part (ca. 3 m are exposed in the cave). The transition from gray to red color between the samples LV 7A and LV 8 (fig. 2b) marks the boundary between La Valute limestone (equivalent to the Boden limestone of the Wolayer area) and Findenig limestone (fig. 3).

Beds at the lower part of the section are about 5 to 20 cm in thickness and consist of mud- to wackestone with thin iron oxide crusts. The depositional character changes approx. 1.5 m below the formation boundary. Beds are thinner (2-10 cm) and consist of silty limestone. At the boundary nodular limestone is intercalated by intervals of dark to beige calcareous shale. In thin sections thin-shelled skeletal grains are commonly preserved as fragments and thus most of them can only be identified as filaments. Beside this, the upper part of La Valute limestone (samples LV 1-LV 7; compare fig. 4a, b) yields some few sponge spicule, trilobites, articulated ostracod shells, orthocone nautiloids (1-3 mm in diameter), some strongly fragmented crinoid stem-plates and brachiopod shells, dacryoconarids and conodonts. Whereas dacryoconarids are sparsely distributed in the lower part of the section their abundance increases drastically after the formation boundary hence they dominate the fauna from sample LV 8 onward. Other fossils found in the basal 3 meters of the Findenig limestone are represented by fragments of trilobites, ostracods, small orthocone nautiloids and crinoid stem-plates (fig. 4c, d). Compared to the La Valute limestone, only few conodont elements are obtained from this unit. In general, changes in the microfacies across the formation boundary reflect a gradual deepening of the regional pelagic regime.

Conodont data

Fifteen conodont samples have been collected from La Valute section (fig. 3, tab. I). About 45 kg of rock have been dissolved with conventional formic acid technique and more than 400 conodont elements have been isolated and determined.

In general state of preservation is quite poor, and about two thirds of the fauna is represented by indeterminable fragments.

Conodont color is dark brown, corresponding to a Color Alteration Index (CAI) of 4. The abundance varies between 34 and 0 elements/kg, and is in general higher in the lower part of the section. Some samples (i.e. LV 7A and LV 8A) are barren.

Eighteen taxa belonging to ten genera (*Ancyrodelloides*, *Belodella*, *Dvorakia*, *Flajsella*, *Lanea*, *Oulodus*, *Pedavis*, *Pseudooneotodus*, *Wurmiella* and *Zieglerodina*) have been identified (fig. 3, tab. I).

The entire fauna is housed in the Earth Sciences Department, University of Cagliari (DSTC), under numbers 30118-30145. Horizon and catalogue numbers of figured specimens are given in the plate captions.

