CONODONT DISTRIBUTION AT THE TOURNAISIAN/VISEAN BOUNDARY IN THE CARNIC ALPS (SOUTHERN ALPS, ITALY)

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Perri, M.C. and Spalletta, C. 1998. Conodont distribution at the Tournaisian/Visean boundary in the Carnic Alps (Southern Alps, Italy). *In:* H. Szaniawski (ed.), Proceedings of the Sixth. European Conodont Symposium (ECOS VI). — *Palaeontologia Polonica* **58**, 225–245.

Nineteen stratigraphic sections of the Lower Carboniferous, goniatite-bearing, pelagic limestone sequence of the Carnic Alps have been measured and sampled for conodonts. The detailed biostratigraphical analysis allows for the recognition of five, late Tournaisian–early Visean biozones from the *isosticha*–Upper *crenulata* Zone to the *texanus–homopunctatus* Zone. The *anchoralis–latus* and *texanus–homopunctatus* zones are best represented. Because the species *Gnathodus texanus* is very rare in the Carnic area, the presence of the *texanus–homopunctatus* Zone is inferred by the composition of the associated fauna, represented mainly by a few species of gnathodids, vogelgnathids, and very rare polygnathids. In most sections, the occurrence of *Pseudognathodus homopunctatus, Lochriea cracoviensis*, and *Gnathodus praebilineatus* is used for the zonal assignement. *Scaliognathus anchoralis*, and pseudopolygnathids, disappear abruptly below the first occurrences of the above mentioned species. The Tournaisian/Visean boundary, considered as corresponding to the lower limit of the *texanus–homopunctatus* Zone, was traced in six sections. In all sections the biofacies reflect the pelagic environment also indicated by the lithofacies.

Key words: Conodonta, biostratigraphy, biofacies, late Tournaisian, early Visean, Carnic Alps, Italy.

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Received 21 December 1996, accepted 10 February 1998

INTRODUCTION

The Carnic Alps, stituated along the Italian-Austrian border, constitute the easternmost part of the Southern Alps. They reveal a well exposed Paleozoic sequence ranging in age from Late Ordovician to Late Permian. The sequence is interrupted by a relatively short gap of Westphalian (Early/Late Carboniferous) age, aa a result of the Hercynian orogeny. The Hercynian deformation gave rise to the Paleocarnic Chain and involved Upper Ordovician–Lower Carboniferous units represented mainly by Devonian carbonates and uppermost Lower Carboniferous terrigenous turbidites.

The entire Lower Paleozoic sequence, together with the late- and post-Hercynian cover, were also involved in the Alpine orogeny. Consequently, the present structural setting of the Lower Paleozoic sequence (Paleocarnic Chain) is complicated. It is, however, mostly represented by non-metamorphic rocks piled up into serrated tectonic thrust sheets. The sequence is well known for its well-preserved fossils and it has been the subject of investigations since the end of the 19th century (SELLI 1963; VAI 1976; SCHÖNLAUB 1979, 1992; SPALLETTA *et al.* 1982; VAI and COCOZZA 1986; SPALLETTA and VENTURINI 1990, 1994; VENTURINI 1983, 1986, 1990, 1991; LÄUFER 1996).

This paper is focused on stratigraphy of the thick, continuous, goniatite-bearing, pelagic limestone sequence that was deposited during Late Devonian to Early Carboniferous times and crops out in the Carnic Alps. The data deal with the Lower Carboniferous part of the pelagic unit that includes the Tournaisian/Visean boundary interval and that is exposed on the Italian side of the central and eastern Carnic Alps, from Mt. Coglians to Mt. Cavallo (Fig. 1). The investigated sections are located in two areas: the first one between Mt. Coglians and Monte Croce Carnico Pass, the second one in the area around Mt. Cavallo. Some isolated outcrops are also scattered between the two areas (Fig. 1). In the examined sequence, special emphasis was given to the position and recognition of the Tournaisian/Visean boundary. For this purpose, nineteen stratigraphic sections and 16 isolated test samples were sampled for conodonts. The 172 collected samples (median weight of 1500 g) produced a very rich conodont fauna with a total of 19,550 elements. The distribution of all **Pa** elements was analyzed. The conodont fauna is mostly composed of gnathodid **Pa** elements (Tables 1–4).

The material used in this investigation is reposited at Museum G. Capellini in Bologna under the numbers: IC 1580–IC 1610 (figured elements), IC 1611 (non figured elements).

Acknowledgments. — We are indebted to Zdzisław BELKA, Carl B. REXROAD, and Hans P. SCHÖNLAUB for their critical review of the manuscript and fruitful suggestions. We are also grateful to Charles A. SANDBERG and Corrado VENTURINI for their kind advice, and to F. AMADESI, A. ARGNANI, E. ARMINI, W. CAVAZZA, C. DIMOPOULOS, V. GIROMBELLI, R. MARTELLI, A. NEGRI, S. RIVOSECCHI, and S. RUBATTA, for the help in collecting and processing of most of the samples. C. STROCCHI made part of the drawings and P. FERRIERI the SEM micrographs. Both authors contributed equally to the present paper; C. SPALLETTA is responsible for the geological part.

STRATIGRAPHICAL SETTING AND LITHOLOGY

Pelagic facies were deposited in the Carnic domain since the Early Silurian time (VAI 1976; SCHÖNLAUB 1979, 1985; SPALLETTA *et al.* 1982; SPALLETTA and VENTURINI 1990). From Late Silurian to Middle Devonian, tentaculite pelagic limestones were deposited, but they represent only a small fraction of all deposits accumulated during this time interval; dominated by carbonate shallow water facies. Reefs started to appear during the Early Devonian and reached their maximum development during Middle Devonian.

It was only during the Late Devonian that pelagic deposition extended over the entire Paleocarnic basin. At that time, intensive syn-sedimentary extensional tectonics affected the Paleocarnic domain. Extensional faulting led to a break up of the carbonate platform, and a fast subsidence favored the onset of pelagic sedimentation all over the basin (CANTELLI *et al.* 1982; KREUTZER 1990, 1992; SPALLETTA and VENTURINI 1994).

Climenid- and goniatite-bearing pelagic limestone is nearly the only facies deposited in the Carnic Basin from late Frasnian (Late Devonian) to Dinantian (Early Carboniferous), and one of the best exposed units of the whole Paleozoic sequence.

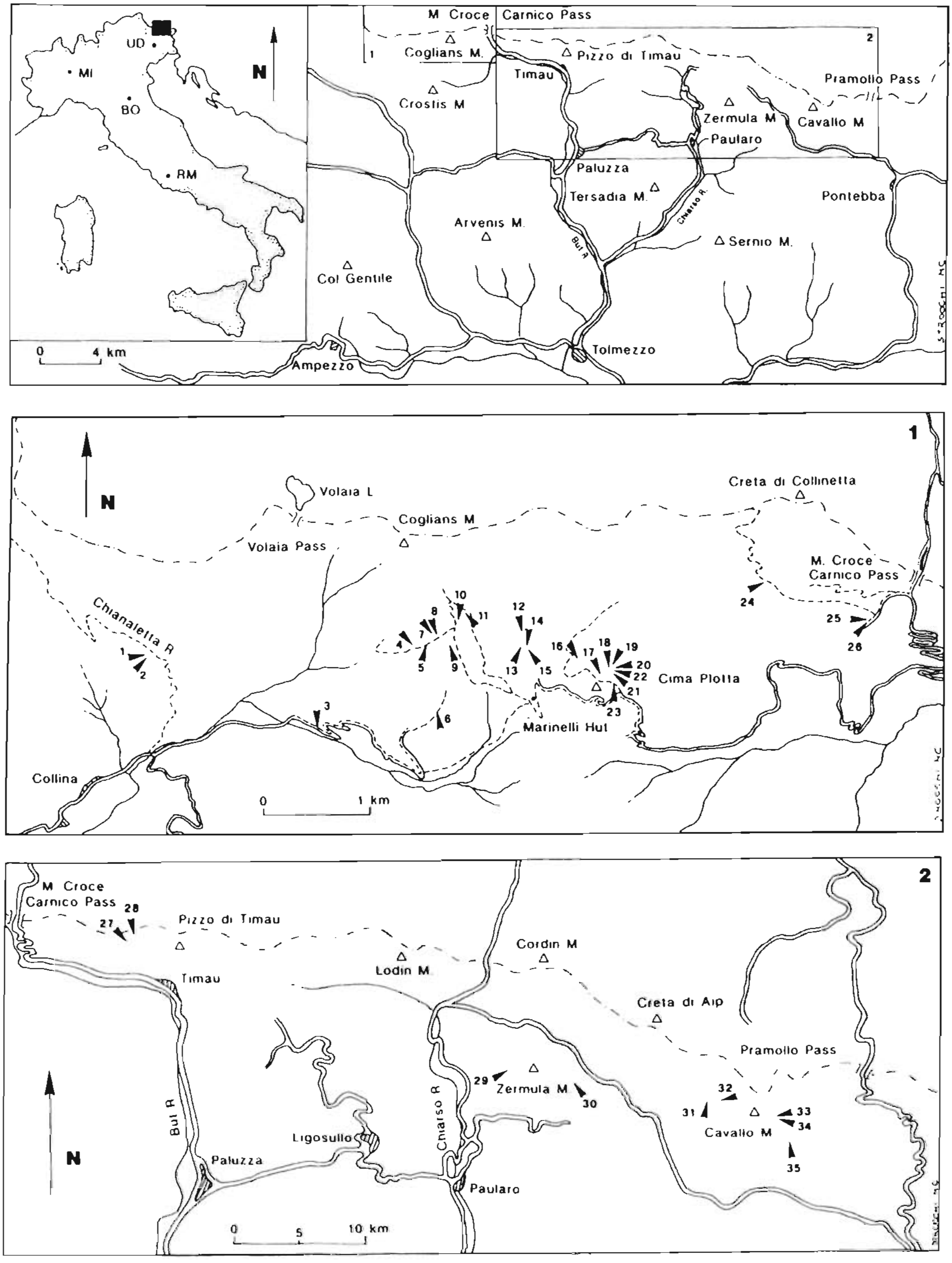

Fig. 1

Location map of sections and test samples. 1 – Rio Chianaletta Alto (RCA), 2 – Rio Chianaletta (RC), 3 – B535, 4 – Spinotti Basso (SPB), 5 – Spinotti (SP), 6 – B534, 7 – Postazione 5A (PS5A), 8 – Postazione (PS), 9 – B533, 10 – Sotto Sentiero per Forcella Monumenz (SSFM), 11 – Forcella Monumenz 1 (FM1), 12 – Dolina Ovest 1 (DLO1), 13 – Dolina (DL), 14 – Dolina Est (DLE), 15 – Stop 46 (S46), 16 – Torbiera (TOR), 17 – Sotto Cima Plotta (SCP), 18 – Piastrone Plotta Ovest 1 (PPLO1), 19 – Piastrone Plotta (PPL), 20 – Piastrone Plotta Est 1 (PPLE1), 21 – Plotta Passo 1 (PLP1), 22 – Plotta Passo 2 (PLP2), 23 – Passo ß (Pß), 24 – Casera Collinetta di Sopra (CCS), 25 – Casera Collinetta di Sotto A (CSA); 26 – Casera Collinetta di Sotto A 14L (CSA14L), 27 – Trincea A 7 (TRA7), 28 – Trincea (TR), 29 – FV43; 30 – FV54, 31 – Creta di Rio Secco C (CRSC), 32 – 172b, 33 – M. Cavallo B (MCB) 34 – M. Cavallo A (MCA), 35 – Pricot (PRT). Sections 1, 2, 5, 8, 10, 13, 17, 19, 23, 24, 25, 31, 34, 35 and test samples 3, 6, 7, 9, 15, 18, 26, 27, 29, 30, 32 yield conodont fauna useful for biozonal assignment. Sections 4, 14, 16, 28, 33 and test samples 11, 12, 20, 21, 22 yield a few long ranging gnathodid species which could not be useful for biozonal assignment. In the text, sections and samples are cited arranged from west to east.

