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New conodont faunas from the Late Ordovician of the Central Carnic Alps, Austria

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ABSTRACT – Conodont faunas recovered from both the Uggwa and Wolayer limestones of the Central Carnic Alps, Austria, documented unequivocally the *Amorphognathus ordovicicus* Zone. *Hamarodus europaeus* (Serpagli, 1967), *Scabbardella altipes* (Henningsmoen, 1948) and *Walliserodus amplissimus* (Serpagli, 1967) represent some of the characteristic species. The association closely matches in composition and age the conodont material described on the Italian side of the Alps.

A younger fauna was recovered immediately above a well-known brachiopod Hirnantia Fauna in the Cellon section, a classic reference for Silurian conodont biostratigraphy. The association keeps a clear Ordovician aspect having its markers in *A. cf. A. ordovicicus* Branson & Mehl, 1933 and *A. lindstroemi* (Serpagli, 1967). Elements of "Dichodella-Birksfeldia", possibly corresponding to the distinctive North American Gamachian genus *Gamachignathus*, are well represented. Taxa previously common in colder regimes, such as *Sagittodontina* and *Istorinus*, are also present. The abundance and moderate diversity of this fauna, composed of about twenty species, allow a first significant definition of the Hirnantian conodont fauna from the Atlantic Faunal Region.

RIASSUNTO – [Conodonti dell'Ordoviciano superiore delle Alpi Carniche Centrali, Austria] – Faune a conodonti ritrovate nel calcare di Uggwa e nel calcare di Wolaya delle Alpi Carniche Centrali Austriache hanno documentato in modo inequivocabile la zona ad *Amorphognathus ordovicicus*. Alcune delle specie più caratteristiche sono *Hamarodus europaeus* (Serpagli, 1967), *Scabbardella altipes* (Henningsmoen, 1948) e *Walliserodus amplissimus* (Serpagli, 1967). Le associazioni rinvenute richiamano fortemente in composizione ed età le faune descritte sul versante italiano delle Alpi.

Una fauna più recente, che mantiene ancora un chiaro aspetto ordoviciano, è stata rinvenuta immediatamente al di sopra di una associazione a brachiopodi ad Hirnantia nella sezione di Cellon, riferimento classico nella biostratigrafia a conodonti del Siluriano. *A. cf. A. ordovicicus* Branson & Mehl, 1933 e *A. lindstroemi* (Serpagli, 1967) sono presenti. Elementi di "Dichodella-Birksfeldia", probabilmente corrispondente al genere Nord Americano "Gamachignathus" caratteristico del Gamachiano, sono ben rappresentati assieme anche a taxa che erano precedentemente diffusi in regimi più freddi quali *Sagittodontina* ed *Istorinus*. L'abbondanza e la moderata diversità di questa associazione, composta di circa venti specie, permette una prima significativa definizione della fauna a conodonti dell'Hirnantiano della Regione Faunistica Atlantica.

INTRODUCTION

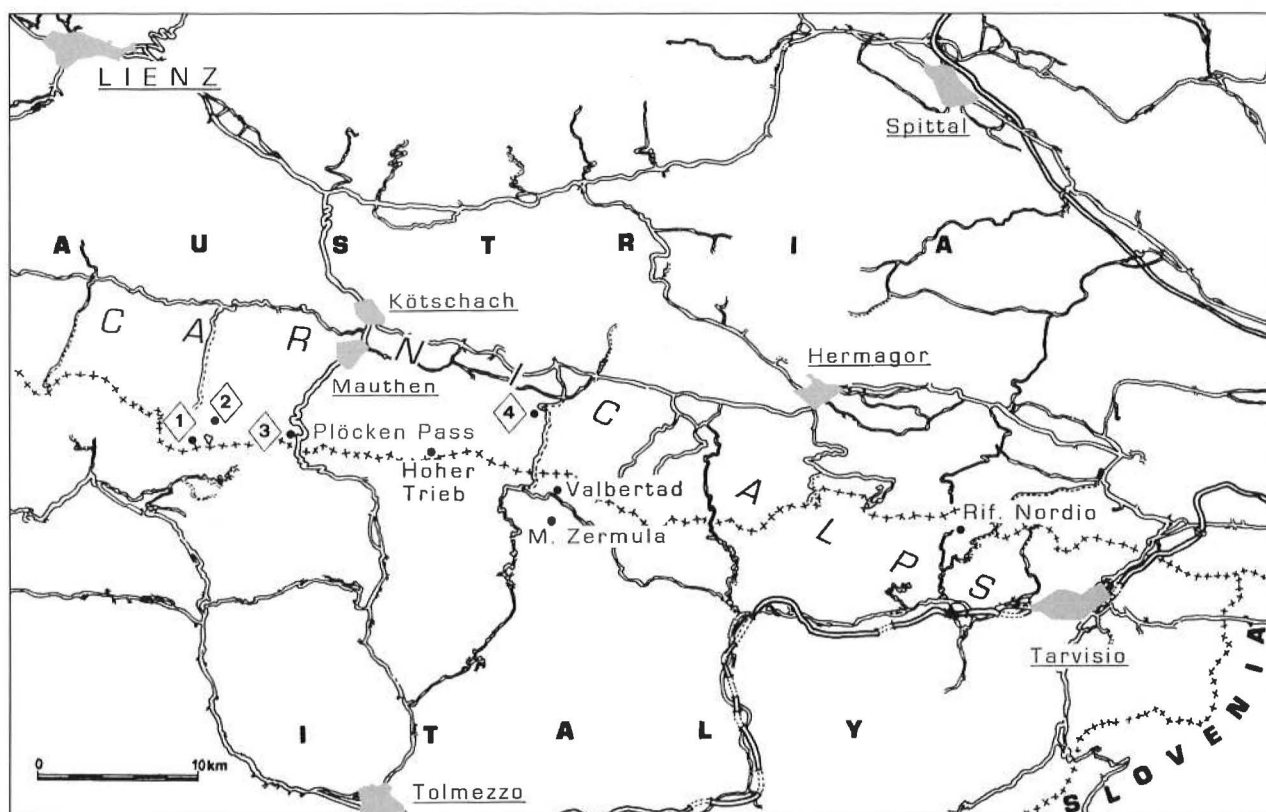
The Carnic Alps exposed in Southern Austria and Northern Italy (Text-fig. 1) are one of the very few places in the world in which an almost continuous fossiliferous sequence of Paleozoic age has been preserved. Almost 130 years ago, in this region, the first fossils of Ordovician age were discovered by the famous geologist Eduard Suess in the section near Rifugio Nordio in the Uggwa Valley of Northern Italy. He handed them over to Guido Stache from the Austrian Geological Survey who in 1874 identified several taxa and in 1884 published a comprehensive paper correlating what he named "*Strophomena* Horizont des Uggwagraben's" with strata in the Barrandian region which, in the British chronostratigraphical terminology (Fortey *et al.*, 1995), indicates the Caradoc Series. This exposure yielded by far the most abundant and diversified fauna of the early Late Ordovician of the entire Carnic Alps. Although this fauna still represents the oldest known megafossils in that area, during the following decades many other localities from both the Italian and Austrian part of

the Carnic Alps have provided numerous additional litho- and biostratigraphic data resulting thus in a fairly detailed knowledge of the stratigraphic subdivision and the paleogeographic relationship with adjacent Lower Paleozoic sequences.