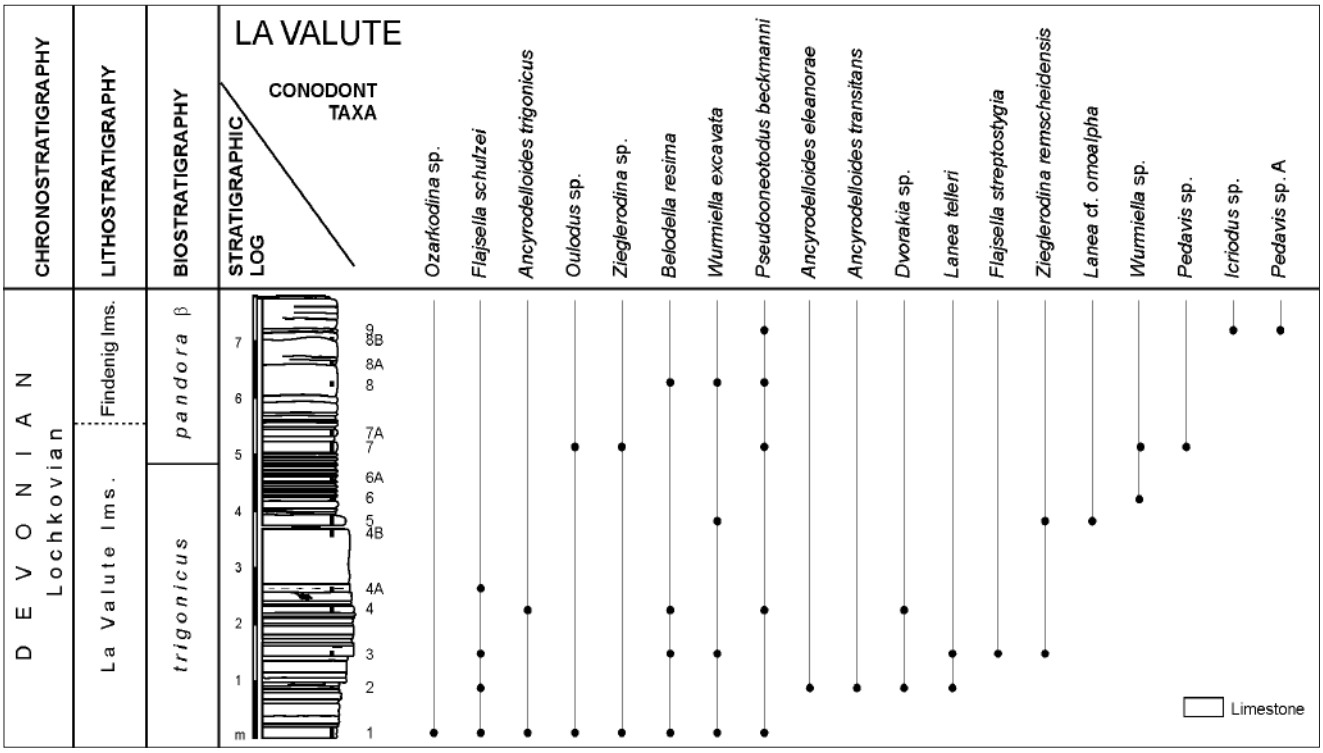


Fig. 3 - Stratigraphic column of La Valute section and conodont distribution.
- *Colonna stratigrafica e distribuzione dei conodonti nella sezione de La Valute.*

Biostratigraphy

The biozonation scheme followed in this paper is that proposed by Murphy & Valenzuela-Ríos (1999): these authors proposed to subdivide the middle Lochkovian *delta* Zone of previous zonation schemes (i.e.: Weddige, 1996) into four biozones, based on first occurrences of species of genera *Lanea* and *Ancyrodelloides* (from base to top the *omoalpha* Zone, the *transitans* Zone, the *eleanorae* Zone and the *trigonicus* Zone), and to rename the first zone of the late Lochkovian as *pandora* β Zone.

The conodont fauna allows the recognition of two zones: the *trigonicus* Zone and the *pandora* β Zone.

The *trigonicus* Zone

The occurrence of the marker *Ancyrodelloides trigonicus* at the base of the section (sample LV 1) allows to attribute the lower part of the section, up to sample LV 6, to this zone; the upper limit is marked by the occurrence of elements of *Pedavis* in sample LV 7. The occurrence of representatives of genus *Flajsella* and of *Lanea telleri* confirms this zonal attribution.

The *pandora* β Zone

The *pandora* β Zone is recognised from sample LV 7 to the top of the section, thank to the occurrence of coniform elements of *Pedavis* in sample LV 7 and of two P1 elements in sample LV/9. In fact, according to Valenzuela-Ríos & Murphy (1997) the first occurrence of representatives of genus *Pedavis* approximate the base of this Zone. The conodont association is very scarce in this interval.

Systematic palaeontology

Since almost all the species found are well known, taxonomic description is limited to the only questionable taxon.

Genus *Pedavis* Klapper & Philip, 1961

Pedavis sp. A
Figs 5.9-5.10

Description: P1 element of *Pedavis* characterized by a wide and well developed asymmetrical platform, with three strong processes. The lateral processes make a 90° angle.

The central process is stronger and longer than the lateral processes and bears three or more ridges of laterally compressed nodes. Nodes usually form a straight line on each ridge with the central node being somewhat larger that the lateral ones. The lateral inner process bears two or three transverse ridges of small nodes and is shorter than the lateral outer process. It bears four transverse ridges of nodes and its distal part may be straight or deflected. The position of nodes on ridges of the lateral processes does not show a distinctive pattern. They can be set straight in line or form a V-shape. A