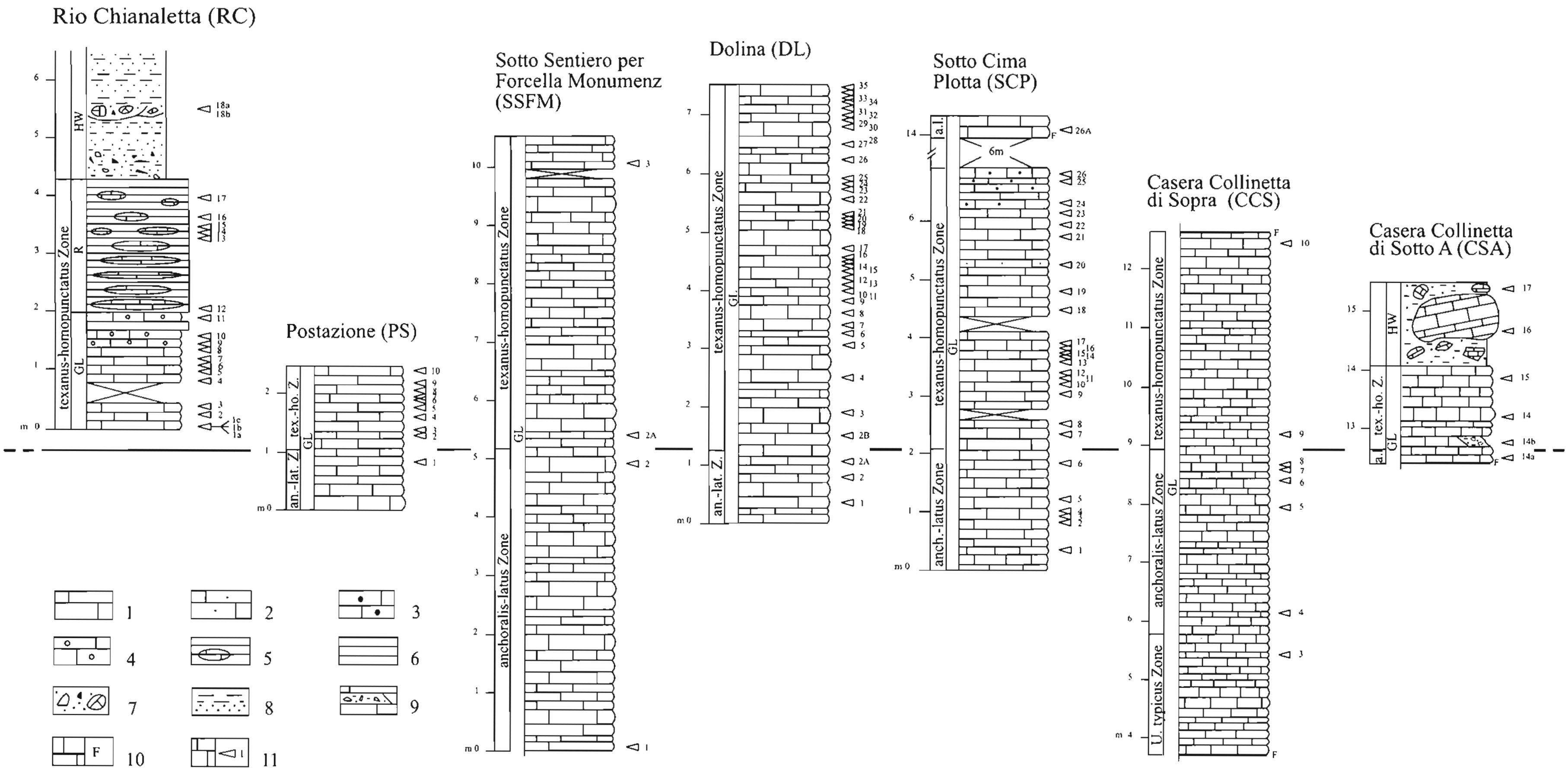

Fig. 2

Selected stratigraphic sections showing lithologies and biozonal assignments. The boundary *anchoralis–latus/texanus–homopunctatus* Zone is marked. Goniatite-bearing pelagic limestone (GL): 1 biomicrite, 2 calcilutite, 3 calcarenite, 4 radiolarian-enriched mudstone. Radiolarian chert (R): 5 radiolarian chert with interbedded limestone levels and lenses, 6 radiolarian chert. Hochwipfel Formation (HW): 7 breccias and olistostromes, 8 arenite and pelite, 9 sedimentary dyke, 10 fault, 11 sample position.

During Early Carboniferous the sedimentary evolution of the Paleocarnic Domain was controlled primarily by a transpressional dextral shear zone, which, most likely, belonged to Insubric Paleolineament (Gailtal Paleoline, SPALLETTA and VENTURINI 1994). The activation of this lineament, supposedly born as a transform fault (VAI 1976, 1991), produced differential, local uplift of some tectonic blocks. It did not affect, however, the general transgressive trend that led to the deposition of the thick (80–200 m), pelagic limestone sequence, followed by a few meters of radiolarian chert, and by about 1000 m of the thick terrigenous turbidite deposits of the Hochwipfel Formation (SPALLETTA and VENTURINI 1994 and references therein).

One of the problems regarding the Carnic Alps concerns the precise age of the topmost part of the pelagic limestone; in the opinion of the authors the studies of MANZONI (1966), GEDIK (1974), and SCHÖNLAUB and KREUTZER (1993) are not definitive. The determination of the age of the top of the limestone would be of great help in establishing the time interval in which sedimentation of the Hochwipfel turbidites was initiated. Radiolarian cherts are present only in places where the complete Early Carboniferous succession was deposited and preserved (SPALLETTA 1983; SPALLETTA and VENTURINI 1994). According to HERZOG (1988) and SCHÖNLAUB *et al.* (1991), some radiolarian cherts, on the basis of their conodont content, may be attributed to the late Tournaisian (*anchoralis–latus* Zone).

The Hochwipfel Formation turbidites and volcanoclastic and volcanic rocks of the Dimon Formation constitute together the so-called Hercynian "Flysch" which reaches up to 2000 m in thickness (VAI 1976; SPALLETTA and VENTURINI 1990).

The turbidite beds are predominately unfossiliferous and only scattered plant remains have been reported; the youngest of these plants have been dated as middle Visean in age (AMEROM *et al.* 1984). It is noteworthy, that the first, and for many years, the only study on floras from the Hochwipfel Formation was that of FRANCAVILLA (1966), who found spores of Namurian A age.

In accordance with the ages of the topmost part of pelagic limestone, radiolarian beds, and plant remains, the base of the Visean (or, at least, the upper part of Tournaisian) was assumed by SCHÖNLAUB (1985) to correspond to the beginning of the turbidite sedimentation.

Recently, KULLMANN and LOESCHKE (1994), on the basis of various regional data (from Spain to Serbia) on the Hercynian Flysch, proposed a Bashkirian age for the base of Hochwipfel Formation. Moreover, KULLMANN and LOESCHKE (1994) stated that the sedimentation in the Carnic Alps and Karawanke was interrupted for at least 10 million years, after the deposition of pelagic limestone and radiolarian chert and before the Hochwipfel turbidites. On the other hand, in order to support their interpretation of the Hochwipfel turbidites as deposited in an accretionary prism (LÄUFER *et al.* 1993) these Authors needed also to postpone the Hochwipfel Formation to the Dimon Formation in contrast to all field evidences (LÄUFER 1996).

The present study was initiated to investigate the age of the topmost part of the pelagic limestone by means of a detailed conodont biostratigraphy.

The upper part of the Lower Carboniferous, goniatite-bearing, pelagic limestone has an estimated total maximum thickness of about 50 m. The shortest section (Trincea A-TRA, Fig. 1), less than 1 m thick, is embedded within Upper Devonian pelagic limestone (SPALLETTA and PERRI 1994), whereas the longer sections are between 25 and 30 m (Figs 1, 4, Spinotti-SP and Pricot -PRT).

Most of the sections are limited by faults and/or thrusts; sometimes the Carboniferous pelagic limestone lies directly on Middle to early Upper Devonian shallow-water limestone from which it is separated by irregular surfaces parallel to the bedding. These disconformity surfaces represent, most likely, episodes of very slow sedimentation or non-deposition which are easily explained considering the Late Devonian–Early Carboniferous evolution of the Paleocarnic Domain (SPALLETTA and VENTURINI 1994). In the fragmented, articulated basins, the sedimentation was tectonically controlled. Scattered, residual, and/or newborn, structural highs were present until Late Devonian or at least Early Carboniferous times. Afterwards, they resubsided and pelagic sedimentation, represented by calcareous ooze, took place once again.

The Lower Carboniferous, goniatite-bearing, pelagic limestone (Fig. 2, GL) consists of grey to light pink biomicrite with 0.5–3 cm thick beds. They are represented mainly by wackestone, rich in pelagic, completely preserved skeletal elements of goniatites, trilobites, and radiolarians. In some places, rare, thin, calcarenitic to calcilutitic layers, containing goniatites, radiolarians, brachiopods, and crinoid columnals, are present. They have been interpreted as distal turbidites. The original, planar to slightly wavy bedded, layers are usually overprinted by stylolites. At places, the limestone is interrupted by neptunian dykes, sometimes in form of sills, filled with clayey to sandy matrix supporting radiolarian chert, sandstone, and limestone clasts, ranging in size from 2–3 mm to several centimeters. The matrix has of the same

Table 1

Numerical distribution of conodont elements in Rio Chianaletta, Rio Chianaletta Alto, Spinotti and Sotto Sentiero per Forcella Monumenz sections. Samples RC 18a and RC 18b are from olistostrome clasts. (fr.) = fragments.