The Late Ordovician so far investigated on the Austrian side for conodonts did not yield diagnostic conodonts, and all data permitted rough age assignments with no precise location of the stage boundaries. Samples for conodont digestion were recently collected in an attempt to have a better stratigraphic definition of the hiatus at the Ordovician/Silurian boundary. The recovered associations for the first time allowed a precise age definition of the Upper Ordovician formations by means of conodonts. Indications on the composition of a conodont fauna immediately above a well-established Hirnantian brachiopod level were also provided.

THE ORDOVICIAN OF THE AUSTRIAN CARNIC ALPS

In the Carnic Alps, rocks of Ordovician age have long been known from both classical, i.e. fossiliferous



Text-fig. 1 - Location of selected outcrops in the Central Carnic Alps. 1) Seekopf Sockel; 2) Rauchkofel Boden; 3) Cellon; 4) Oberbuchach 1.

localities of the central part, and unfossiliferous sequences which dominate the western region (Schönlaub, 2000). In the latter, the Ordovician age is mainly inferred by its occurrences below Silurian and Devonian strata and by some radiometric ages (Meli, 1998). During the Early Ordovician this western area was characterized by pelitic sedimentation which was succeeded in the Middle (?) and Late Ordovician by bimodal volcanics, i.e. rhyodacites to rhyolites and mildly alkaline basalts, respectively. All volcanics were altered to metavolcanics and hence represent either porphyroids or diabase sills. This volcanic centre acted as a source area for the widespread volcanoclastic Fleons Formation (Text-fig. 2) which comprises a wide spectrum ranging from conglomerates in a proximal setting, and graywackes and various kinds of clastic rocks in a fan-delta setting. Even more basinward the pelitic Val Visdende Formation was deposited. East of the Plöcken Pass and the Valentin Valley, south of Kötschach-Mauthen, no indication of Ordovician volcanism exists. In this region the fossiliferous Uggwa Shale of Caradoc age is the dominant lithology which grades upward and also laterally into the Himmelberg Sandstone. Presumably at the beginning of the Ashgill both formations are succeeded by a limestone unit which comprises either cystoid and bryozoan bearing massive limestones in a

more shallow water environment or argillaceous flaser limestones in a more offshore and apparently deeper setting (Dullo, 1992). The former is named the Wolayer Limestone, the latter the Uggwa Limestone.

In the Carnic Alps the world-wide occurring glacioeustatic regression can also be traced in strata assigned to the Hirnantian Stage. This event resulted in the appearance of coarse-grained bioclastic limestones of the Plöcken Formation grading upward into impure sandstones which are characterized by graded bedding, reworking and channelling. On top of this regressive sequence a significant disconformity occurs locally suggesting stratigraphic gaps at the onset of the Silurian.

Based on the available litho- and biodata the Ordovician of the Carnic Alps reflects close relationships to Baltica and Avalonia, which occupied a moderate latitudinal position during this time. However, temporarily a cold water influx from Northern Africa can also be recognized which led to the conclusion that the Carnic Alps were located between 40° and 50° South during the Late Ordovician (Schönlaub, 1992, 1998). This assumption is strongly supported by paleomagnetic data.

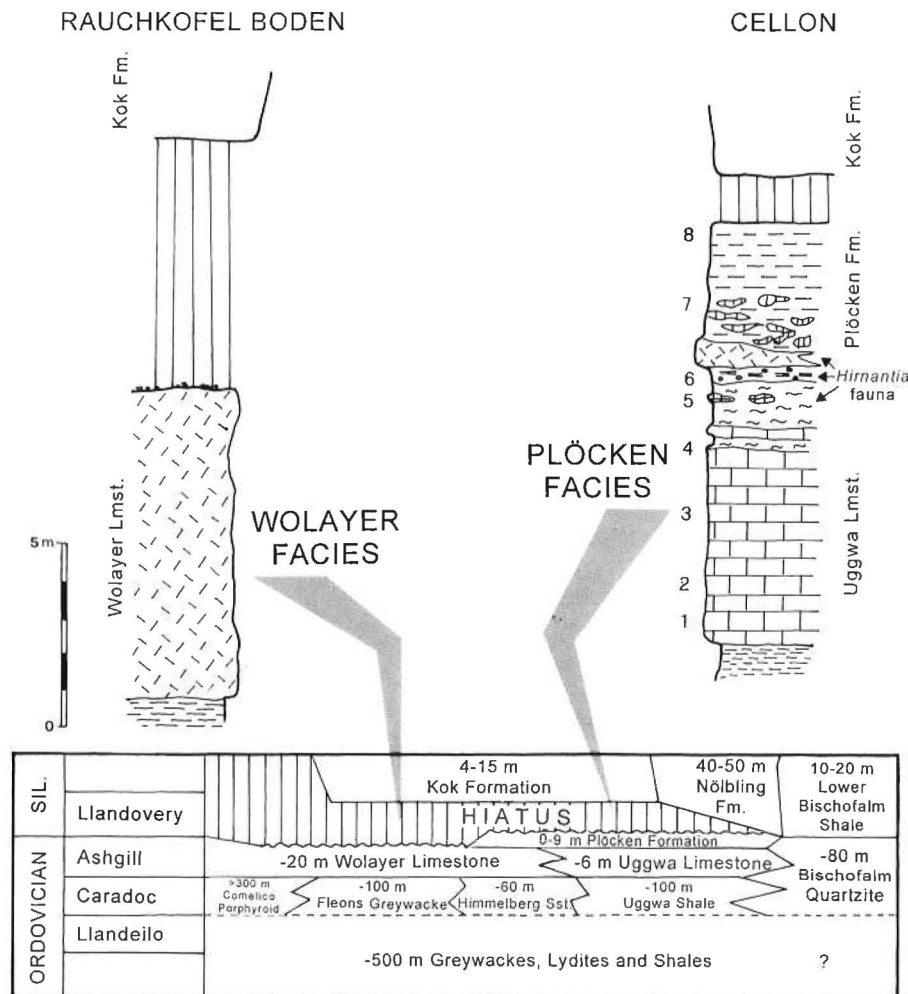
Lower Silurian rocks of the Austrian Carnic Alps were deposited in different environments ranging from highly energetic shallow water to basinal graptolitic settings. These different environments are represented

by four laterally intergrading facies which are named the Wolayer, Plöcken, Findenig and Bischofalm Facies for the Silurian to Early Devonian interval.