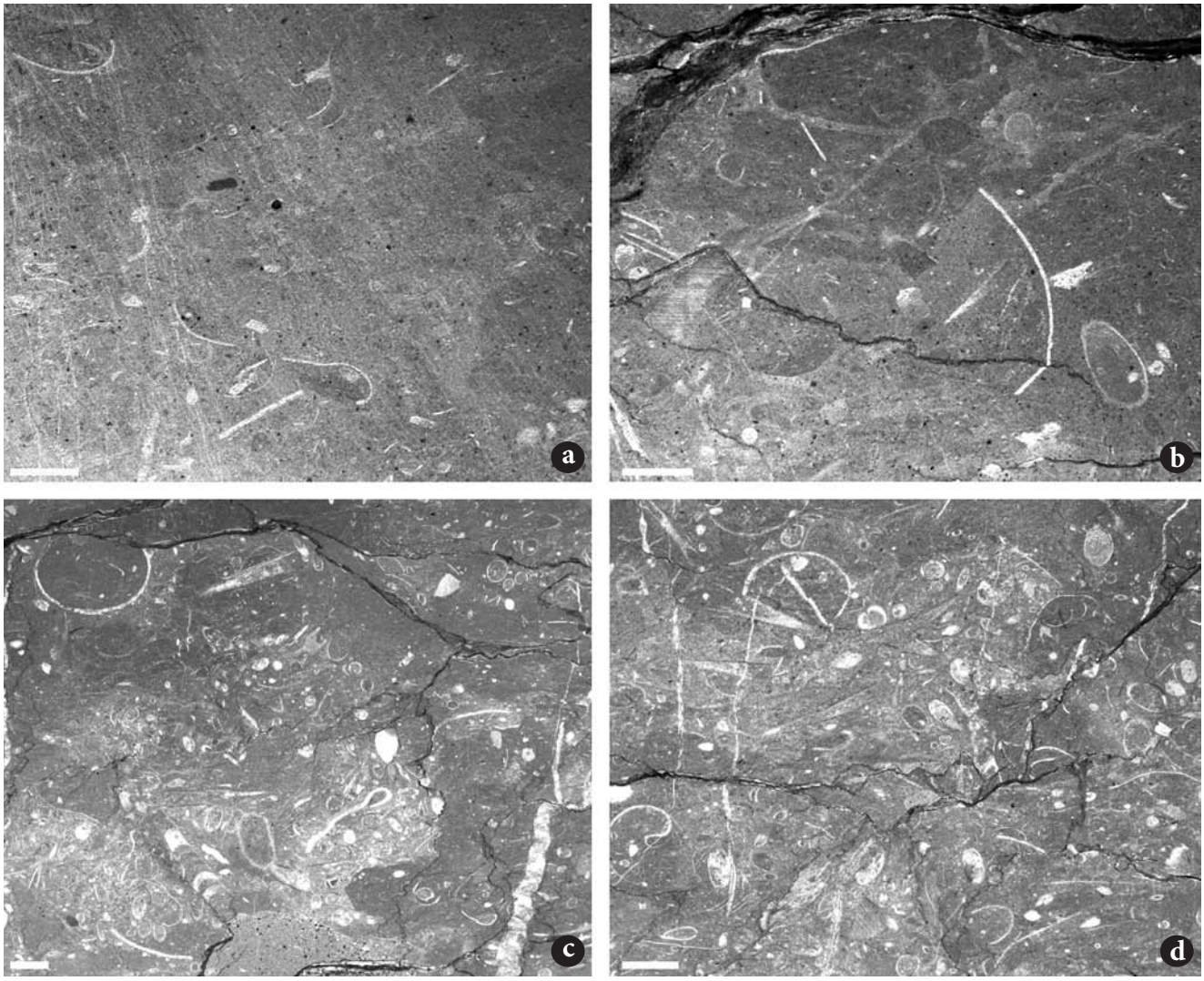


Fig. 4 - Facies of the La Valute section. a) fine grained mudstone-wakestone with some filaments, La Valute limestone, sample LV 5; b) mudstone-wakestone with iron crusts and some thin-shelled skeletal grains, ostracods and dacryoconarids; La Valute limestone, sample LV 7; c-d) wakestone (to packstone) with densely packed dacryoconarids, trilobites, orthocone nautiloids and other bioclasts; Findenig limestone, sample LV 9. Scale bar = 1 mm.
- *Microfacies della sezione de La Valute. a) mudstone-wakestone con alcuni filamenti, calcare de La Valute, campione LV 5; b) mudstone-wakestone con croste ferruginose e alcuni sottili frammenti di gusci, ostracodi e dacryoconaridi; calcare de La Valute, campione LV 7; c-d) wakestone (tendente a packstone) con concetrazioni di with densely packed dacryoconaridi, trilobiti, nautiloidi ortoconi e altri bioclasti; calcare del Findenig, campione LV 9. Scala = 1 mm.*

posterior process is absent. Instead a single node occurs at the posterior end of the element.