2 Rio Chianaletta (RC)

		texanus - homopunctatus Zone																				t.h.Z.	t.h.Z.
Samples		RC1a	RC1b	RC1c	RC2	RC3	RC4	RC5	RC6	RC7	RC8	RC9	RC10	RC11	RC12	RC13	RC14	RC15	RC16	RC17		RC18a	RC18b
Weight (g)		925	850	725	1750	2475	950	950	2500	5425	3650	2075	2775	1125	275	400	1800	225	525	475		875	1225
Species																					Total		
Gn. cuneiformis	Pa	17	18	13	32	40	92	27	79	144	14	54	273	115		1	1	8	24		952	6	4
Gn. pseudosemiglaber	Pa	1			20	1	12	3	54	59	6		83	5							244	2	
Gn. sp.	Pa	5	3	2	5	5	14	9	5	10	12	15	8	5					2	1	101		
Gn. sp. juv.	Pa	17	8	12	3	18	22	12	12	34	91	25	98	280	2			3	37		674	5	24
Po. flabellus	Pa	4	4	1		3	1														13		
Pd. homopunctatus	Pa	7	2					3	6	10	1	2	64	70							165	2	2
Pd. symmutatus	Pa	4	1						1		1		15	38		1					61	2	
Gn. praebilineatus	Pa		2	1	2	6	8			1	4	4		19		1			4		52		
Gn. semiglaber	Pa			1	6	1	54	36	27	23	46	77	2								273		9
Vo. campbelli	Pa								25	7	11			30		1			7		81		1
Gn. texanus	Pa										1	4		1							6		2
Lc. cracoviensis	Pa											2	7	51					4		64		
Ge. sp.	Pa																				0		1
Total		55	38	30	68	74	203	90	209	288	187	183	550	614	2	4	1	11	78	1	2686	17	43

1 Rio Chianaletta Alto (RCA)

		i.-U.c.Z.	L.ty.Z.	tex.-homop. Z.		
Samples		RCA-3	RCA-2	RCA-1	RCA0	
Weight (g)		2000	1625	3175	3025	
Species						Total
Bispathodus stabilis	Pa	4		3		7
Gnathodus punctatus	Pa	3				3
Gnathodus semiglaber	Pa	51	7		206	264
Gnathodus sp.	Pa	12	3	5	11	31
Gnathodus sp. juv.	Pa	324	3	112	230	669
Polygnathus flabellus	Pa	1		5	15	21
Protognathodus praedelicatus	Pa	3				3
Volgegnathus campbelli	Pa	1			1	2
Gnathodus cuneiformis	Pa		4	24	5	33
Gnathodus pseudosemiglaber	Pa			21		21
Gnathodus praebilineatus	Pa				2	2
Pseudognathodus homopunctatus	Pa				3	3
Total		399	17	170	473	1059

5 Spinotti (SP)

		U.typ.Z.	anchoralis-latus Zone					
Samples		SP 4	SP 5	SP 6	SP 7	SP 8	SP 9	
Weight(g)		2225	1100	1225	1110	1180	2050	
Species								Total
Dollymae bouckaerti	Pa	1						1
Eotaphrus sp.	Pa	1						1
Gnathodus cuneiformis	Pa	1	11	64	1			77
Gnathodus semiglaber	Pa	1		21			1	23
Polygnathus communis carina	Pa	1						1
Polygnathus communis communis	Pa	6						6
Protognathodus praedelicatus	Pa	2						2
Pseudopolygnathus sp.	Pa	1				1		2
Bispathodus stabilis	Pa		3	3				6
Gnathodus pseudosemiglaber	Pa		5		1			6
Pseudopolygnathus pinnatus M2	Pa		7					7
Scaliognathus anchoralis anchoralis	Pa		5					5
Hindeodella segaformis (fr.)	Sc		8					8
Gnathodus sp.	Pa			25	3	3	1	32
Gnathodus sp. juv.	Pa			45		1		46
Pseudopolygnathus oxypageus M3	Pa			1				1
Total		14	39	159	5	5	2	224

10 Sotto Sentiero per Forcella Monumenz (SSFM)

		anchoralis-latus Z.		texanus-homop. Zone		
Samples		SSFM1	SSFM2	SSFM2A	SSFM3	
Weight (g)		1075	1100	1375	1220	
Species						Total
Bispathodus stabilis	Pa	16				16
Doliognathus latus M3	Pa	3				3
Gnathodus cuneiformis	Pa	52	3	29	45	129
Gnathodus delicatus	Pa	6	3			9
Gnathodus pseudosemiglaber	Pa	35		40	7	82
Gnathodus semiglaber	Pa	11		11	11	33
Gnathodus sp.	Pa	15	5	18	20	58
Gnathodus sp. juv.	Pa	40	10	31	50	131
Polygnathus bischoffi	Pa	1				1
Polygnathus communis communis	Pa	33				33
Protognathodus cordiformis	Pa	7				7
Pseudopolygnathus oxypageus M2	Pa	1				1
Pseudopolygnathus pinnatus M2	Pa	32	3			35
Scaliognathus anchoralis anchoralis	Pa	35	5			40
Scaliognathus anchoralis europensis	Pa	71	3			74
Hindeodella segaformis (fr.)	Sc	58	4fr			58
Vogelgnathus campbelli	Pa			20		20
Gnathodus praebilineatus	Pa				36	36
Polygnathus flabellus	Pa				6	6
Pseudognathodus homopunctatus	Pa				4	4
Total		416	32	149	179	776

23 Passo ß (Pß)

		anchoralis-latus Zone			
Samples		Pß 1	Pß 2	Pß 5	
Weight (g)		1400	1250	1035	
Species					Total
Bispathodus stabilis	Pa	8	7	6	21
Eotaphrus burlingtonensis	Pa	1			1
Gnathodus cuneiformis	Pa	16	11	27	54
Gnathodus semiglaber	Pa	3	4	6	13
Gnathodus pseudosemiglaber	Pa	7		9	16
Gnathodus sp.	Pa	9	15	7	31
Gnathodus sp. juv.	Pa	40	105	66	211
Protognathodus praedelicatus	Pa	1			1
Pseudopolygnathus oxypageus M2	Pa	18			18
Scaliognathus anchoralis europensis	Pa	25	2		27
Hindeodella segaformis (fr.)	Sc	58			58
Vogelgnathus campbelli	Pa	12			12
Gnathodus delicatus	Pa		20	2	22
Gnathodus typicus M2	Pa		5		5
Polygnathus bischoffi	Pa		1		1
Pseudopolygnathus pinnatus M2	Pa		4		4
Scaliognathus anchoralis anchoralis	Pa		19		19
Total		198	193	123	514

composition as the Hochwipfel beds. The thickness of the dykes ranges from a few centimeters to several decimeters (in some cases, up to one meter). In the authors opinion, their presence testifies to an intensive extensional tectonic activity. Fractures filled with clastic material derived from the Hochwipfel Formation were interpreted as related to karstification (SCHÖNLAUB *et al.* 1991). On the other hand, karstification could have taken place on the top of some uplifted tectonic block, as suggested by SPALLETTA and VENTURINI (1994).

In the present study, the Rio Chianaletta (Figs 1, 2, RC) section is the only one that shows a continuous transition from the pelagic limestone to radiolarian chert and terrigenous turbidites of the Hochwipfel Formation. The last 1 m of limestone is represented by a radiolarian-rich wackestone interbedded with radiolarian chert. The following 2.2 m are represented by light-grey to black, radiolarian chert with discontinuous, lenticular limestone layers and/or lenses, that decrease upward in thickness and frequency (Fig. 2, R). Some of the lenticular layers and lenses were sampled for conodonts (Fig. 2). The pelagic limestone-radiolarian chert sequence is followed by the arenites and pelites of the Hochwipfel Formation (HW, Fig. 2) interbedded with two olistostrome horizons supporting large limestone clasts.

Olistostromes and megabreccias (debris flows) are often present in the lower part of the Hochwipfel Formation, close to the boundary with the underlying limestone (SPALLETTA *et al.* 1980, 1982; SPALLETTA 1983; AMEROM, VAN *et al.* 1984; SPALLETTA and VENTURINI 1988, 1994). Some of the limestone contained clasts within oligostromes were sampled for conodonts.

BIOSTRATIGRAPHY

Fourteen out of the nineteen sections and eleven out of the sixteen, isolated test samples examined yielded a fauna that allowed for the assignment of biozones.

Because the remaining five sections (Fig. 1, SPB, DLE, TOR, TR, MCB) and five isolated test samples (Fig. 1, FM1, DLO1, PPLE1, PLP1, PLP2) produced only a few long ranging gnathodid species (e.g., *Gnathodus semiglaber, G. cuneiformis*, and *G. pseudosemiglaber*) they were excluded from the biostratigraphic analysis and will not be taken into consideration here. Few samples were collected from the excluded sections except for the Trincea (TR) section from which seven samples were collected, yielding a reworked conodont fauna composed of Late Devonian elements mixed with very rare, indigenous, gnathodid elements of Carboniferous age (SPALLETTA and PERRI 1994).

The zonation, proposed as preliminary standard conodont zonation by LANE, SANDBERG and ZIEGLER (1980) and ZIEGLER and LANE (1987), was applied for the biostratigraphic analysis with the only exception of the *texanus* Zone. Because this zonation was presented as standard, we maintained mainly the original biozonal names taking, however, in consideration some suggestions given by BELKA (1985). The biozone above the *anchoralis–latus* Zone is here named *texanus–homopunctatus* Zone. Five biozones were recognized: *isosticha*–Upper *crenulata*, Lower *typicus*, Upper *typicus*, *anchoralis–latus*, and *texanus–homopunctatus* Zone. The species *Gnathodus typicus* and *G. texanus* are less frequent in European Carboniferous sequences than in North American ones. Therefore, some more frequent, coeval species have been used for the biozonal subdivisions. Except for the *anchoralis–latus* Zone, nearly always indicated by the markers, some species of the genera *Dollymae, Lochriea, Gnathodus, Polygnathus, Prothognathodus*, and *Pseudopolygnathus* were utilized as an additional aid in recognizing the biozones. Few levels were assigned to the *isosticha*–Upper *crenulata* Zone, the Lower *typicus* Zone, and Upper *typicus* Zone, whereas the majority belonged to the *anchoralis–latus* and *texanus–homopunctatus* Zones. In the *anchoralis–latus* Zone, we found the greatest number of taxa. The biozonal assignments for all 170 samples studied has been listed in the Appendix.

The inferred stratigraphic distribution of all found species is given on Fig. 3.

***isosticha*–Upper *crenulata* Zone.** — The first appearance of *Gnathodus delicatus* defines the base of the zone. The species is present in two samples. The co-occurrence of (1) *Gnathodus punctatus* and *G. semiglaber* in level RCA-3 of Rio Chianaletta Alto section; (2) *G. delicatus*, *Pseudopolygnathus multistriatus*, *P. triangulus*, and one element of *Siphonodella* sp. in level CRSC1 of Creta di Rio Secco C section; and (3) *G. delicatus, Dollymae sagittula*, and *Si. isosticha* in test sample 172b allowed for the recognition of the zone (Tables 1–4).

Lower *typicus* Zone. — The first occurrence of *Gnathodus typicus* M_2 defines the base of the zone. The species was not found in any of our samples. It seems to be very rare in the Carnic Alps and was found only in samples attributed to the *anchoralis–latus* Zone. In 1985, BELKA proposed a biozonation where the *typicus* Zone of LANE *et al.* (1980) was substituted by a zone named *cuneiformis*. This substitution was justified by a relatively low frequency of the *G. typicus* occurrences in the Carboniferous rocks of Europe.