As previously indicated, the most prominent lithology of the Late Ordovician is represented by a fossiliferous calcareous horizon of early Ashgill age up to 20 m thick. This limestone is assigned to two lithofacies, i. e. the Wolayer and Plöcken Facies, respectively (Text-fig. 2). The former is characterized by the massive white-greyish Wolayer Limestone composed of parautochthonous bioclasts of cystoids and bryozoans. In the Rauchkofel Boden section (Text-fig. 3) this unit is 8.6 m thick and it is disconformably covered by Lower Silurian limestones of the *Pterospirifer* *amorphognatoides* Zone. In thin section, the limestone is a packstone almost entirely represented by echinoderm debris, associated with rare bryozoans and trilobites (Ferretti *et al.*, 1999). The Wolayer Limestone is also present, but with a reduced thickness, in the Seekopf Sockel section. Laterally, this facies grades into the bed-

ded wackestones of the Uggwa Limestone representing the latter and more basinal facies of minor thickness. At the Cellon section the scarcely fossiliferous Uggwa Shales are overlain by the 7.3 m thick greyish Uggwa Limestone (Text-fig. 4) which comprises indistinctly bedded argillaceous wackestones, the upper portion of which is interbedded with laminated greenish-greyish siltstones. In the latter, some 0.40 m below the base of the Plöcken Formation, a distinct accumulation of abundant representatives of the *Hirnantia* fauna occurs (Text-fig. 2) showing evidence of transportation and bioturbation along a distinct erosional surface (Jaeger *et al.*, 1975; Schönlaub, 1988).

Yet, the late Ashgill Hirnantian Stage has been recorded only from the Plöcken Facies but not from the Wolayer Facies. In the former it was recognized in marly intercalations and arenaceous bioclastic limestones of the Plöcken Formation which presumably corresponds to the *Glyptograptus? persculptus* graptolite Zone (Schönlaub, 1996). In most sections, however,



Text-fig. 2 - Stratigraphy of the Paleozoic sequence of the Carnic Alps limited to the Late Ordovician-earliest Silurian (modified after Schönlaub, 1985) and most representative stratigraphic sections of the Wolayer and Plöcken Facies (modified after Schönlaub, 1988, see there for details). Numbers 1-8 in the Cellon section are after Walliser (1964).



Text-fig. 3 - Outcrop photograph of the Ordovician/Silurian Boundary at the Rauchkofel Boden section. The Wolayer Limestone (light grey) is disconformably covered by the darker Kok Formation.

the Plöcken Formation is unfossiliferous as at Oberbuchach 1 (Text-fig. 1, loc. 4), while in others, the base of the Silurian rests directly upon the Wolayer Limestone reflecting thus a significant stratigraphic gap at the Ordovician/Silurian boundary. Such an example is best displayed at the Rauchkofel Boden section where both the latest Ordovician and/or the earliest Silurian is missing. Generally, the thickness of the Upper Ordovician Plöcken Formation varies between 0 and 9 m, the latter being exposed on the southern slope of Mount Rauchkofel (Schönlaub, 1988). At the Cellon section the 4.8 m thick Plöcken Formation (Text-fig. 5) is clearly separated from the underlying mud- and siltstones and consists of coarse grained and massive impure limestones which grade into calcareous sandstones above. In the lower part, contorted deformation structures, slumpings, channel fillings, loosely packed matrix-supported subangular clasts of varying composition (e.g. sandstone pebbles, carbonates, quartzites, granites) and accumulation of fossil debris are very common (Text-fig. 2). The latter in particular may be seen 0.40 m above bed no. 6 of Walliser's conodont sampling and some 0.30 m above his bed no. 7 suggesting reworking and transportation in a predominant highly energetic regressive sedimentary regime. At these levels the *Hirnantia* fauna occurs as poorly sorted and mostly disarticulated brachiopod valves. Although brachiopods are most common, the associated fauna comprises also trilobites, cystoids, ostracodes, spicules and conodonts. Besides the Cellon section, the *Hirnantia* fauna has as yet only been recorded from the Hoher Trieb and Uggwa sections in the Carnic Alps but may also occur at other localities such as the southern slope of Rauchkofel or Valbertad. The Cellon succession is disconformably covered by sediments of the *Pterospirifer celloni* Zone.

PREVIOUS CONODONT STUDIES

Late Ordovician conodonts from the Carnic Alps are mostly known thanks to the pioneer work of Serpagli (1967) from the Rifugio Nordio and M. Zermula localities, both exposed on the Italian side (Text-fig. 1). A rich and well-preserved conodont fauna was there described using the single-element taxonomy in use at that time and preliminarily revised in multi-element taxonomy by Sweet & Bergström (1984). New material from the nearby Valbertad section (Text-fig. 1) was recently reported by Bagnoli *et al.* (1998). On its own, the Austrian side is mostly associated with the Silurian successions there exposed, among all the famous Cellon section (Walliser, 1964) which still represents a classic reference of much of the Silurian conodont zone succession. Other important sections, including Upper Ordovician as well as Lower Silurian strata, are also present (Schönlaub, 1969, 1971a, b, 1979, 1980; Jaeger *et al.*, 1975; Jaeger & Schönlaub, 1977). The Ordovician conodont faunas have so far not been studied comprehensively as for example those from the Wolayer Limestone are more scarce than at Cellon and represent mostly poorly preserved material. They were dated mostly by comparison with Serpagli's material as no M elements of the Late Ordovician age-diagnostic *Amorphognathus* species have ever been recovered.



Text-fig. 4 - Outcrop photograph of the Uggwa Limestone exposed at Cellon (level no. 1 of Walliser, 1964).



Text-fig. 5 - Outcrop photograph of the Plöcken Formation exposed at Cellon. The Silurian starts immediately above the path. The arrow indicates the reference point no. 6 of Walliser's conodont based collection.

