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ORDOVICIAN OF THE WORLD






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Editors: Juan Carlos Gutiérrez-Marco
Isabel Rábano
Diego García-Bellido

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Cover images (photos by J.C. Gutiérrez-Marco except lower middle –L. Carcavilla– and lower right –N. Sennikov–)

Upper left: outcrops of the Late Ordovician glaciomarine Melaz Shuqran Fm, overlying Cambrian sandstones (Tihemboka Arch, Sahara desert, SW Libya).

Upper right: giant traces (> 11 m long) of marine worms in Early Ordovician quartzites from the Cabañeros National Park (central Spain), which serve as logo for the symposium.

Middle left: outcrops of the Late Ordovician Calapuja Fm (foreground mountains) in the Peruvian Altiplano, more than 4,500 m high.

Middle right: Global Stratotype Section at Point for the base of the Middle Ordovician series and of Dapingian stage, Huanghuachang section, Hubei province (South China).

Lower left: Early Ordovician shales (San José Formation) at the Inambari river, Amazonian basin (Eastern Peru).

Lower middle: A view of the Mount Everest (Tibet), whose summit (8,848 m) is formed by the Early-Middle Ordovician limestones of the Qomolangma Fm.

Lower right: Middle Ordovician dolomitic marls and mudstones of the Middle Guragir Fm at the key Kulyumbe river section (northwestern part of the Siberian Platform, Russia).

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THE LATE ORDOVICIAN GLACIAL EVENT IN THE CARNIC ALPS (AUSTRIA)

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INTRODUCTION

The Carnic Alps of Southern Austria and Northern Italy (Fig. 1) represent one of the very few places in the world where an almost continuous biostratigraphically well-constrained succession of Lower Paleozoic rocks is preserved and is as such a key locality along the Northern Gondwana Margin regarding Lower Paleozoic correlation. For example, the world-famous Cellon Section has been utilized as a geographic reference district (RD) for both Silurian conodont correlation studies (Kleffner, 1995) and for the evaluation of Silurian global eustatic changes (Brett et al., 2009; Johnson, 2010) for the North Gondwana region and across the peri-Gondwana Terranes.

However, studies on the Ordovician succession in the Carnic Alps date from the early 1960s to the 1980s and need revision in light of recent research trends (e.g. Bergström et al., 2009; Cramer et al., 2010; Finnegan et al., 2011) to define relationships between the new global series and stages on a regional basis for improving global correlation. The data from current research projects on the Late Ordovician - early Silurian interval of this middle latitude temperate sector are summarised here with regard to identification of global signals in the Carnic Alps.

Figure 1. Main regions of anchizonal to lower greenschist metamorphosed fossiliferous Paleozoic strata in the Eastern Alps. Note the Periadriatic Line separating the Carnic Alps and the Karavanke Mountains (Southern Alps) from other Alpine Paleozoic remnants belonging to the Eastern Alps. Enlarged map shows the localities referred to in the text.

LITHOSTRATIGRAPHY

Due to tectonic deformation disparate facies are juxtaposed in close proximity with a series of distinctive paleogeographic/paleoenvironmental settings being represented in each of the different nappes or thrust sheets of the Carnic Alps.

The Middle to Upper Ordovician series of the Central and Western Carnic Alps are divided into a tripartite sequence of rocks with various clastics to volcanoclastics at the base, overlain by a limestone dominated succession with a few meters of sandstones at the top (Fig. 2). Fossils occur in all three levels although the equivalents of the Darriwilian and Sandbian stages have not yet been recognized. In particular, this applies to the fossiliferous Uggwa Shale in the Central and Eastern Carnic Alps from which a rich brachiopod fauna has been collected in recent years. Mapping in the Western Carnic Alps clearly indicates that the lateral equivalents of this formation are the Himmelberg Sandstone, Fleons Graywacke and Comelico Porphyry. In the Central Carnic Alps, apparently coeval sections at the base of Mount Cellon, Nölblinggraben, Rauchkofel South, Rauchkofel Boden, Oberbuchach, Hoher Trieb and Valbertad are well known; however, most have only been studied to a minor degree. Complementary sections occur in the Uggwa Valley of the Eastern Carnic Alps and at Feistritzgraben in the Western Carnic Alps.