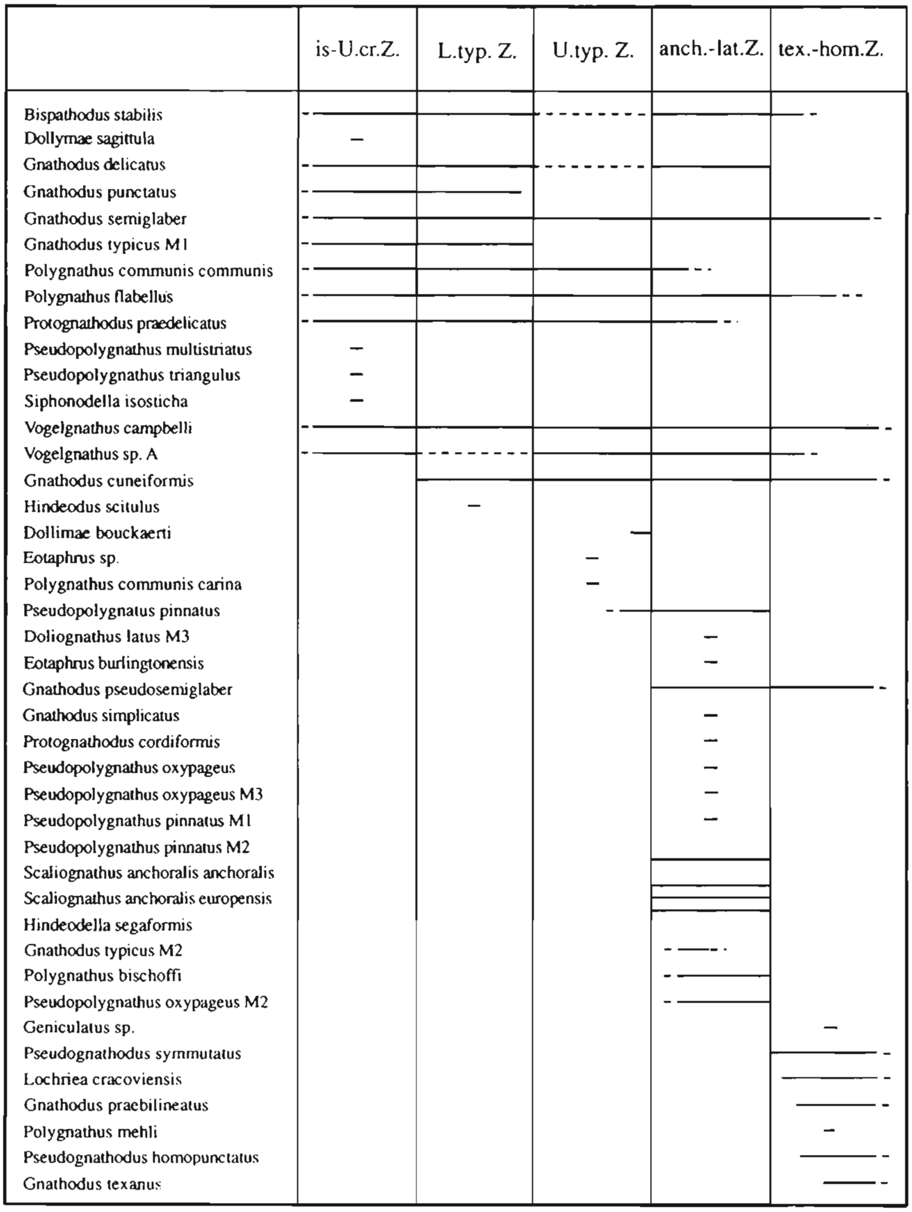

Fig. 3
Relative ranges of conodont species in the Carnic Alps.

According to BELKA (1985), the stratigraphic distribution of *G. cuneiformis* nearly overlaps that of *G. typicus* M_2. The first appearance of *G. cuneiformis* is estimated to be slightly above the first appearance of *G. typicus* M_2. According to BELKA (1985), *G. cuneiformis* is well represented both in European or in North America deposits and this authorizes the choice of this species as biozonal marker.

We agree with most of BELKAS arguments. In our material *G. typicus* is very rare; expecially its morphopype 2, used by LANE *et al.* (1980) to define the lower limit of their Lower *typicus* Zone. On the other hand, LANE *et al.* (1980) reported the first appearance of *G. cuneiformis* as the most important event near the base of the discussed zone after the first appearance of the marker. *G. cuneiformis* is represented with a very high frequency in the Carnic Alps. Consequently, we used its first appearance, together with disappearance of siphonodellids, to recognize the biozone.

The base of this zone is traced only in section Rio Chianaletta Alto (RCA), with the first appearance (Table 1) of *G. cuneiformis* in sample RCA-2. Its co-occurrence with *G. punctatus* in Piastrone Plotta (PPL) section (Table 3) was used for the biozonal recognition. *G. semiglaber* and *G. delicatus* are the numerically most frequent species.

Table 2
Numerical distribution of conodont elements in Dolina and Sotto Cima Plotta sections. (fr.) = fragments.

13 Dolina (DL)

		anchor.-lat. Z.			texanus-homopunctatus Zone																																	
Samples		DL1	DL2	DL2A	DL2B	DL3	DL4	DL5	DL6	DL7	DL8	DL9	DL10	DL11	DL12	DL13	DL14	DL15	DL16	DL17	DL18	DL19	DL20	DL21	DL22	DL23	DL24	DL25	DL26	DL27	DL28	DL29	DL30	DL31	DL32	DL33	DL34	DL35	
Weight (g)		900	1025	1400	1300	1250	950	750	1450	675	900	800	2275	450	600	2250	1375	1025	975	1125	475	550	875	1550	1050	1125	925	725	1000	725	1150	1625	1200	700	1075	1350	1600	1725	
Species																																							Total
Bi. stabilis	Pa	2			2																																		4
Gn. pseudosemiglaber	Pa	42	14	11	40	16	8	9		2	2	27	35	5		2						4	4	2				20	62	31	4	33	13	1	5	1	3	5	401
Gn. sp	Pa	6	7	2	6	10	12	3	8	1	3	20	15	3	2	15	10	3	7	14	1	5	4	2	5	3	3	5	10	64	7	4	9	4	10	5	6	15	309
Gn. sp juv	Pa	35	15	10	54	6			10		6	20	66	4	1	21	7	13	9	51	6	9	9		3	1	8	1	42	394	12		22	13	52	45	118	18	1081
Po. bischoffi	Pa	2		2																																			4
Ps. pinnatus	Pa	3																																					3
Ps. sp.	Pa	3																																					3
Sc. anch. europensis	Pa	5	2	2																																			9
Hi. segaformis (fr.)	Sc	8	1	5																																			14
Gn. cuneiformis	Pa		15	11	23	29	11	1	13	6	1	29	21			2		1		2	1	12	27	6	9	2	3	24	11	256	30	25	6	4	13	3	3	15	615
Gn. semiglaber	Pa		2	6	8	3	1	6	3	1	3	3	54	5	4	124	35	35	28	113	14	3	13	4	9		34	2	16	228	11	8	34	17	58	27	30	3	945
Ps. oxypageus M2	Pa		3																																				3
Vo. campbelli	Pa		1		43	13	9							5		22	4	11		2										10	21	8	79	5	8		34	1	276
Po. sp.	Pa			1																																			
Sc. anch. anchoralis	Pa			1																																			
Gn. praebilineatus	Pa								2				3									2	2							4			6				3		22
Lc. cracoviensis	Pa					2																																	2
Po. flabellus	Pa									1				2		2	2	3	1	13		1	5	2	3	1	6	1	2	6									51
Pd. symmutatus	Pa											5	1											1						1									8
Pd. homopunctatus	Pa																1			1			1				1			21	3	5	7	1		2	2	18	63
Total		106	60	51	176	79	41	19	36	11	15	104	195	24	7	188	59	66	45	196	22	36	65	17	29	7	55	53	143	1015	88	83	176	45	146	83	199	75	3813

17 Sotto Cima Plotta (SCP)

		anchoralis-latus Zone						texanus-homopunctatus Zone																		a.-l.Z.	
Samples		SCP1	SCP2	SCP3	SCP4	SCP5	SCP6	SCP7	SCP8	SCP9	SCP10	SCP11	SCP12	SCP13	SCP14	SCP15	SCP16	SCP17	SCP18	SCP19	SCP20	SCP21	SCP22	SCP23	SCP24	SCP25	SCP26	SCP26A	
Weight (g)		1425	775	875	1575	1000	650	1000	900	1370	2030	2250	1920	1500	1025	950	650	650	575	650	910	1225	1175	1465	1425	1350	3625	525	
Species																													Total
Bi. stabilis	Pa	8	17	2	3	4	3		7																			5	49
Gn. cuneiformis	Pa	1	1			32	5	11	42	118	70	7	25	9	16	11	20	15	8	9						2			402
Gn. pseudosemiglaber	Pa	26	8	9	22	10	2			43	41		8	3	17	30				2								1	222
Gn. typicus M2	Pa	20	4	5																									29
Gn. sp	Pa	4		4	10	3	3	6	11	23	14	23	7	9	5	7	9	2	10	7	7	21	16	34		1	12	3	253
Gn. sp juv	Pa	103	45	81	33	33	9	22	86	154	106	53	94	33	44	47	27	20	28	12	56	72	59	106	9	3	27	13	1375
Po. bischoffi	Pa	3	1	1	3	1	1																						10
Ps. pinnatus M2	Pa	12	18	19	19	7	6																						81
Sc. anchoralis anchoralis	Pa	1																											1
Sc. anchoralis europensis	Pa	21	28	12	19	21	7																					1	109
Hn. segaformis (fr.)	Sc	23	16	23	8	19																						3	92
Vo. campbelli	Pa	29	42							466	2	35	9	131	20	12					8	6					2		762
Gn. semiglaber	Pa			3	2	2		1	7	25	31	74	108	73	35	15	24	12	14	6	25	44	26	41	2	1	41	2	614
Ps. oxypageus M3	Pa			1																									1
Po. sp juv	Pa										1	2																	3
Po. flabellus	Pa														1				2			4		4	4	2	4		21
Gn. praebilineatus	Pa																										8		8
Gn. simplicatus	Pa																											3	3
Total		253	380	160	119	132	36	46	153	829	265	194	251	258	138	122	80	49	62	36	96	147	101	185	15	9	94	33	4035

Table 3

Numerical distribution of conodont elements in Postazione, Piastrone Plotta, Casera Collinetta di Sotto A, Casera Collinetta di Sopra and Creta di Rio Secco C sections, and in isolated test sample PPLO. (fr.) = fragments.