Walliser (1964) reported what he defined as the "Bereich I" from levels 1 to 8 of the Cellon section ("Untere Schichten") which was regarded as Early Silurian in age (von Gaertner, 1931). The fauna was revised by Schönlaub (1971a). Manara & Vai (1970) and Flajs & Schönlaub (1976) described conodont faunas, still using the morphospecies concept, respectively from the southern slope of M. Rauchkofel and from the Northern Graywacke Zone of Styria (Central Austria). The latter fauna, dominated by *Hamarodus europaeus*, *Scabbardella altipes* and *Amorphognathus* sp., was correctly attributed to the *A. ordovicicus* Zone but no "holodontiform" elements, critical for species differentiation inside the genus, were found.

Vai & Spalletta (1980, p. 50) reported in the Italian Uggwa section, corresponding to the Rifugio Nordio section of Serpagli (1967), conodont faunas from limestone pebbles or blocks at the top of a sandstone formation bearing brachiopods of the *Hirnantia* fauna (including *Kinnella* cf. *kielanae* and *Dalmanella*). In spite of the dominance of Ordovician morphotypes, they attributed a Llandovery age to the exotic blocks owing to the presence of *Icriodella* and *Synprioniodina*.

HIRNANTIAN CONODONT FAUNAS ELSEWHERE

Early Ashgill conodont faunas from the Atlantic Faunal Region (*sensu* Bergström, 1990) appear well established in general composition. On the contrary the Hirnantian associations are much less defined. This may be explained by the limited number of available outcrops and lithologies mostly unsuitable for conodont extraction. Small and age-undiagnostic

collections, whose identification was mainly possible only at a generic level, were reported by Barnes & Williams (1988) from the systemic boundary stratotype of Dob's Linn in Scotland. Many attempts have been made to obtain conodonts from North Wales, a historical area for Hirnantian research, but with no success (e.g. Orchard, 1980). Poor faunas were reported from the North of England (Aldridge, 1975; Orchard, 1980; Bergström & Orchard, 1985). No diagnostic species are however present in these faunas, which are nevertheless clearly of Ordovician aspect as the constituent species are unknown in the Silurian. Even in Scandinavia, the Hirnantian rocks are very poor in conodonts (Barnes & Bergström, 1988).

As a result, the general knowledge of Hirnantian conodont associations from the Atlantic Faunal Region has so far been limited to sporadic occurrences of sparse faunas, from which it has been impossible to draw general outlines.

More significant data come from the Midcontinent Faunal Region (*sensu* Bergström, 1990), where important sections spanning the Ordovician/Silurian boundary are known. Owing to the strong Late Ordovician provincialism, a conodont biozonation different from that in use in the Atlantic Faunal Region was here adopted and the Richmondian and Gamachian North American Stages were introduced. The latter includes a Hirnantian equivalent and possibly also the uppermost part of the Rawtheyan (Fortey *et al.*, 1995). Informal units indicated respectively as Fauna 12 and Fauna 13 roughly correspond to the *A. ordovicicus* Zone and to the Ashgill standard British Series (Barnes & Bergström, 1988).

The continuous record across the systemic boundary has made Anticosti Island a classic area for conodont studies (Nowlan & Barnes, 1981; McCracken & Barnes, 1981; McCracken & Nowlan, 1988; Barnes, 1988). The abundant Richmondian faunas are dominated by elements of *Panderodus* (up to 50%), *Drepanoistodus* (up to 15%), *Oulodus* (12%), *Phragmodus* (9%) and *Amorphognathus* (4.5%) (Nowlan *et al.*, 1997).

Gamachian faunas of the Ellis Bay Formation record a change in composition and abundance, with collections composed of about 40 species but with elements of *Panderodus* and *Gamachignathus* representing up to 90% of the fauna (Nowlan *et al.*, 1997). The latter genus, restricted to the latest Ordovician, is most common in the Gamachian and is regarded as deriving from stocks of colder regimes of the Atlantic Faunal Region, being similar to the genera *Sagittodontina* of the Mediterranean Province and *Birksfeldia* of the British Province (Nowlan *et al.*, 1997). Its widespread diffusion in the Gamachian might indicate an oceanic cooling event reaching the Midcontinent Faunal Region (McCracken & Nowlan, 1988).

Plectodina is not present in the top middle part of the Richmondian Vauréal Formation (McCracken, 1987) and completely disappears in the Ellis Bay Formation corresponding to Fauna 13 (Barnes, 1988; Barnes & Bergström, 1988, fig. 5). It is uncertain if this absence might be diagnostic of Fauna 13 (McCracken & Nowlan, 1988). In addition, elements of *Amorphognathus* are missing in the uppermost *Gamachignathus ensifer* Zone (McCracken, 1987).

CONODONT FAUNAS

From the four localities investigated in the Central Carnic Alps (Rauchkofel Boden, Cellon, Seekopf Sockel and Oberbuchach 1; Text-fig. 1), nine samples for a total of about 30 kg of limestone were digested in formic or acetic acid. All of the samples have yielded conodont elements. A more detailed sampling in the light of the latest data, involving also other Upper Ordovician sections, is in progress. Illustrated specimens are stored in the Paleontological Section of the Earth Sciences Department of the University of Modena and Reggio Emilia under repository numbers IPUM 27544-27589.

WOLAYER AND UGGWA LIMESTONES

Topmost layers of the Wolayer Limestone, just below the contact with the Silurian, were collected from the Rauchkofel Boden and Seekopf sections. All samples were processed with formic acid. The conodont fauna appears better preserved in the latter section, where it is associated with abundant ostracodes in the light fraction. Elements from the

Rauchkofel Boden section are often deformed. CAI values from both collections, ranging from 5 to 6, indicate thermal maturation in the range of 300°–550° C (Epstein *et al.*, 1977; Rejebian *et al.*, 1987).

The Uggwa Limestone was sampled from the Cellon section in correspondence to level no. 4 of Walliser (1964). The material was processed with acetic acid and provided a large and extremely fossiliferous heavy residue. The majority of specimens shows mineral overgrowth; CAI values range from 5 to 6 (Epstein *et al.*, 1977; Rejebian *et al.*, 1987). Again many ostracodes are present in the light fraction.

No significant difference in composition appears to exist between the two conodont faunas from the Uggwa and Wolayer limestones (Tab. 1). Species which were found only from one of the two formations are present with elements so rare that their absence may simply reflect lack of recovery.

The following species have been recognized:

Amorphognathus ordovicicus Branson & Mehl, 1933

Amorphognathus lindstroemi (Serpagli, 1967)

Amorphognathus sp. A

Ansella pseudorobusta (Serpagli, 1967)

Cornuodus longibasis (Lindström, 1955)

Dapsilodus mutatus (Branson & Mehl, 1933)

Decoriconus minutus (Serpagli, 1967)

Hamarodus europaeus (Serpagli, 1967)

Panderodus gracilis (Branson & Mehl, 1933)

Plectodina alpina (Serpagli, 1967)

Scabbardella altipes (Henningsmoen, 1948)

Walliserodus amplissimus (Serpagli, 1967)

Icriodella sp.