Remarks: *Pedavis* sp. A has been compared to several species known from Lochkovian-Pragian strata globally, but due to the absence of a posterior process, and other features observed, it differs from all of them (*P. pesavis* (Bischoff & Sannemann, 1958); *P. mariannae* Lane & Ormiston, 1979; *P. biexoramus* Murphy & Matti, 1983; *P. brevicauda* Murphy & Matti, 1983; *P. breviramus* Murphy & Matti, 1983; *P. gilberti* Valenzuela-Ríos, 1990; *P. robertoi* Valenzuela-Ríos, 1994; *P. striatus* Valenzuela-Ríos, 1994).

The obtained specimens share a similar angle between the lateral processes with *Pedavis gilberti*, but length of lateral processes, the evidence of a short posterior process and surface-ornamentation separates them from this species. Actually, *Pedavis* sp. A comes most close to *Pedavis brevicauda*, as this species is characterized by a short, peg-like posterior process, but differs in the angle between the lateral processes and ornamentation (neither costae nor striae are observed on the surface of the La Valute specimens).

The number of specimens obtained is insufficient and comparable material from other regions lacks, hence we only document its evidence, but do not raise a new species of *Pedavis*.

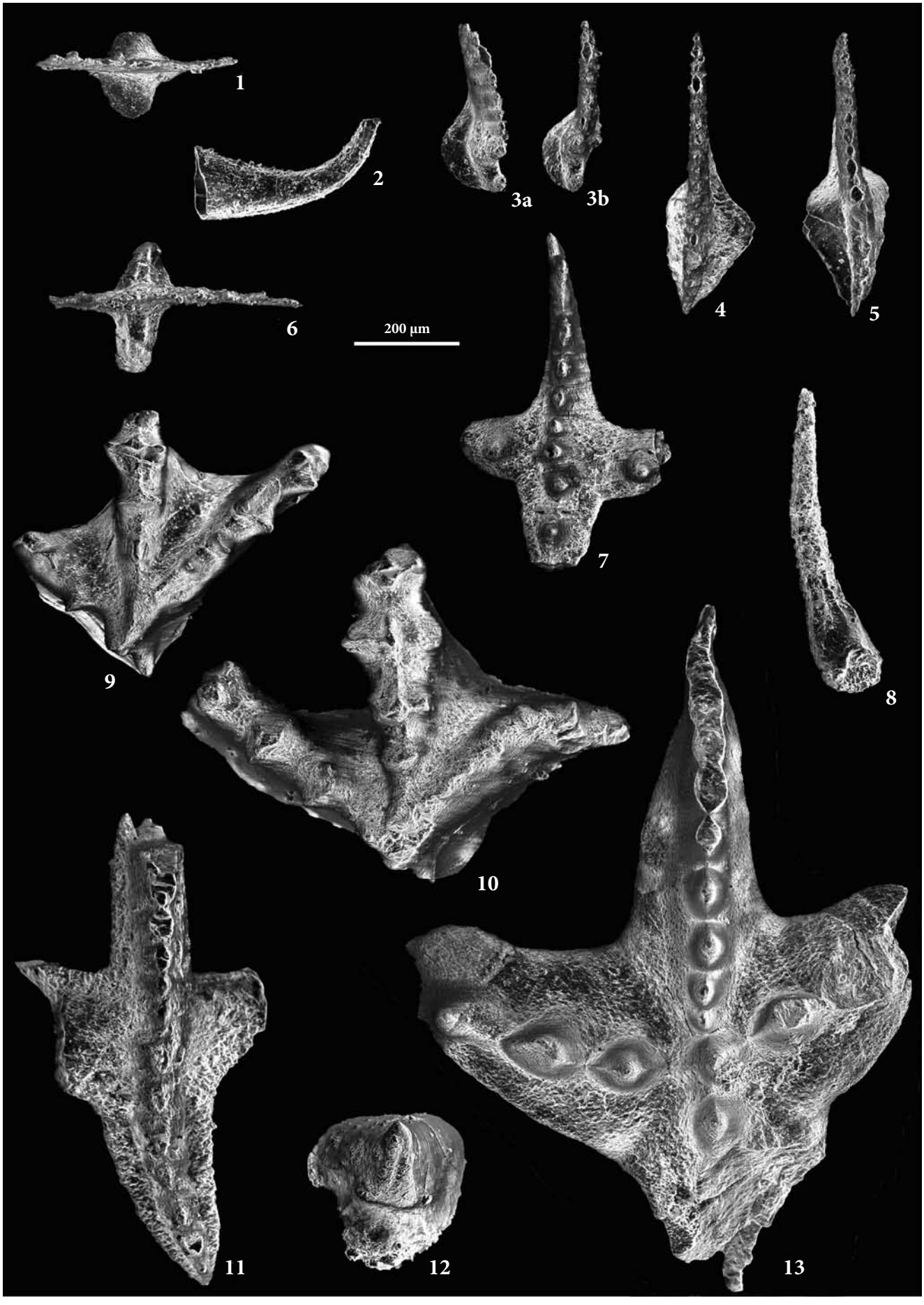
Studied material: 2 P1 elements from sample LV 9.