Two major facies associations are displayed in the Late Ordovician of the Central Carnic Alps: massive cystoid-rich limestones (Wolayer Limestone Formation), quartz arenites and graywackes representing the shallow-water environments and shales and bedded wackestones representing more basinal settings (Uggwa Limestone Formation). In deeper water settings the Hirnantian Plöcken Formation, belonging to the *Normalograptus persculptus* graptolite Zone, succeeds the latter. Periglacial deposits which clearly reflect the diamictite nature of part of the Plöcken Fm. thus provide unequivocal evidence of the Hirnantian glaciation in this region. The Bischofalm Quartzite succession represents the lateral equivalent of the above formations. The data presented here focuses on the former three of the sections being studied and a brief overview of the lithological successions for each area is given below.

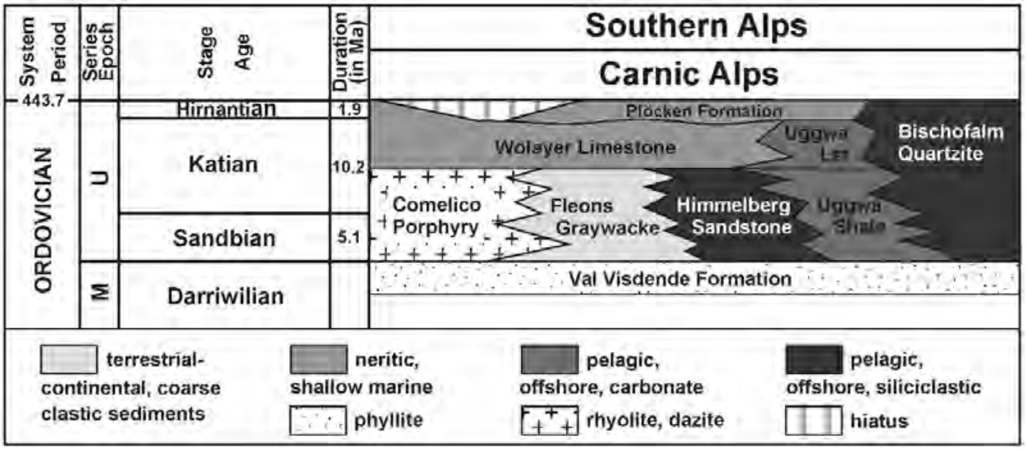

Figure 2. Middle to Upper Ordovician stratigraphy of the Carnic Alps.

Cellon Section

The section is exposed in the Cellon avalanche gully near Plöcken Pass at an altitude of 1500 m, approximately 1 km from the Austrian–Italian border. The succession forms part of the Cellon Nappe and is dominated by shales, siltstones and bedded wackestones representing a more basinal setting (Fig. 3). Sampling (see below) for brachiopods, graptolites, conodonts as well as chemostratigraphy and chronostratigraphy is in progress.

Uggwa Shale. At the base of the Cellon Section the Uggwa Shale attains a thickness of at least 100 m. The greenish to grayish shales mainly comprise claystones to siltstones which grade into the overlying marlstones and argillaceous limestones attributed to the Uggwa Limestone.

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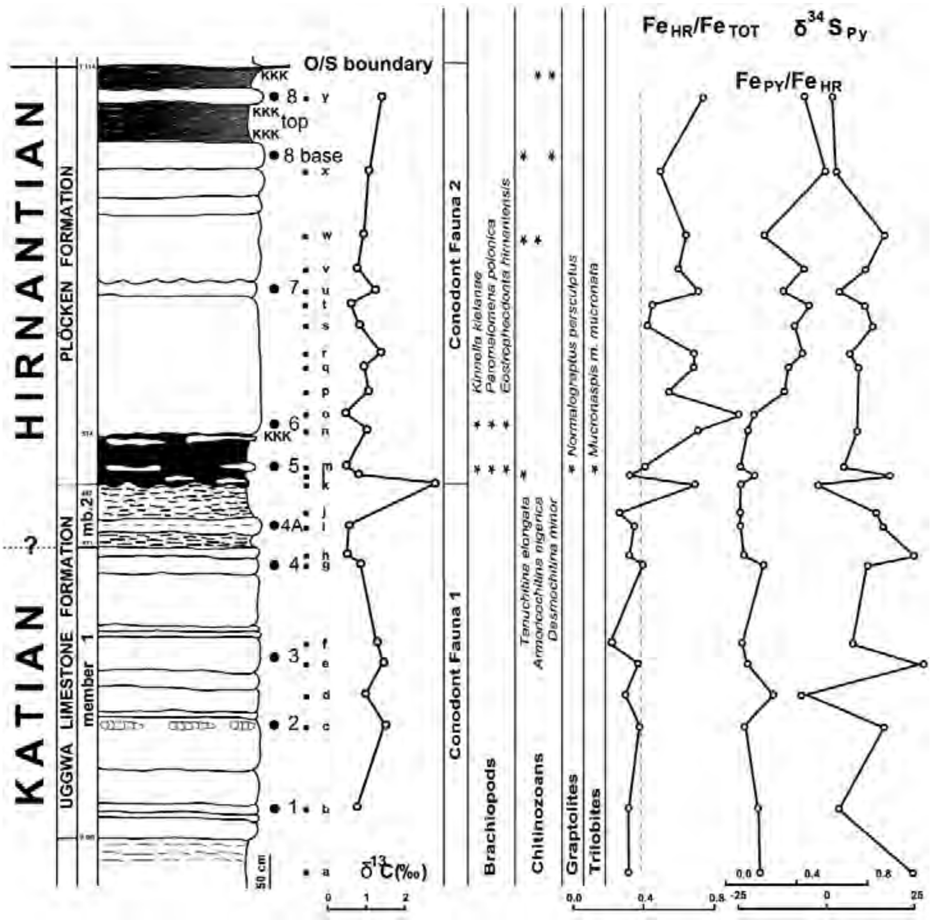