Pseudooneotodus sp.

"carniodiform" elements *sensu* Ferretti & Barnes, 1997.

It is evident from data presented in this report that these conodont faunas are strikingly similar in composition and age to the material documented from the Northern Italian localities, namely the "Tonflaserkalk" or Uqua Formation (Serpagli & Greco, 1965; Serpagli, 1967; Vai, 1971; Vai & Spalletta, 1980; Bagnoli *et al.*, 1998). All species here recognized, with the sole exception of *Amorphognathus* sp. A, are in fact already present in Serpagli's collection (Tab. 1). As regards some of the missing ones in our fauna (e.g. *Nordiodus italicus*), we do not exclude that they might be found in the near future. Furthermore, the recent material provided by the Valbertad section (Bagnoli *et al.*, 1998) and dominated by small individuals such as *Nordiodus italicus* and "*Acodus trigonius*" s.f., might also indicate that some sorting could have occurred.

In spite of this, our collection documents unequivocally for the first time the *A. ordovicicus* Zone in Austria with the recovery of the marker (Pl. 1, fig. 8) from both formations, together with platform and ramiform elements identified as *Amorphognathus* sp. (*ordovicicus-lindstroemi* Group).

In addition, M elements of *A. lindstroemi* and *A. sp. A*, the latter having a denticle anterior to the cusp (Pl. 1, fig. 9), are also present. *Hamarodus europaeus* and *Scabbardella altipes* are well-represented, the former being expressed by abundant M elements while P elements are on the contrary rare. *Walliserodus amplissimus* becomes dominant in the uppermost horizons.

Conodonts recovered from these limestones belong to the HDS (*Hamarodus europaeus*-*Dapsilodus mutatus*-*Scabbardella altipes*) biofacies of Sweet & Bergström (1984). This evidence stresses once more stronger links of the Carnic Alps with Sardinia compared to other Southern European areas (i.e. Sierra Morena and Iberian Chains in Spain and Thuringia in Germany), considered to have been parts of North Gondwana (Ferretti & Serpagli, 1999). Furthermore, deeper affinities with lower latitude areas (i.e. Avalonia and Baltica) sharing the same conodont biofacies are indicated even by this paper. Other faunas, i.e. brachiopods (Havlíček, 1976; Havlíček *et al.*, 1987) and ostracodes (Schall-

reuter, 1990), had already suggested the connection with warm water faunas of lower latitudes in the Late Ordovician, with just a few exceptions (e.g. the *Hirnantia* fauna) indicating temporary minor cold water influences from southern high latitudes (Schönlaub, 1992). According to faunistic, lithologic and paleomagnetic data, a 40°-50° South latitude position was proposed by Schönlaub (1992), still under the influence of a warm water circuit reaching the outer regions of Northern Gondwana (Schönlaub, 1992; Ferretti *et al.*, 2000). This model has been recently confirmed by the recovery of the warm alga *Cyclocrinites* in the Caradoc of Southwestern Sardinia (Serpagli & Hammann, 2000; Hammann & Serpagli, in press).

PLÖCKEN FORMATION

Shaley mud intercalations of the uppermost Uggwa Limestone grade, in the Cellon section, to the arenaceous and bioclastic limestones of the Plöcken

LATE ORDOVICIAN CONODONTS FROM THE CARNIC ALPS					
CONODONT TAXA	ITALIAN SIDE		AUSTRIAN SIDE		
	Serpagli (1967)	Bagnoli <i>et al.</i> (1998)	THIS PAPER		
			Wolayer Lmst.	Uggwa Lmst.	Plöcken Fm.
<i>Amorphognathus ordovicicus</i>	X	X	X	X	cf.
<i>Amorphognathus lindstroemi</i>	X	X		X	X
<i>Amorphognathus sp. A</i>				X	
<i>Ansella pseudorobusta</i>	X	X		X	X
<i>Cornuodus longibasis</i>	X	X	X	X	
<i>Dapsilodus mutatus</i>	X	X	X	X	X
<i>Decoriconus minutus</i>	X	X	X		X
<i>Dichodella exilis</i>	X	X			cf.
<i>Drepanoistodus suberectus</i>	X	X			?
<i>Hamarodus europaeus</i>	X	X	X	X	X
<i>Icriodella cf. I. prominens</i>					X
<i>Istorinus erectus</i>					X
<i>Nordiodus italicus</i>	X	X			X
<i>Panderodus gracilis</i>	X	X	X	X	X
<i>Plectodina alpina</i>	X	X	X		
<i>Protopanderodus liripipus</i>	X	X			
<i>Pseudooneotodus mitratus</i>					X
<i>Scabbardella altipes</i>	X	X	X	X	X
<i>Strachanognathus parvus</i>	X				
<i>Walliserodus amplissimus</i>	X	X	X		
<i>Icriodella sp.</i>		X	X		
<i>Protopanderodus sp.</i>					X
<i>Pseudooneotodus sp.</i>	X	X	X	X	X
<i>Sagittodontina sp.</i>					X
<i>Walliserodus sp.</i>					X
<i>Cornuodus? sp.</i>					X
<i>Dapsilodus? sp.</i>					X

Tab. 1 - Multi-element conodonts from the Late Ordovician of the Carnic Alps. Form-elements reported by Walliser (Bereich I, 1964), Manara & Vai (1970), Schönlaub (1971a), Flajs & Schönlaub (1976) will be considered after revision.

Formation which represents a regressive sedimentary facies. It corresponds to the "Untere Schichten" of old authors. Important levels with *Hirnantia* Fauna (Text-fig. 2) were reported at the top of the Uggwa Limestone, immediately before the beginning of the Plöcken Unit, and within the lower part of the latter formation (Schönlaub, 1971a; Jaeger *et al.*, 1975; Schönlaub, 1980).

Three different horizons (6, 7 base and 7 top of Walliser's reference conodont numbers of 1964) were sampled and processed respectively with acetic (level 6) and formic acid (base and top of level 7). Exhaustive picking produced collections, in places abundant, composed of small and often fragmentary faunal elements. Remarkable is the poor preservation of the elements at the base of the formation, with encrusted elements associated with a lot of pyrite and pyritized organisms (mostly gastropods). A slightly better preservation occurs especially in the middle sampled layer. CAI value 5 indicates heating temperatures of about 300° C (Epstein *et al.*, 1977).