La Valute (LV)		1	2	3	4	4A	4B	5	6	6A	7	7A	8	8A	8B	9	totale
Ancyrodelloides transitans	P1		1														1
Ancyrodelloides trigonicus	P1	1			1												2
Belodella resima	S0			4	1								1				6
	S1	1															1
Dvorakia sp.			1		1												2
Flajsella schulzei	P1	6	2	14		1											23
	P2	1	1	1													3
	S0	2		9													11
	S1	1		3													4
	S2	3		15													18
Flajsella streptostygia	P1			2													2
Icriodus sp.	P1															1	1
	conif															2	2
Lanea eleanorae	P1		1														1
Lanea cf. *omoalpha*	P1							1									1
Lanea telleri	P1		1	1													2
Oulodus sp.	S2	3									1						4
Ozarkodina sp.	P1	1															1
Pedavis sp. A	P1															2	2
	conif										1						1
Pseudooneotodus beckmanni		1			2						13		1			1	18
Wurmiella excavata	P1	3	2					1					1				7
	P2												1				1
	M	1															1
	S0												2				2
	S1												2				2
	S2		1										2				3
Wurmiella sp.	P1								1		2						3
	P2								1								1
	M										1						1
Zieglerodina remscheidensis	P1			2													2
	P2			1				1									2
	S2			1													1
Zieglerodina sp.	P1	3									1						4
	P2	1									1						2
Indetermined coniforms																11	11
Fragments		15	4	15	53			41	7		34		48			52	269
Total		43	14	68	58	1	0	44	9		54	0	58	0	0	69	418
kg. rock		3,00	3,00	2,00	2,50	1,40	3,00	2,50	3,00	2,85	5,00	2,30	3,00	1,10	3,15	5,50	43,3
conodonts/kg		14,3	4,7	34,0	23,2	0,7	0,0	17,6	3,0	0,0	10,8	0,0	19,3	0,0	0,0	12,5	9,7

Tab. I - Conodont distribution chart.
- *Tabella di distribuzione dei conodonti.*

Fig. 5 - Conodonts from La Valute section. 1) *Zieglerodina remscheidensis* (Ziegler, 1960), P1 element, DSTC 30118, upper view, sample LV 3 (*trigonicus* Zone); 2) *Belodella resima* (Philip, 1965), S0 element, DSTC 30119, lateral view, sample LV 4 (*trigonicus* Zone); 3) *Flajsella streptostygia* Valenzuela-Ríos & Murphy, 1997, P1 element, DSTC 30120; upper-lateral (a) and upper (b) views, sample LV 3 (*trigonicus* Zone); 4) *Flajsella schulzei* (Bardashev, 1989), P1 element, DSTC 30121, upper view, sample LV 1 (*trigonicus* Zone); 5) *Flajsella schulzei* (Bardashev, 1989), P1 element, DSTC 30122, upper view, sample LV 1 (*trigonicus* Zone); 6) *Lanea telleri* (Schulze, 1968), P1 element, DSTC 30123, upper view, sample LV 2 (*trigonicus* Zone); 7) *Ancyrodelloides transitans* Bischoff & Sannemann, 1958, P1 element, DSTC 30124, upper view, sample LV 2 (*trigonicus* Zone); 8) *Pesavis* sp., M element, DSTC 30125, lateral view, sample LV 9 (*pandora* β Zone); 9) *Pesavis* sp. A, P1 element, DSTC 30126, upper view, sample LV 9, (*pandora* β Zone); 10) *Pesavis* sp. A, P1 element, DSTC 30127, upper view, sample LV 9 (*pandora* β Zone); 11) *Lanea eleanorae* (Lane & Ormiston, 1979), P1 element, DSTC 30128, upper view, sample LV 2 (*trigonicus* Zone); 12) *Pseudooneotodus beckmanni* (Bischoff & Sannemann, 1958), DSTC 30129, upper view; sample LV 7 (*pandora* β Zone); 13) *Ancyrodelloides trigonicus* Bischoff & Sannemann, 1958, P1 element, DSTC 30130, upper view, sample LV 1 (*trigonicus* Zone).