Figure 3. Late Ordovician interval of the Cellon Section. Lithostratigraphic column based on new field measurements by HPS and AF, bed numbers mainly after Walliser (1964). Vertical trends in key geochemical parameters (Iron, sulphur and carbon isotopes) across the Hirnantian glacial event are illustrated; letters a-y indicate sampling points. Letters KKK indicate position of K-bentonite levels sampled for radiometric dating. New and revised biostratigraphical data indicate the standard *Normalograptus persculptus* Graptolite Zone, the *Amorphognathus ordovicicus* Conodont Zone, the *Tanuchitina elongata* Chitinozoan Zone and the diagnostic *Hirnantia* brachiopod fauna. Trilobite faunas are also indicative of this interval.

Uggwa Limestone. The bedded continuous wackestone known as the Uggwa Limestone. has a thickness of 4.11 m (Bed nos. 1 – 4: after Walliser, 1964). It is overlain by 20 cm of greenish siltstones and 25 cm of argillaceous lime- to marlstones (Bed 4A). This more compact bed is succeeded by 40 cm of unfossiliferous greenish siltstones. In our view the whole package represents the Uggwa Limestone Formation which can be subdivided into two members: Member 1 represents the compact limestone unit (Bed nos.1 - 4), Member 2 the overlying greenish siltstones including Bed 4A.

Plöcken Formation. With a distinct change in colour, this sequence of strata is followed by grayish siltstones with intercalations of impure bioclastic limestone lenses containing fossil remains of the *Hirnantia* brachiopod fauna and of poorly preserved and rare graptolites. In total this shaly horizon comprises 0.77 m (Bed no. 5). It is overlain by 5.40 m of more massive impure pyritiferous limestones and sandstones (Bed nos. 6 - 8). This 6.17 m-thick rock sequence is attributed to the Plöcken Formation.

Nölblinggraben Section

This section is located c. 10.6 km to the northeast of the Cellon locality at an altitude of 1110 m and belongs not only to another tectonic unit but also represents another facial development. The Late Ordovician to Silurian succession is dominated by black graptolitic shales and cherts with sporadic limestone intercalations. It thus represents a deep-water setting. Sampling (see below) for graptolites and chitinozoans as well as chronostratigraphy is in progress. Dropstones have been identified in the Plöcken Fm. and are biostratigraphically constrained by graptolites within the Hirnantian.

Uggwa Limestone. Overlying unfossiliferous shales of the Late Ordovician are the equivalents of the Uggwa Limestone and these closely resemble the corresponding calcareous Member 1 at the Cellon Section although this interval is here only 1.30 m thick. Member 2 is represented by greenish siltstones with intercalations of argillaceous limestone lenses showing a thickness of 5.20 m (Jaeger and Schönlaub, 1977).

Plöcken Formation. Member 2 of the Uggwa Limestone is unconformably overlain by a 0.15 cm-thick pyritic, pebble-bearing sandstone bed which grades into 1.60 m-thick grayish siltstones with intercalations of impure bioclastic layers. Of particular interest are clasts of exotic crystalline rocks including plagioclasites, silexites and granites showing dimensions as large as 5 cm in diameter (Schönlaub and Daurer, 1977) that are being reanalyzed for provenance. Sedimentary debris comprises clay- and siltstones, micaceous sandstones and quartzites. A probable K-bentonite level overlying the clast layer was sampled for radiometric dating and a poorly preserved chitinozoan fauna from the bioclastic intervals is being studied.