Small bivalves, brachiopods, ostracodes and sponge spiculae were also obtained from the acid insoluble residue.

The constituent species of this conodont collection are:

Amorphognathus cf. *A. ordovicianus* Branson & Mehl, 1933
Amorphognathus lindstroemi (Serpagli, 1967)
Ansellia pseudorobusta (Serpagli, 1967)

Dapsilodus mutatus (Branson & Mehl, 1933)
Decoriconus minutus (Serpagli, 1967)
Dichodella cf. *D. exilis* Serpagli, 1967
Drepanoistodus? suberectus (Branson & Mehl, 1933)
Hamarodus europaeus (Serpagli, 1967)
Icriodella cf. *I. prominens* Orchard, 1980
Istorinus erectus Knüpfner, 1967
Nordiodus italicus Serpagli, 1967
Panderodus gracilis (Branson & Mehl, 1933)
Pseudooneotodus mitratus (Moskalenko, 1973)
Scabbardella altipes (Henningsmoen, 1948)
Protopanderodus sp.
Pseudooneotodus sp.
Sagittodontina sp.
Walliserodus sp.
Cornuodus? sp.
Dapsilodus? sp.
 "carniodiform" elements *sensu* Ferretti & Barnes, 1997.

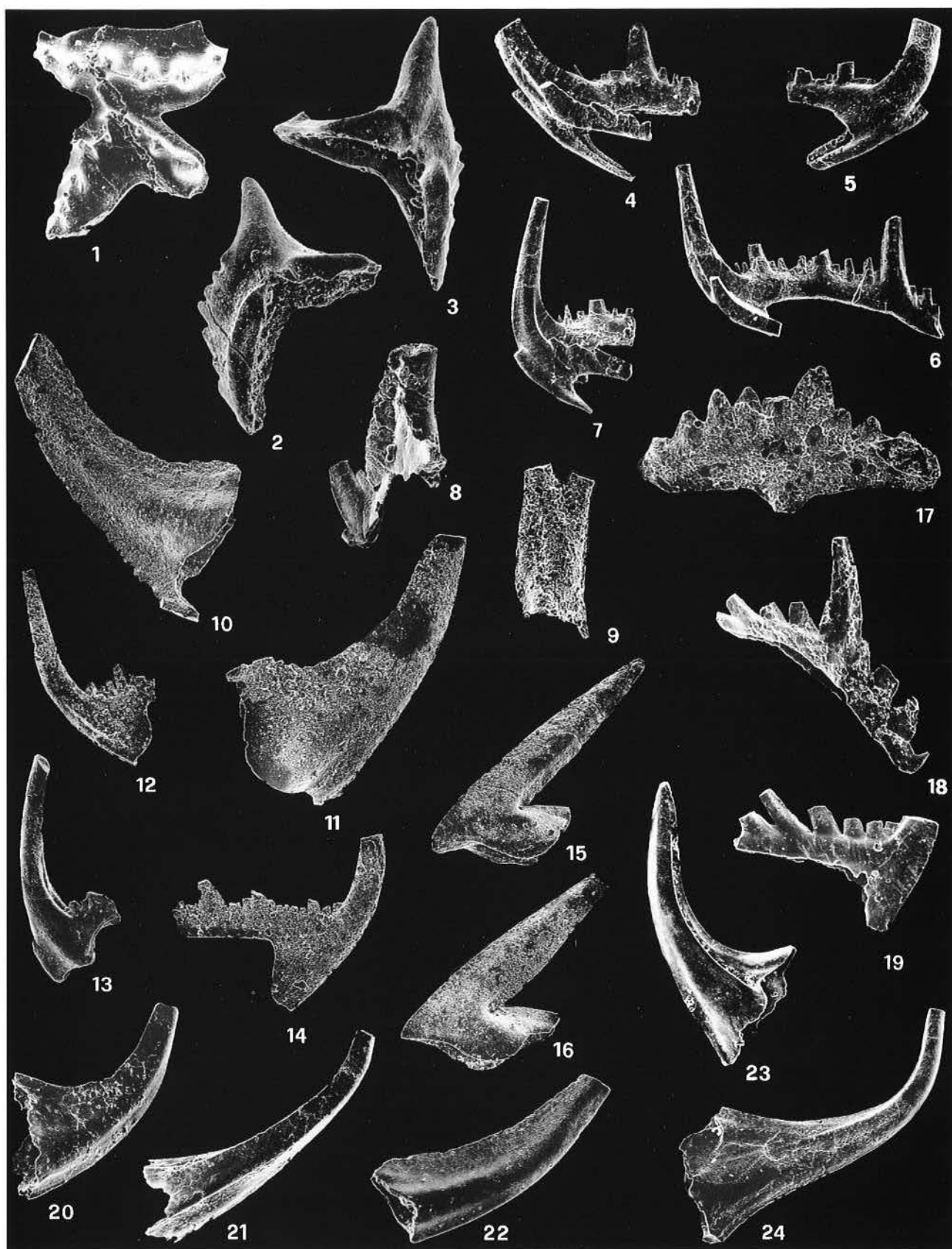
M elements of *A. cf. ordovicianus* (Pl. 2, fig. 6) as well as of *A. lindstroemi* (Pl. 2, fig. 7) occur in this fauna. The genus *Amorphognathus* is represented by a large number of "ambalodiform" Pb elements and fragments of platform Pa elements, while other elements of the apparatus are rare. A similar and unexplained marked underrepresentation of ramiform elements in the same genus was reported by Nowlan (1983) in the Upper Ordovician Grog Brook Group of NW New Brunswick.

Compared to conodont faunas from older horizons

EXPLANATION OF PLATE 1

Scanning electron micrographs of selected conodonts recovered from the Late Ordovician of the Central Carnic Alps, Austria.