- *Conodonti della sezione de La Valute. 1)* Zieglerodina remscheidensis *(Ziegler, 1960), elemento P1, DSTC 30118, veduta superiore, campione LV 3 (Biozona a* trigonicus*); 2)* Belodella resima *(Philip, 1965), elemento S0, DSTC 30119, veduta laterale, campione LV 4 (Biozona a* trigonicus*); 3)* Flajsella streptostygia *Valenzuela-Ríos & Murphy, 1997, elemento P1, DSTC 30120; veduta obliqua (a) e superiore (b), campione LV 3 (Biozona a* trigonicus*); 4)* Flajsella schulzei *(Bardashev, 1989), elemento P1, DSTC 30121, veduta superiore, campione LV 1 (Biozona a* trigonicus*); 5)* Flajsella schulzei *(Bardashev, 1989), elemento P1, DSTC 30122, veduta superiore, campione LV 1 (Biozona a* trigonicus*); 6)* Lanea telleri *(Schulze, 1968), elemento P1, DSTC 30123, veduta superiore, campione LV 2 (Biozona a* trigonicus*); 7)* Ancyrodelloides transitans *Bischoff & Sannemann, 1958, elemento P1, DSTC 30124, veduta superiore, campione LV 2 (Biozona a* trigonicus*); 8)* Pesavis *sp., elemento M, DSTC 30125, veduta laterale, campione LV 9 (Biozona a* pandora *β); 9)* Pesavis *sp. A, elemento P1, DSTC 30126, veduta superiore, campione LV 9, (Biozona a* pandora *β); 10)* Pesavis *sp. A, elemento P1, DSTC 30127, veduta superiore, campione LV 9 (Biozona a* pandora *β); 11)* Lanea eleanorae *(Lane & Ormiston, 1979), elemento P1, DSTC 30128, veduta superiore, campione LV 2 (Biozona a* trigonicus*); 12)* Pseudooneotodus beckmanni *(Bischoff & Sannemann, 1958), DSTC 30129, veduta superiore; campione LV 7 (Biozona a* pandora *β); 13)* Ancyrodelloides trigonicus *Bischoff & Sannemann, 1958, elemento P1, DSTC 30130, veduta superiore, campione LV 1 (Biozona a* trigonicus*).*


1
2
3a
3b
4
5
6
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8
9
10
11
12
13

Conclusion and discussion

The boundary between the La Valute limestone and the Findenig limestone in La Valute area occurs near the base of the upper Lochkovian, in the lower part of the *pandora* β Zone. Based on the biostratigraphic constraint of this formation boundary at La Valute, further correlation with other Lower Devonian sections in the Carnic Alps will contribute to the general understanding of the sedimentary development and relation of neritic and pelagic units of the entire region.

Apart from this, the distinctive conodont assemblage obtained from this section supports recent developments in stratigraphy, which aim a higher biostratigraphic resolution of the well-known mid-Lochkovian *delta* Zone, by dividing it into 4 conodont biozones: *omoalpha*, *transitans*, *eleanorae* and *trigonicus* zone (Murphy & Valenzuela-Ríos 1999).

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Authors' addresses - Indirizzi degli Autori:
- Maria G. Corriga
  Dipartimento di Scienze della Terra
  Università degli Studi di Cagliari
  Via Trentino 51, I-09127 CAGLIARI
  e-mail: maria.corriga@unica.it
- Thomas J. Suttner
  Austrian Academy of Sciences (CPSA)
  c/o University of Graz, Institute for Earth Sciences
  Heinrichstrasse 26, A-8010 GRAZ
  e-mail: thomas.suttner@uni-graz.at
- Carlo Corradini
  Dipartimento di Scienze della Terra
  Università degli Studi di Cagliari
  Via Trentino 51, I-09127 CAGLIARI
  e-mail: corradin@unica.it
- Erika Kido
  Austrian Academy of Sciences (CPSA)
  c/o University of Graz, Institute for Earth Sciences
  Heinrichstrasse 26, A-8010 GRAZ
  e-mail: erika.kido@uni-graz.at
- Monica Pondrelli
  International Research School of Planetary Sciences
  Dipartimento di Scienze
  Università degli Studi d'Annunzio
  Viale Pindaro 42, I-65127 PESCARA
  e-mail: monica@irsps.unich.it
- Luca Simonetto
  Museo Friulano di Storia Naturale
  Via Marangoni 39-41, I-33100 UDINE
  e-mail: luca.simonetto@comune.udine.it