8 Postazione (PS)

		a.-l. Z.	texanus - homopunctatus Zone									
Samples		PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9	PS10	
Weight (g)		1270	1025	1150	1200	1330	1025	1420	1900	1490	1000	
Species												Total
Gnathodus cuneiformis	Pa	22	7	60	24	44	11	33	32	18		251
Gnathodus pseudosemiglaber	Pa	18	10	24	15	38	38	19	26	11		199
Gnathodus semiglaber	Pa	6	3	24	10	13	12	9	19	26	26	148
Gnathodus sp.	Pa	12	6	38	7	21	10	14	32	16	9	165
Gnathodus sp. juv.	Pa	14	6	30	24	25	9	17	5	21	10	161
Polygnathus bischoffi	Pa	2										2
Scaliognathus anchoralis europensis	Pa	16										16
Hindeodella segaformis (fr.)	Sc	7										7
Vogelgnathus campbelli	Pa		1	37	8	58	10	54	5	2	1	176
Pseudognathodus symmutatus	Pa				1	4	1	1				7
Polygnathus mehli	Pa								1			1
Polygnathus sp.	Pa									2		2
Pseudognathodus homopunctatus	Pa									1		1
Total		97	33	213	89	203	91	147	120	97	46	1136

18 Piastrone Plotta Ovest (PPLO)

		tex.-h.Z.
Sample		PPLO1
Weight (g)		880
Species		
Gnathodus cuneiformis	Pa	7
Gnathodus praebilineatus	Pa	2
Gnathodus pseudosemiglaber	Pa	3
Gnathodus semiglaber	Pa	9
Gnathodus texanus	Pa	1
Gnathodus sp.	Pa	6
Gnathodus sp. juv.	Pa	4
Pseudognathodus homopunctatus	Pa	3
Total		35

19 Piastrone Plotta (PPL)

		Lower typicus Zone						
Samples		PPL1	PPL2	PPL3	PPL4	PPL5	PPL6	
Weight (g)		1225	1400	1360	1470	1525	1700	
Species								Total
Gnathodus cuneiformis	Pa	17	3	3	3	9	2	37
Gnathodus delicatus	Pa	2	6	5				13
Gnathodus semiglaber	Pa	10	5	9	15	39	47	125
Gnathodus typicus M1	Pa	13	7	2	7	23	8	60
Gnathodus sp.	Pa	6	3	10	8	10	7	44
Gnathodus sp. juv.	Pa	6	6	5	4	8	41	70
Pseudopolygnathus sp	Pa	1						1
Polygnathus flabellus	Pa		1	1			1	3
Gnathodus punctatus	Pa			1	1	1	1	4
Vogelgnathus campbelli	Pa			5	5	12	13	35
Bispathodus stabilis	Pa					1		1
Hindeodus scitulus	Pa						1	1
Total		55	31	41	43	103	121	394

25 Casera Collinetta di Sotto A (CSA)

		anch.-l. Z.	texanus-homopunc. Zone			
Sample		CSA14A	CSA14B	CSA14	CSA15	
Weight (g)		860	865	3075	3000	
Species						Total
Gnathodus pseudosemiglaber	Pa	7	11	83	36	137
Gnathodus semiglaber	Pa	6	19	72	9	106
Gnathodus sp.	Pa	2		47	15	64
Polygnathus bischoffi	Pa	2	3			5
Scaliognathus anchoralis europensis	Pa	1				1
Hindeodella segaformis (fr.)	Pa	1				1
Vogelgnathus campbelli	Pa	4	5	21	6	36
Gnathodus cuneiformis	Pa		13	38	24	75
Gnathodus symmutatus	Pa		1			1
Gnathodus sp. juv.	Pa		17	80	9	106
Total		23	69	341	99	532

24 Casera Collinetta di Sopra (CCS)

		U.ty.Z.	anchoralis-latus Zone					tex.-homop. Z.		
Samples		CCS3	CCS4	CCS5	CCS6	CCS7	CCS8	CCS9	CCS10	
Weight (g)		490	1695	1365	2050	1440	2690	1875	1025	
Species										Total
Gnathodus cuneiformis	Pa	4		7	68	78	107	33	6	303
Gnathodus semiglaber	Pa	68	26		12	10	18	4	3	141
Gnathodus sp.	Pa	28	8	4	18	18	23	13	5	117
Gnathodus sp. juv.	Pa	88	7	22	60	112	323	39		651
Polygnathus flabellus	Pa	8			3	2				13
Pseudopolygnathus pinnatus	Pa	1		2			4			7
Vogelgnathus campbelli	Pa	31								31
Vogelgnathus sp.A	Pa	12	7		8		4	30		61
Gnathodus pseudosemiglaber	Pa		2		3	15	12	14	2	48
Bispathodus stabilis	Pa			3	5	3	12			23
Scaliognathus anchoralis anchoralis	Pa			1						1
Scaliognathus anchoralis europensis	Pa			4	36	37	5			82
Hindeodella segaformis (fr.)	Sc			14	70	12	2			98
Pseudopolygnathus pinnatus M1	Pa				2					2
Pseudopolygnathus pinnatus M2	Pa				20	15				35
Polygnathus bischoffi	Pa					4				4
Pseudopolygnathus oxypageus	Pa					9				9
Total		240	50	57	305	315	510	133	16	1626

31 Creta di Rio Secco C (CRSC)

		i.-U.c.	an.-l.Z.	
Samples		CRSC1	CRSC2	
Weight (g)		1900	2300	
Species				Total
Gnathodus delicatus	Pa	2		2
Gnathodus semiglaber	Pa	3		3
Gnathodus typicus M1	Pa	1		1
Gnathodus sp. juv.	Pa	3	7	10
Polygnathus communis communis	Pa	8		8
Protognathodus praedelicatus	Pa	4		4
Pseudopolygnathus multistriatus	Pa	1		1
Pseudopolygnathus triangulus	Pa	1		1
Siphonodella sp.	Pa	1		1
Vogelgnathus sp. A	Pa	1		1
Gnathodus sp.	Pa		1	1
Pseudopolygnathus oxypageus	Pa		2	2
Pseudopolygnathus pinnatus	Pa		2	2
Scaliognathus anchoralis europensis	Pa		1	1
Hindeodella segaformis (fr.)	Sc		2	2
Total		25	15	40

Upper *typicus* Zone. — According to LANE *et al.* (1980), the first occurrence of *Pseudopolygnathus nudus* and *P. oxypageus* define the base of the zone. They were not found in any of our samples. *P. oxypageus* occurs only in associations with *Scaliognathus anchoralis.* Two samples were assigned to the zone: the sample from level SP4 of the Spinotti section (Table 1), based on the presence of *Dollymae bouckaerti*, a species restricted to the considered Zone; and the sample from level CCS3 of Casera Collinetta di Sopra section (Table 3), based on the presence of *Pseudopolygnathus pinnatus*, also found

Table 4
Numerical distribution of conodont elements in M. Cavallo A and Pricot sections, and in isolated test samples B534, 172b, and Stop 46. (fr.) = fragments.

34 M. Cavallo A (MCA)

Samples		MCA9	MCA10	MCA11	MCA12	
		texanus-homopunctatus Zone				
Weight (g)		2495	2430	2340	2175	
Species						Total
Gnathodus cuneiformis	Pa	1	3		3	7
Gnathodus praebilineatus	Pa	2	1			3
Gnathodus pseudosemiglaber	Pa	3	11	9	7	30
Gnathodus semiglaber	Pa	4	1	4	2	11
Polygnathus flabellus	Pa	2	2			4
Gnathodus sp.	Pa		14	13	10	37
Gnathodus sp. juv.	Pa		13	23	21	57
Vogelgnathus campbelli	Pa				3	3
Total		12	45	49	46	152

35 Pricot (PRT)

Samples		PRT10	PRT8	PRT6	PRT5	PRT2	
		anchoralis-latus Zone					
Weight (g)		1275	1225	1150	800	1825	
Species							Total
Gnathodus sp.	Pa	4				1	5
Polygnathus sp.	Pa	1					1
Gnathodus pseudosemiglaber	Pa		5				5
Gnathodus semiglaber	Pa		2				2
Pseudopolygnathus pinnatus	Pa		3	4			7
Scaliognathus anchoralis europensis	Pa		5	4	2	5	16
Hindeodella segaformis (fr.)	Sc		2	4	1	1	8
Protognathodus cordiformis	Pa			4		1	5
Pseudopolygnathus oxypageus	Pa			1			1
Gnathodus cuneiformis	Pa				2		2
Pseudopolygnathus pinnatus M2	Pa				3		3
Protognathodus praedelicatus	Pa					1	1
Pseudopolygnathus sp. juv.	Pa					1	1
Total		5	17	17	8	10	57

6 B 534

Sample		B534
		a.-l.Z.
Weight (g)		3650
Species		
Bisphathodus stabilis	Pa	18
Gnathodus cuneiformis	Pa	89
Gnathodus delicatus	Pa	4
Gnathodus pseudosemiglaber	Pa	7
Gnathodus semiglaber	Pa	4
Gnathodus sp.	Pa	20
Gnathodus sp. juv.	Pa	19
Polygnathus bischoffi	Pa	7
Polygnathus communis communis	Pa	1
Pseudopolygnathus pinnatus M2	Pa	40
Scaliognathus anchoralis europensis	Pa	43
Hindeodella segaformis (fr.)	Sc	12
Vogelgnathus campbelli	Pa	5
Total		269

32 172b

Sample		172b
		i.-U.c.Z.
Weight (g)		4275
Species		
Bispathodus stabilis	Pa	2
Dollymae sagittula	Pa	3
Gnathodus cuneiformis	Pa	7
Gnathodus punctatus	Pa	1
Gnathodus typicus M1	Pa	6
Polygnathus communis communis	Pa	8
Polygnathus flabellus	Pa	2
Protognathodus praedelicatus	Pa	5
Pseudopolygnathus multistriatus	Pa	7
Siphonodella isosticha	Pa	3
Vogelgnathus sp.A	Pa	3
Total		47

15 Stop 46 (S46)

Sample		S46
		t.-h. Z.
Weight (g)		1250
Species		
Gnathodus cuneiformis	Pa	6
Gnathodus pseudosemiglaber	Pa	7
Gnathodus semiglaber	Pa	128
Gnathodus sp.	Pa	32
Gnathodus sp. juv.	Pa	279
Pseudognathodus homopunctatus	Pa	3
Pseudognathodus symmutatus	Pa	8
Vogelgnathus campbelli	Pa	55
Total		518

in *anchoralis–latus* Zone. The level CCS3 belongs, most likely, to the uppermost part of the biozone, where *P. pinnatus* starts (LANE *et al.* 1980) and elements of the long ranging species *Gnathodus semiglaber* and *G. cuneiformis* are numerous.

***anchoralis–latus* Zone.** — The biozone is defined by the presence of *Scaliognathus anchoralis* and *Doliognathus latus. S. anchoralis* is represented by two subspecies *S. a. anchoralis* and the more frequent *S. a. europensis. Hindeodella segaformis*, considered the **Sc** element of the *Scaliognathus* apparatus, is always present in association with **Pa** element of *Scaliognathus.* Test samples B535 and FV53 were assigned to the zone based on the co-occurrence of *Pseudopolygnathus pinnatus* $\mathbf{M_2}$ and *Gnathodus pseudosemiglaber.* Thirty eight samples were assigned to the zone. For the complete list of the samples, please refer to the Appendix. *Gnathodus cuneiformis, G. semiglaber*, and *G. pseudosemiglaber* are the more abundant species followed by *Scaliognathus anchoralis* and *Pseudopolygnathus pinnatus* $\mathbf{M_2}$ (Tables 1–4).