- Figs 1-7 - *Amorphognathus* sp. (*ordovicianus-lindstroemi* Group).
 1) upper view of Pa element, IPUM 27544, sample Rauchkofel Boden 309 top, Wolayer Limestone, x 90;
 2, 3) lateral views of Pb elements, IPUM 27545 and IPUM 27546, sample Cellon 7 base, Plöcken Formation, x 105 and x 110 respectively;
 4) lateral view of Sb element, IPUM 27547, sample Rauchkofel Boden 309 top, Wolayer Limestone, x 120;
 5) lateral view of Sc element, IPUM 27548, sample Rauchkofel Boden 309 top, Wolayer Limestone, x 120;
 6) lateral view of Sa element, IPUM 27549, sample Rauchkofel Boden 309 top, Wolayer Limestone, x 120;
 7) lateral view of Sd element, IPUM 27550, sample Rauchkofel Boden 309 top, Wolayer Limestone, x 100.
- Fig. 8 - *A. ordovicianus* Branson & Mehl, 1933. Posterior view of M element, IPUM 27551, sample Rauchkofel Boden 309, Wolayer Limestone, x 125.
- Fig. 9 - *Amorphognathus* sp. A. Posterior view of M element, IPUM 27552, sample Cellon 4, Uggwa Limestone, x 110.
- Figs 10-16 - *Hamarodus europaeus* (Serpagli, 1967).
 10) lateral view of Pa element, IPUM 27553, sample Cellon 4, Uggwa Limestone, x 70;
 11) lateral view of Pb element, IPUM 27554, sample Cellon 4, Uggwa Limestone, x 70;
 12) lateral view of Sa element, IPUM 27555, sample Cellon 4, Uggwa Limestone, x 95;
 13, 14) lateral views of Sc elements, IPUM 27556 and IPUM 27557, sample Rauchkofel Boden 309 top (Wolayer Limestone) and Cellon 4 (Uggwa Limestone), x 70 and x 95 respectively;
 15, 16) lateral views of M elements, IPUM 27558 and IPUM 27559, sample Cellon 4, Uggwa Limestone, x 60 both.
- Figs 17-19 - *Plectodina alpina* (Serpagli, 1967). All from sample Rauchkofel Boden 309 top, Wolayer Limestone.
 17) Outer-lateral view of Pa element, IPUM 27560, x 105;
 18) Inner-lateral view of Pb element, IPUM 27561, x 110;
 19) Inner-lateral view of Sc element, IPUM 27562, x 110.
- Figs 20-21 - *Walliserodus amplissimus* (Serpagli, 1967). Lateral views, IPUM 27563 and IPUM 27564, samples Rauchkofel Boden 309 top and Seekopf O/S, Wolayer Limestone, x 105 both.
- Fig. 22 - *Walliserodus* sp. Lateral view, IPUM 27565, sample Cellon 7 base, Plöcken Formation, x 80.
- Figs 23-24 - *Scabbardella altipes* (Henningsmoen, 1948). Lateral views, IPUM 27566 and IPUM 27567, samples Cellon 7 base (Plöcken Formation) and Rauchkofel Boden 309 top (Wolayer Limestone), x 60 and x 80 respectively.



described herein and by previous authors, it is interesting to note the first appearance in this level of *Sagittodontina* and *Istorinus*, genera typical of the Mediterranean Province and regarded as indicators of polar to subpolar regions of higher latitudes. They occur in the Plöcken Formation with just a few elements and not certainly with the richness of *Gamachignathus* in the Midcontinent, which had been interpreted as an evidence of oceanic cooling (McCracken & Nowlan, 1988). Worthy of note is also the absence of the genus *Plectodina* which, as discussed above, might possibly be indicative of the Gamachian Fauna 13 compared to Richmondian Fauna 12 (McCracken & Barnes, 1981). This genus is widely present in Serpagli's material (1967) and in the recently described Valbertad collection (Bagnoli *et al.*, 1998), while it is present in our material only in the Wolayer Limestone. *Hamarodus europaeus* is still present in this younger limestone but with a minor abundance. Other common taxa are *Pseudooneotodus mitratus*, *Icriodella* cf. *I. prominens* and *Protopanderodus* sp. *Dichodella* cf. *D. exilis* is also well represented in the Plöcken Formation. Bagnoli *et al.* (1998) have recently suggested, on the basis of new material from the Italian Carnic Alps, that the genus *Birksfeldia* Orchard, 1980 might be a junior synonymous with the genus *Dichodella* Serpagli, 1967. Furthermore, *Gamachignathus* has an apparatus structure which is very similar and might represent another synonymous form. The fragmentary nature of the material from

our collections prevents a more complete assignment so far.

Barnes & Bergström (1988) explained the marked difference existing between Early Silurian and Late Ordovician conodont faunas, suggesting a replacement of Ordovician taxa by forms of Silurian aspect possibly in the latest Ashgill. Conodont faunas of mixed aspect, i.e., composed of both Ordovician and Silurian taxa, were reported on Anticosti Island (McCracken & Barnes, 1981), Northwest Territories (Melchin *et al.*, 1991), possibly the Great Basin (Leatham, 1985) and Greenland (Armstrong, 1995). In particular, the work of Melchin *et al.* (1991) was able to correlate conodont data with graptolite biozones and later McCracken (in Norford *et al.*, 1997) related this mixed fauna to a "hassi" interval at the topmost *persculptus* Zone, immediately below the Ordovician/Silurian boundary. In general, the fauna from the Plöcken Formation investigated so far in the Central Carnic Alps, is dominated by elements which are unknown in the Silurian, and therefore still has a clear Ordovician aspect.