***texanus–homopunctatus* Zone.** — In some of the studied sections (Figs 1, 2 and Tables 1–3, PS, SSFM, DL, SCP, CCS, CSA), an abrupt change in the conodont fauna association is clearly recognizable above the last appearance of *Scaliognathus anchoralis.* We interpret this change as transition between the *anchoralis–latus* Zone and the *texanus–homopunctatus* Zone. In these sections, a stratigraphic interval characterized by a monotonous, long-ranging gnathodid fauna is always present in the interval between the last appearance of all scaliognathids and pseudopolygnthids and the first appearance of other species such as *Gnathodus texanus*, *Pseudognatodus homopunctatus*, *Lochriea cracoviensis*, *G. praebilineatus*, and *Pd. symmutatus.* This interval ranges in thickness from 80 cm in Dolina section (DL) to 5 m in Sotto

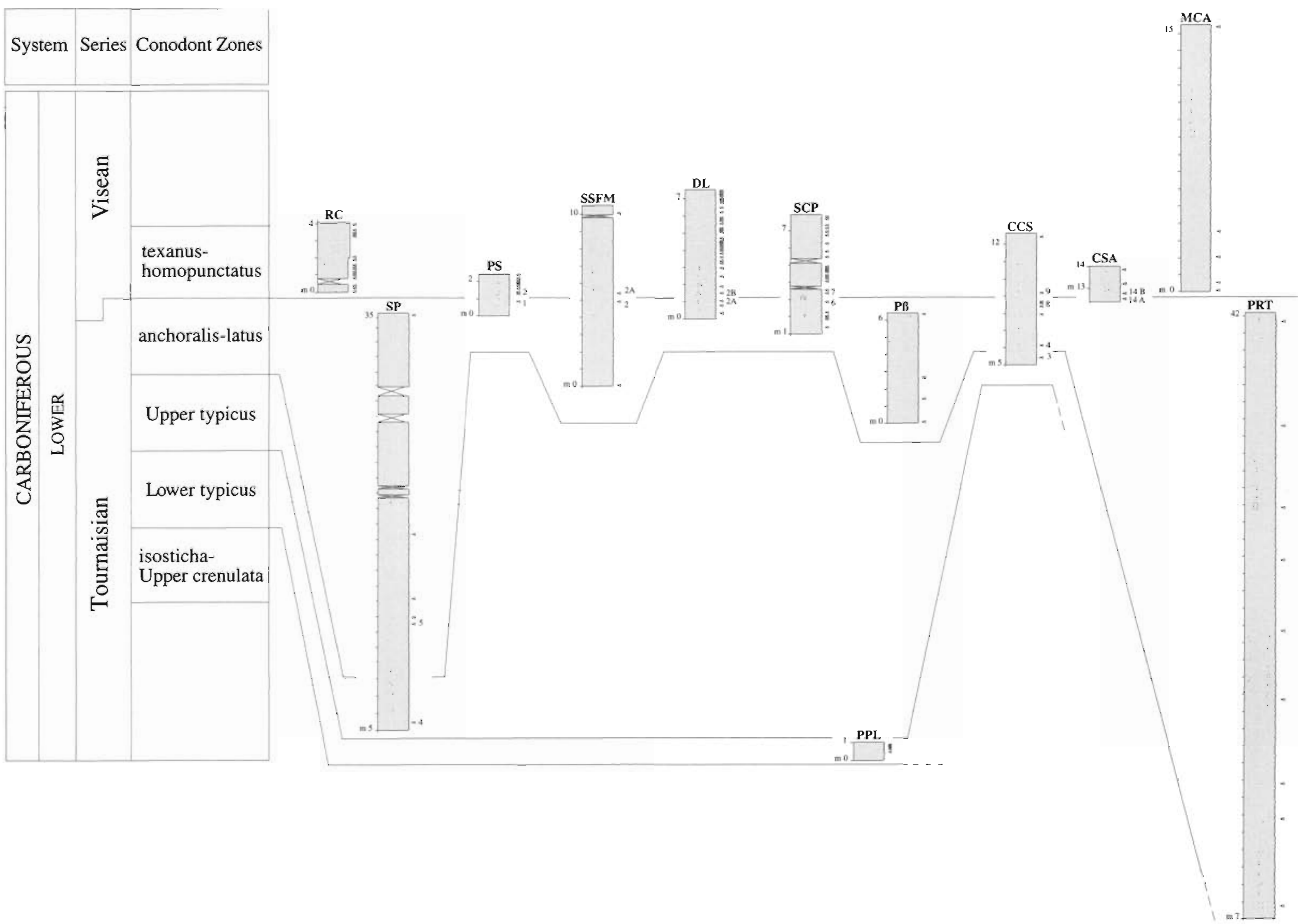

Fig. 4

Correlation of selected stratigraphic sections from the Carnic Alps. The names of sections are indicated with the same abbreviations as on Fig.1. The small arrows on the right of the columns indicate the sample positions. The samples above and below the biozone boundaries are indicated by their own numbers. Sections SP, PS, SSFM, DL, PPL, Pß, CCS, CSA, MCA, and PRT were collected from biomicrite (goniatite-bearing pelagic limestone), for lithological details of sections RC and SCP see Fig. 2.

Table 5
Comparison of different biozonations proposed for the discussed part of the Early Carboniferous.

Western United States Poole and Sandberg, 1991	Pyrenees Perret and Delvolve, 1994	Belgium Groessens, 1974		Poland Belka, 1985	Proposed Standard Zonation Ziegler and Lane, 1987	Carnic Alps this paper
bilineatus-U. Cavusgnathus	Pg nodosus-Gn. bilineatus	beckmanni	commutatus		FU10	
L. Cavusgnathus	Gn. bilineatus-Pg. commutatus			bilineatus	FU9	
				austini	FU8	
homopunctatus-U. texanus mehli-L. texanus	Ps. homopunctatus		homopunctatus	texanus	texanus	texanus-homopunctatus
anchoralis-latus	Sc. anchoralis	anch.	anchoralis burlingtonensis latus	anchoralis	anchoralis-latus	anchoralis-latus
U. typicus	Gn. punctatus-Siphonodella	communis carina	bouckaerti bultyncki cf. bultyncki hassi	cuneiformis	U. typicus	U. typicus
L. typicus					L. typicus	L. typicus
isosticha-U. crenulata				delicatus	isosticha-U. crenulata	isosticha-U. crenulata
L. crenulata				crenulata	L. crenulata	

Cima Plotta section (SCP) (Fig. 2) and contains a conodont fauna that consists mainly of *Gnathodus semiglaber*, *G. pseudosemiglaber*, and *G. cuneiformis*, the species which are numerically most abundant either in the *anchoralis–latus* Zone or in the *texanus–homopunctatus* Zone. This interval is assigned to the *texanus–homopunctatus* Zone, even though the association could also be compatible with the *anchoralis–latus* Zone.

The nearly sinchronous disappearance of scaliognathids and pseudopolygnathids is used here to define the lower limit of the zone. After this double disappearance, the conodont association undergoes an important change: the decrease in generic and species diversity. This decrease documents the post *anchoralis–latus* Zone (early Visean), low diversity episode described by ZIEGLER and LANE (1987) and already recognized in the Carnic area by SCHÖNLAUB and KREUTZER (1993). One hundred and three samples, as detailed in the Appendix, were assigned to the zone.

Our data suggest that, in the Carnic Alps, *Gnathodus texanus* is very rare. We are aware, however, that this may depend on the relatively low weight of samples. The species was found only in the isolated test sample PPLO1 and in the Rio Chianaletta section (RC) (Fig. 2 and Table 1). However, the entire length of the section was assigned to *texanus–homopunctatus* Zone based on the presence of other species such as *Pseudognathodus homopuncatus* that appears starting from the lowermost sample (RC1a). The above mentioned, associated species *Pseudognathodus homopunctatus*, *Lochriea cracoviensis*, *G. praebilineatus*, and *Pd. symmutatus* were used to recognize the zone in all other samples lacking the marker.

In the examined associations (PS, SSFM, DL sections) *Pseudognathodus homopunctatus*, which was used by some authors (GROESSENS 1974; VARKER and SEVASTOPULO 1985; PERRET and DELVOLVE 1994) to define and name the biozone immediately above the *anchoralis–latus* Zone, appears here. Its lowest occurrences are in samples PS9 (Postazione section, Fig. 2 and Table 3) and DL13 (Dolina section, Fig. 2 and Table 2), 1.5 m and 3 m above the disappearance of scaliognathids and pseudopolygnathids respectively. Its distribution is similar to that reported from North America by POOLE and SANDBERG (1991). However, BELKA (1985) found *Pd. homopunctatus* in association with *Scaliognathus anchoralis*.

The appearance of *L. cracoviensis* is here used as an additional aid to recognize the *texanus–homopunctatus* Zone. According to BELKA (1985), *Lochriea cracoviensis* first occurs at the base of the *texanus* Zone. In the examined sections, the lowest occurrence of this species is in sample DL3 (Dolina section, Fig. 2 and Table 2), 80 cm above the disappearance of scaliognathids and pseudopolygnathids.

Gnathodus praebilineatus is also used to recognize this zone. Its lowest occurrence is in sample DL6 (Dolina section, Fig. 2 and Table 2), 1.5 m above the disappearance of scaliognathids and pseudopolygnathids. We assigned to *G. praebilineatus* the elements with a long parapect extending to, or almost to, the posterior tip; a simple posterior blade sometimes very slightly expanded in its posteriormost part; and the outer cup with nodes sometimes arranged in rows (Pl. 2: 9). These forms could be transitional between *G. semiglaber* and *G. praebilineatus*. Moreover, we assigned to *G. praebilineatus* the elements with a parapect reaching the posterior tip, simple posterior blade, and wide outer cup with nodes arranged in rows (Pl. 2: 8). In our opinion, these elements are true *G. praebilineatus*. We found them only in Rio

Chianaletta section (samples RC2, RC7, RC11, RC16, Fig. 2 and Table 1), i.e. the section we believe to be stratigraphically higher. The distribution of *G. praebilineatus* in the Southern Alps is stratigraphically lower than that reported for Poland by BELKA (1985). In fact, the lowest occurrence of the species was described and cited from the base of the *austini* biozone of BELKA, which follows the *texanus* Zone. On the other hand, some scattered occurrence of *G. praebilineatus* in the strata above the last appearance of *S. anchoralis*, were reported from the Pyrenées by PERRET and DELVOLVE (1994). *Pseudognathodus symmutatus* occurs within the *texanus–homopunctatus* Zone.

Taking into account all the previously assembled data, we suggest that, for the Carnic Alps, the discussed zone may be named *texanus–homopunctatus* Zone (Figs 2–4 and Table 5). This is in recognition of the fact that *Pseudognathodus homopunctatus* is best represented numerically (Tables 1–4) among the taxa used as additional aid in recognizing the zone above the *anchoralis–latus* Zone.

While the present study was in progress, a paper on Early Carboniferous conodonts from a section located in the Italian Carnic Alps was published by SCHÖNLAUB and KREUTZER (1993). These authors found, in their Cima di Plotta section, a conodont association very similar to that present in our Sotto Cima Plotta (SCP) section. In fact, Cima di Plotta was sampled only ten meters or so away from SCP. The Cima di Plotta lithologic units are about the same in thickness as those of SCP. SCHÖNLAUB and KREUTZER (1993) reported *Gnathodus praebilineatus* approximately four meters above the disappearance of scaliognathids, which is nearly the distance between samples SCP6 with last appearance of scaliognathids, and SCP26 with *G. praebilineatus*, (Fig. 2, Table 2). However, the concept of *G. praebilineatus* as described and figured by SCHÖNLAUB and KREUTZER (1993: p. 256; pl. 6: 7–11), is not in accordance with the original diagnosis of the species and related remarks as given by BELKA (1985). In our opinion, elements like those figured by SCHÖNLAUB and KREUTZER (1993: pl. 6: 7–11), having a short parapet and expanded posterior blade, should be included in *G. semiglaber*. Moreover, these authors found *G. texanus* both in association with scaliognathids as well as after their disappearance. The elements figured in Pl. 5: 1–3, could represent transitional forms between *G. pseudosemiglaber* and *G. texanus* but are, more likely, to be *G. pseudosemiglaber.* Some elements from sample 91/23 – a few decimeters above the occurrence of those described as *G. praebilineatus*, figured by SCHÖNLAUB and KREUTZER (1993: pl. 6: 12–14) and reported as early representatives of *G. bilineatus bilineatus* – seem to better fit the description of *G. praebilineatus* sensu BELKA (1985). Therefore, these last elements may correspond to those we found in sample SCP 26 (Fig. 2 and Table 2).

CONODONT BIOFACIES

In addition to the biostratigraphic study, a biofacies analysis was also conducted.

The biofacies model of SANDBERG and GUTSCHICK (1984) was applied for the levels assigned to the *anchoralis–latus* Zone. The presence of *Scaliognathus* and rare *Doliognathus* allows for the assignment of those levels to the second (scaliognathid-doliognathid) biofacies of the model. This biofacies indicates a basinal environment; a depositional environment corresponding to offshore, moderately deep, pelagic conditions was inferred using similar data by SCHÖNLAUB and KREUTZER (1993).

All levels assigned to biozones before and after the *anchoralis–latus* Zone produced a high percentage of gnathodids, almost always representing the majority of the fauna. They are often associated with vogelgnathids, considered to be an indicator of pelagic facies (BOOGAARD, VAN DEN 1992), and thus, the levels can be referred to an offshore environment.

In the studied material two species of *Vogelgnathus* are present from the *isosticha*–Upper *crenulata* Zone to the *texanus–homopunctatus* Zone. The **Pa** elements referred here to as *V. campbelli* resemble closely those figured by NORBY and REXROAD (1985: pl. 2: 3–10), but they do not have nodes. *V.* sp. A has about the same length/height ratio as *V. campbelli*, but has a wider basal cavity and shorter recurved denticles bent toward the posterior tip. The numerical distribution is extremely variable (see Table 1, samples SCP9 and SCP10).

In any case, the result of biofacies analysis confirms a basinal setting for the limestones, a finding reinforced by lithologic and sedimentological data. As expected, most of the Lower Carboniferous goniatite-bearing limestones of the Carnic Alps were deposited in a stable, pelagic environment almost completely lacking nearshore influences (SPALLETTA and VENTURINI 1990).

It is noteworthy, that the levels lacking species indicative of the *texanus–homopunctatus* Zone – immediately above the disappearance of scaliognathids and pseudopolygnathids, but still referred to the zone (RCA, PS, SSFM, SCP, CCS, CSA sections) – could be interpreted as indicating a change in biofacies rather than in biozone. The idea of a possible biofacies change was not rejected *a priori*, because a local fluctuation of the sea-level could have been quite well framed in the scheme of geodynamic evolution of the Paleocarnic Domain, as previously discussed.

A paleoenvironmental change from pelagic to more onshore settings during the upper part of the anchoralis-latus Zone, may have led to a biofacies change from the second to the third biofacies of the SANDBERG and GUTSCHICK (1984) model. The third biofacies, indicative of a middle-upper slope environment, is characterized by gnathodids and pseudopolygnathids. In the samples from the studied sections, *Pseudopolygnathus* abruptly disappears always along with *Scaliognathus*. This disappearance, in the authors' opinion, was more likely due to an evolutionary and chronologic event rather than to a biofacies change, and therefore, the discussed levels are assigned here to the *texanus–homopunctatus* Zone.

THE TOURNAISIAN/VISEAN BOUNDARY

In the Lower Carboniferous of Belgium, which contains the type sections of the Tournaisian and Visean series, the boundary is traced on the basis of the appearance of *Pachysphaerina pachysphaerica*. *Pseudognathodus homopunctatus* first appears in a short distance above this level.

Until now, the Tournaisian/Visean boundary has not been linked to the base of any conodont zone. However, most of conodont workers seem to consider the base of the *texanus* Zone as coincident with the lower boundary of the Visean (WEBSTER and GROESSENS 1991). Although these authors stated that the base of the *texanus* Zone may correspond approximately to the first occurrence of *Mestognathus praebeckmanni* in Belgium, they presented on their fig. 2 the lower limit of the *texanus* Zone at the same level as the Tournaisian/Visean boundary (base of *Eoparastaffella*, within Moliniacian stage), well after the first appearance of *Me. praebeckmanni* and not long before the first appearance of *Pd. homopunctatus* in Belgium. Therefore, the definition of the boundary, in terms of conodont zonation, requires further investigations.

In the Carnic Alps, the transition between the *anchoralis–latus* Zone and the *texanus–homopunctatus* Zone is well marked by the synchronous disappearance of scaliognathids and pseudopolygnathids (PS, SSFFM, DL, SCP, CCS and CSA sections). Above this critical interval, which is minimum 80 cm thick, a low diversity conodont association always appears. It is followed by the first occurrences of *Pseudognatodus homopunctatus*, *Lochriea cracoviensis*, *G. praebilineatus*, and *Pd. symmutatus*. All these species are useful as additional aid to recognize the *texanus–homopunctatus* Zone.

None of these species appears immediately after the disappearance of scaliognathids and pseudopolygnathids. In all the examined sections, there is an interval devoid of new appearances, which is characterized by a monotonous, long-ranging, gnathodid faunal association. Moreover, the first appearances of the above mentioned species are, in the different sections, at a variable distance above the disappearance of scaliognathids and pseudopolygnathids. *Lochriea cracoviensis*, *Pseudognathodus homopuncatatus, Gnathodus praebilineatus*, and *Pd. symmutatus* are not always present together and their first occurrences do not follow the same stratigraphic order in the different sections (Fig. 2 and Tables 1–4). The lowest of these first appearances is that of *Lc. cracoviensis* in sample DL3 (Dolina section) about 80 cm above the disappaerance of *Scaliognathus* and *Pseudopolygnathus*. *Lc. cracoviensis* appears in Belgium well above the occurrence of *Pd. homopuncatus*, at about the same level, at which the primitive archaediscids first appear (WEBSTER and GROESSENS 1991). BELKA (1985) described and cited *Lc. cracoviensis* from the base of the *texanus* Zone. In the Dolina section, *Pd. homopunctatus* was found in sample DL14, 250 cm above *Lc. cracoviensis* (Fig. 2, Table 2). We inferred that, in the Carnic Alps, *Lc. cracoviensis* appear not long after the end of the *anchoralis–latus* Zone.

Because the basinal environment was quite stable, we do not believe that the disappearance of scaliognathids and pseudopolygnathids is due to environmental changes. Moreover, we do not have any evidence of gaps in the sequence. Therefore, we use the most clearly recognizable conodont event, the synchronous disappearance of *Scaliognathus* and *Pseudopolygnathus* genera, to define the lower limit of the *texanus–homopunctatus* Zone.

We are aware that the lower limit of the the *texanus–homopunctatus* Zone as defined here may not correspond to the lower limit of the *texanus* Zone as defined by the first occurrence of *Gnathodus texanus*. Therefore, on Fig. 4 we have only tentatively correlated the base of the *texanus–homopunctatus* Zone with the possible position of the Visean/Tournaisian boundary.

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APPENDIX

Sections and samples	No.	Abbrev.	is.-U.cr.Z.	L.typ.Z.	U.typ.Z.	anch.-lat.Z.	tex.-hom.Z.
Rio Chianaletta Alto	1	RCA	RCA-3	RCA-2			RCA-1/RCA0
Rio Chianaletta	2	RC					RC1a-RC17;18 a,b
B535	3	B535				B535	
Spinotti	5	SP			SP4	SP5-SP9	
B534	6	B534				B534	
Postazione 5A	7	PS5A					PS5A
Postazione	8	PS				PS1	PS2-PS10
B533	9	B533				B533	
Sotto Sentiero per Forcella Monumenz	10	SSFM				SSFM1- SSFM2	SSFM2A-SSFM3
Dolina	13	DL				DL1-DL2	DL3- DL35
Stop 46	15	S46					S46
Sotto Cima Plotta	17	SCP				SCP1-SCP6	SCP7-SCP26
Piastrone Plotta Ovest	18	PPLO					PPLO1
Piastrone Plotta	19	PPL		PPL1-PPL6			
Passo ß	23	Pß				Pß1-Pß5	
Casera Collinetta di Sopra	24	CCS			CCS3	CCS4-CCS8	CCS9-CCS10
Casera Collinetta di Sotto A	25	CSA				CSA14A	CSA14B- CSA15
Casera Collinetta di Sotto A 14L	26	CSA14L					CSA14L
Trincea A	27	TRA				TRA7	
FV43	29	FV43				FV43	
FV54	30	FV54				FV54	
Creta di Rio Secco C	31	CRSC	CRSC1			CRSC2	
172b	32	172b	172b				
M. Cavallo A	34	MCA					MCA9-MCA12
Pricot	35	PRT				PRT10-PRT3	

CONODONT DISTRIBUTION AT THE TOURNAISIAN/VISEAN BOUNDARY IN THE CARNIC ALPS (SOUTHERN ALPS, ITALY)

PLATE 1

Dollymae bouckaerti GROESSENS, 1971

1. *a* lower, *b* upper view, sample SP 4, × 81, 932359, IC 1580.

Eotaphrus burlingtonensis PIERCE *et* LANGENHEIM, 1974

2. *a* upper, *b* lower, *c* lateral view, sample Pß 1, × 81, 932354, IC 1581.