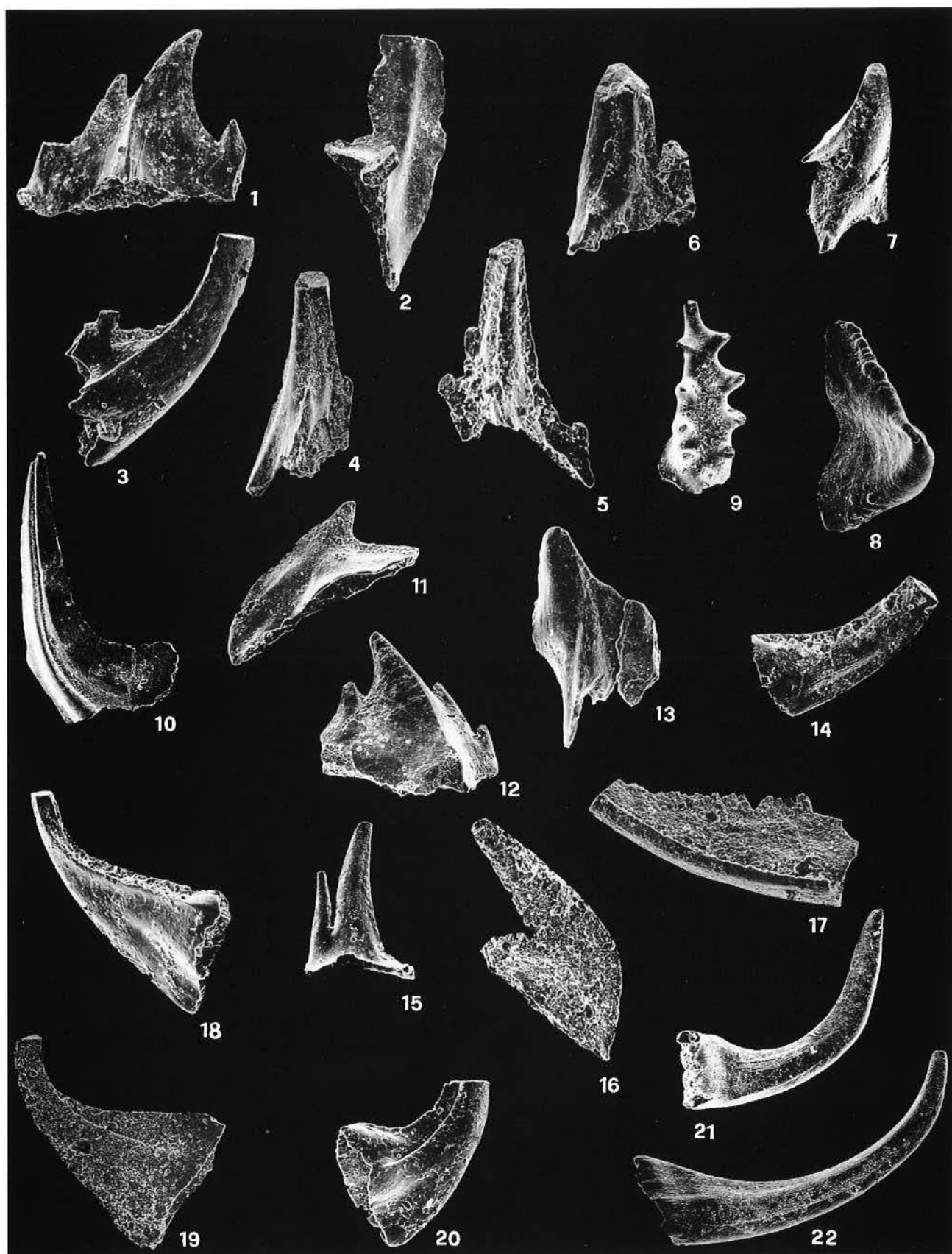
OBERBUCHACH 1

Two of the topmost calcareous intercalations inside the equivalent of the Plöcken Formation in the Oberbuchach 1 section (indicated as basal quartzite; Schönlaub, 1994) were sampled. They were processed with acetic acid and provided a poorly preserved conodont association with representatives of:

EXPLANATION OF PLATE 2

Scanning electron micrographs of selected conodonts recovered from the Late Ordovician of the Central Carnic Alps, Austria.

- Figs 1-5 - *Dichodella* cf. *D. exilis* Serpagli, 1967.
 1) Outer-lateral view of Pa element, IPUM 27568, sample Cellon 7 top, Plöcken Formation, x 105;
 2) Inner-lateral view of M element, IPUM 27569, sample Cellon 7 base, Plöcken Formation, x 90;
 3) Outer-lateral view of Sb element, IPUM 27570, sample Cellon 7 base, Plöcken Formation, x 120;
 4, 5) posterior views of Sa elements, IPUM 27571 and IPUM 27572, samples Cellon 7 base and Cellon 7 top, Plöcken Formation, x 85 and x 135 respectively.
- Fig. 6 - *A. cf. A. ordovicicus* Branson & Mehl, 1933. Postero-lateral view of M element, IPUM 27573, sample Cellon 7 base, Plöcken Formation, x 145.
- Fig. 7 - *A. lindstroemi* (Serpagli, 1967). Postero-lateral view of M element, IPUM 27574, sample Cellon 7 top, Plöcken Formation, x 140.
- Fig. 8 - *Pseudooneotodus mitratus* (Moskalenko, 1973). Upper view, IPUM 27575, sample Cellon 7 base, Plöcken Formation, x 100.
- Fig. 9 - *Icriodella* cf. *I. prominens* Orchard, 1980. Upper view of Pa element, IPUM 27576, sample Cellon 7 base, Plöcken Formation, x 85.
- Fig. 10 - *Protopanderodus* sp. Lateral view, IPUM 27577, sample Cellon 7 base, Plöcken Formation, x 50.
- Fig. 11 - *Nordiodus italicus* Serpagli, 1967. Lateral view, IPUM 27578, sample Cellon 7 top, Plöcken Formation, x 130.
- Figs 12-13 - *Sagittodontina* sp. Lateral views of Pa elements, IPUM 27579 and IPUM 27580, sample Cellon 7 base, Plöcken Formation, x 70 and x 120 respectively.
- Fig. 14 - *Decoriconus minutus* (Serpagli, 1967). Lateral view, IPUM 27581, sample Cellon 7 top, Plöcken Formation, x 140.
- Fig. 15 - *Istorinus erectus* Knüpfer, 1967. Lateral view, IPUM 27582, sample Cellon 7 base, Plöcken Formation, x 130.
- Figs 16-17 - *Ansella pseudorobusta* (Serpagli, 1967).
 16) lateral view of M element, IPUM 27583, sample Cellon 4, Uggwa Limestone, x 120;
 17) lateral view of Sa element, IPUM 27584, sample Cellon 7 top, Plöcken Formation, x 140.
- Fig. 18 - *Dapsilodus?* sp. Postero-lateral view, IPUM 27585, sample Cellon 7 base, Plöcken Formation, x 120.
- Figs 19-20 - *Dapsilodus mutatus* (Branson & Mehl, 1933). Lateral views, IPUM 27586 and IPUM 27587, samples Cellon 4 (Uggwa Limestone) and Raichkofel Boden 309 (Wolayer Limestone), x 105 and x 120 respectively.
- Figs 21-22 - *Panderodus gracilis* (Branson & Mehl, 1933). Lateral views, IPUM 27588 and IPUM 27589, sample Cellon 7 base, Plöcken Formation, x 80 both.



Amorphognathus sp.
?Walliserodus sp.
 "acodiform" elements
 "carniodiform" elements *sensu* Ferretti & Barnes, 1997.

CONCLUSIONS

The final attribution to the *A. ordovicicus* Zone has not only documented the stratigraphic equivalence of the Wolayer and Ugghwa limestones by conodonts, but it has also definitively connected the Austrian calcareous episode with the corresponding "Tonflaserkalk" of Northern Italy. The paleogeographic picture locating the Carnic Alps at lower latitudes compared to other areas of North Gondwana, already many times defined with litho-, faunistic and paleomagnetic data, is once more supported by conodont data.

The preliminary report of a Hirnantian conodont fauna gives some indications on the faunal composition of the latest Ashgill conodont association from the Atlantic Faunal Region, which appears to maintain a definite Ordovician aspect.

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