Gnathodus cuneiformis MEHL *et* THOMAS, 1947

3. Upper view, sample DL 13, × 60, 944313, IC 1582.
4. Upper views, sample SCP 9, × 60, 932385, IC 1583.

Gnathodus delicatus BRANSON *et* MEHL, 1938

5. Upper view, sample B 535, × 60, 932378, IC 1584.

Protognathodus cordiformis LANE, SANDBERG *et* ZIEGLER, 1980

6. Upper view, sample SSFM 1, × 60, 932375, IC 1585.

Protognathodus praedelicatus LANE, SANDBERG *et* ZIEGLER, 1980

7. Upper view, sample Pß 1, × 60, 932374, IC 1586.

Gnathodus punctatus (COOPER, 1939)

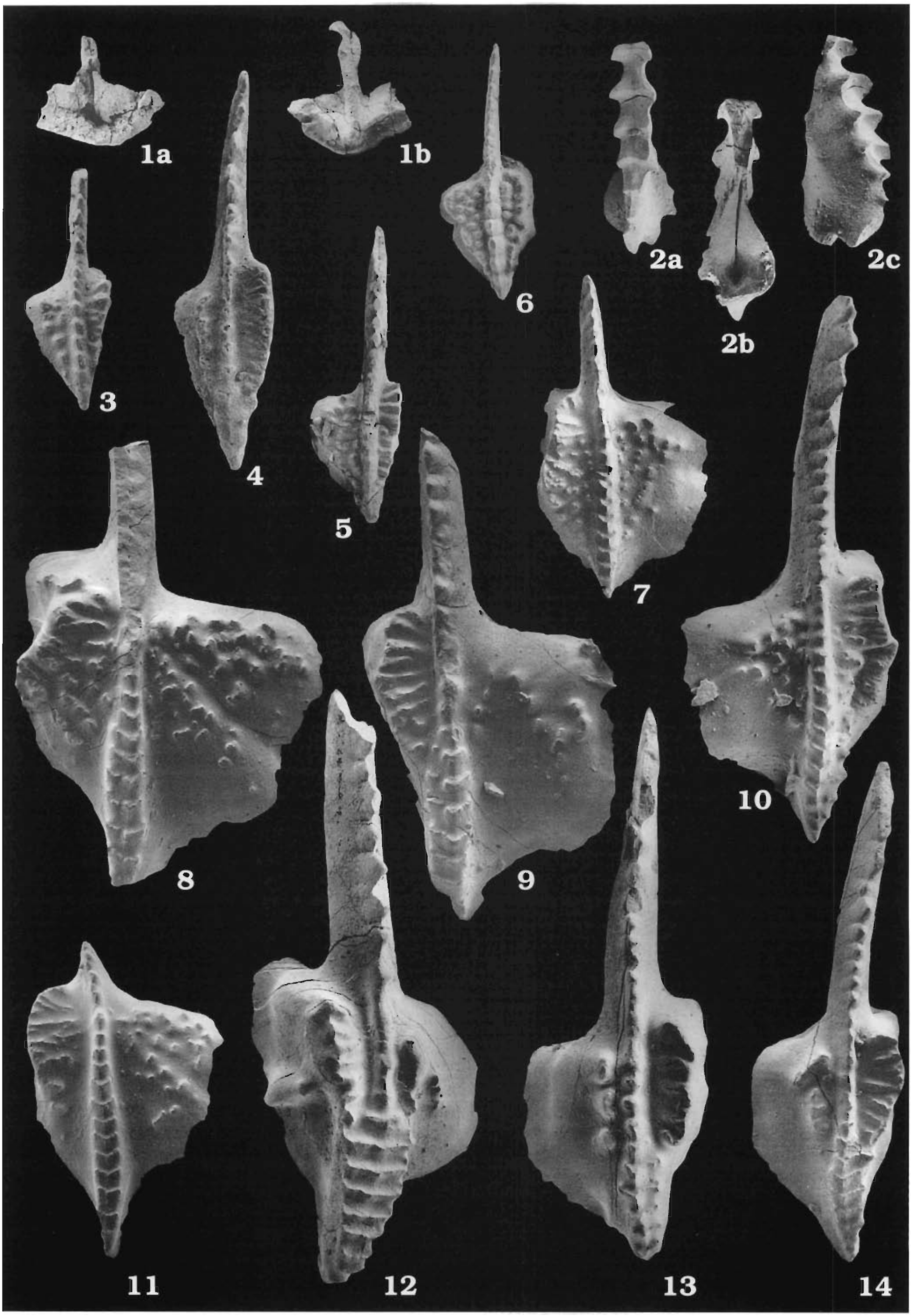
8. Upper view, sample RCA -3, × 60, 944300, IC 1587.

Gnathodus semiglaber BISCHOFF, 1957

9. Upper view, sample RC 4, × 60, 944305, IC 1588.
10. Upper view, sample SCP 12, × 60, 932404, IC 1589.
11. Upper view, sample DL 17, × 60, 944289, IC 1590.

Gnathodus pseudosemiglaber THOMPSON *et* FELLOWS, 1970

12. Upper view, sample SCP 15, × 60, 932405, IC 1591.
13. Upper view, sample SCP 9, × 60, 932408, IC 1592.
14. Upper view, sample DL 9, × 60, 944286, IC 1593.


1a
1b
2a
2b
2c
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CONODONT DISTRIBUTION AT THE TOURNAISIAN/VISEAN BOUNDARY IN THE CARNIC ALPS (SOUTHERN ALPS, ITALY)

PLATE 2

Doliognathus latus $\mathbf{M_3}$ BRANSON *et* MEHL, 1941

1. *a* upper; *b* lower view, sample SSFM1, × 60, 932361, IC 1594.

Scaliognathus anchoralis anchoralis BRANSON *et* MEHL, 1941

2. *a* upper; *b* lower view, transitional form from *S. anchoralis europensis*, sample SSFM 1, × 60, 932363, IC 1595.

Scaliognathus anchoralis europensis LANE *et* ZIEGLER, 1983

3. *a* upper, *b* lower view, sample SCP 2, × 60, 932366, IC 1596.

Gnathodus texanus ROUNDY, 1929

4. Upper view, sample RC 11, × 60, 944073, IC 1597.
5. Upper view, sample RC 8, × 60, 944308, IC 1598.

Pseudognathodus homopunctatus (ZIEGLER, 1962)

6. Upper view, sample DL 30, × 81, 944396, IC 1599.
7. Upper view, sample DL 35, × 81, 944397, IC 1600.
13. Upper view, sample SSFM 3, × 81, 932373, IC 1601.

Gnathodus praebilineatus BELKA, 1985

8. Upper view, sample RC 11, × 60, 944309, IC 1602.
9. Upper view, transitional form from *G. semiglaber*, sample DL 30, × 60, 944291, IC 1603.

Lochriea cracoviensis BELKA, 1985

10. Upper view, sample RC 11, × 60, 944331, IC 1604.
11. *a* upper, *b* lateral view, sample RC 11, × 60, 944334, IC 1605.

Gnathodus pseudosemiglaber THOMPSON *et* FELLOWS, 1970

12. Upper view, sample SCP 4 × 60, 932411, IC 1606.

Polygnathus flabellus BRANSON *et* MEHL, 1938

14. *a* lower, *b* upper view, sample RC 3, × 60, 944320, IC 1607.

Vogelgnathus campbelli (REXROAD, 1957)

15. Lateral view, sample DL 30, × 81, 944327, IC 1608.

Pseudopolygnathus pinnatus $\mathbf{M_2}$ VOGES, 1959

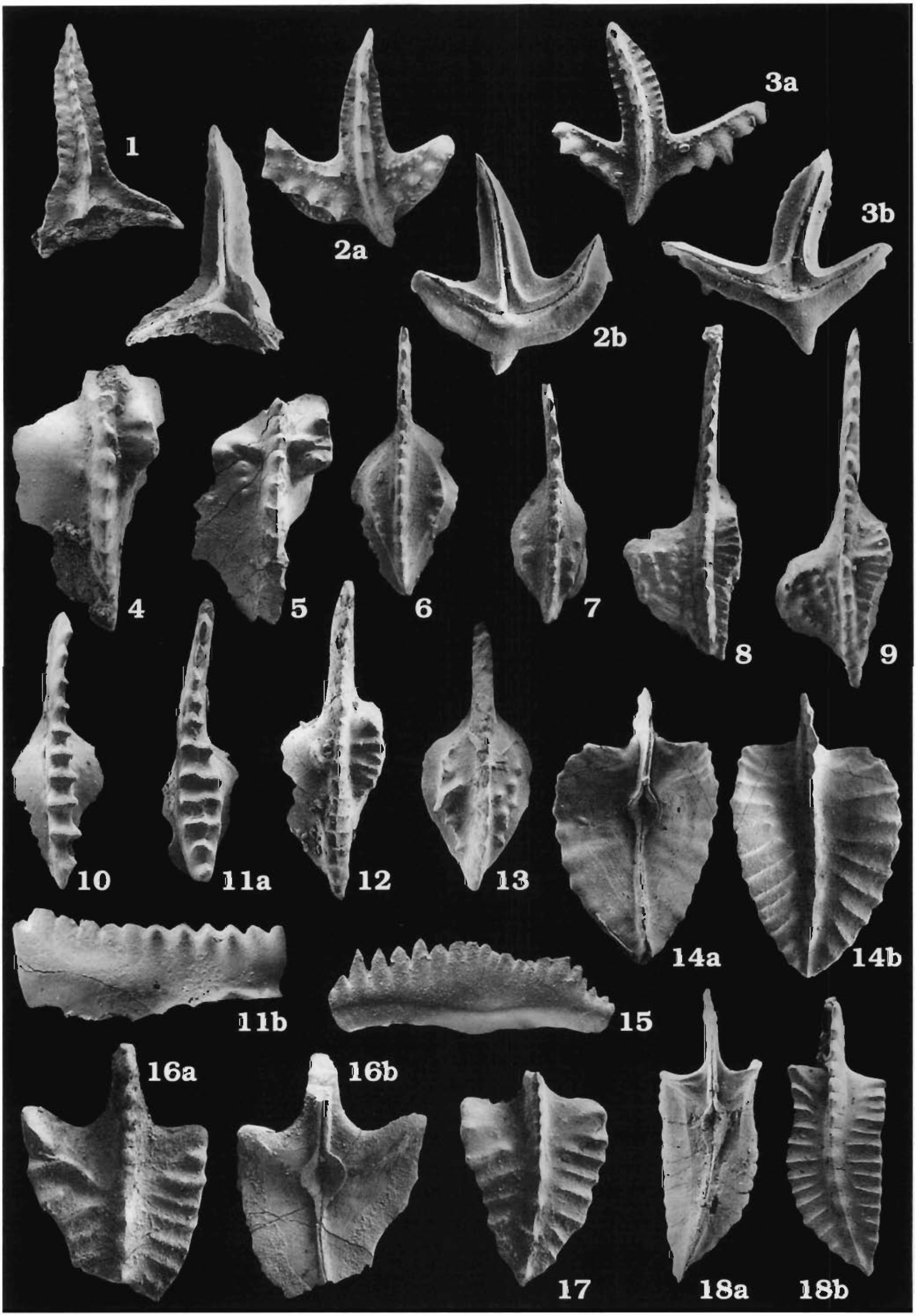
16. *a* upper, *b* lower view, DL 1, × 60, 944315, IC 1609.

Pseudopolygnathus oxypageus LANE, SANDBERG *et* ZIEGLER, 1980

17. Upper view, sample DL 2, × 60, 944318, IC 1610.

Polygnathus bischoffi RHODES, AUSTIN *et* DRUCE, 1969

18. *a* lower, *b* upper view, sample PS 1, × 60, 932347, IC 1611.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