The Plöcken Fm. is succeeded by a 1.80 m-thick package of laminated quartzites with interbedded black schists. Age-diagnostic graptolites have yet not been found in this horizon but occur in the overlying black schists (Jaeger and Schönlaub, 1977) indicating a *C. vesiculosus* Zone age within the middle Rhuddanian at its base. Consequently, the quartzites below may represent the *P. acuminatus* or even the *A. ascensus* Zone of the base of the Silurian.

Rauchkofel South Section

This section is exposed on the southern flank of Mount Rauchkofel at an altitude of 2000 m (Schönlaub, 1971, 1985, 1988). The slightly overturned succession starts with the Uggwa Shale and is followed by the Uggwa Limestone, the Plöcken Fm. and various Silurian (Brett et al., 2009) to Lower Devonian limestones.

Plöcken Formation. Of particular interest is the sharp boundary between the Uggwa Limestone and the overlying 9 m-thick, pebble-bearing blackish sandstone of the Plöcken Fm. It is composed of medium-grained sandstones with rounded and angular, irregularly distributed clasts of limestones, quartzites and quartz. These are interpreted as dropstones and reinforce the evidence found at other sections for the diamictite nature of part of the Plöcken Fm. and the waning effects of the Hirnantian glaciation in the region. Analyses of the clasts are in progress and graptolites biostratigraphically constrain the interval.

BIOSTRATIGRAPHY

Graptolites

Uppermost Ordovician graptolites were first reported in the Carnic Alps by Jaeger et al. (1975) from the Feistritzgraben Gorge (see also Schönlaub, 1988), from the lowermost Plöcken Fm. just above the Uggwa Limestone. Abundant graptolite rhabdosomes, confined to black slate rich in globular pyrite and affected by tectonic strain, have been tentatively assigned to *Normalograptus persculptus* (Elles and Wood). Poorly preserved specimens of the upper Hirnantian zonal index graptolite *Normalograptus persculptus*, however, can be easily misidentified with its likely ancestor *Normalograptus ojsuensis* (Koren and Mikhaylova) which is common in the lower Hirnantian *Normalograptus extraordinarius* Zone. Hence, the Late Hirnantian age of this graptolite occurrence must be considered with some reservation.

Uncommon, but better preserved specimens, assignable to *Normalograptus persculptus*, co-occur with the *Hirnantia* fauna in grayish siltstones of the lowermost Plöcken Fm. at the Cellon Section (Fig. 3).This association is assignable to the upper Hirnantian *Normalograptus persculptus* Zone.

In the Nölblinggraben (or Bischofalm) Section, silty-shaly intercalations high in the Bischofalm Quartzite yielded several poorly to moderately well preserved rhabdosomes of *Normalograptus* ex gr. *normalis*. The biostratigraphic significance of this monospecific *Normalograptus normalis* s.l. assemblage is limited, although closely similar occurrences are known from shaly interbeds within the post-glacial, late Hirnantian through to Llandovery Los-Puertos Quartzite (Gutiérrez-Marco et al., 1998) and Criadero Quartzite (Štorch et al., 1998) in Spain. At Nölblinggraben, the highest quartzite bed in the sequence is overlain by a silty black shale in which H. Jaeger found the mid-Rhuddanian index graptolite *Cystograptus vesiculosus* and abundant graptolites of the lowermost Aeronian *Demirastrites triangulatus* Zone (Jaeger and Schönlaub, 1977; Schönlaub, 1985).

At the Waterfall Section near Zollnersee Hütte a definite graptolite assemblage of early Rhuddanian (earliest Silurian) age is identified from an apparently overturned succession of black lydites and siliceous shales, *c.* 1 m below the massive Bischofalm Quartzite. The assemblage includes *Parakidograptus acuminatus* (Nicholson), *Normalograptus normalis* (Lapworth), *Normalograptus mirnyensis* (Obut and Sobolevskaya), *Glyptograptus* aff. *tamariscus* (Nicholson), *Neodiplograptus bifurcus* (Ye) and *Neodiplograptus lautus* Štorch and Feist and indicates the lower part of the *Par. acuminatus* Zone. The assemblage, however, is rather peculiar since some taxa typical of coeval faunas on other Peri-Gondwanan sections are missing [*Neodiplograptus lanceolatus* Štorch and Serpagli and *Normalograptus trifilis* (Manck)] whereas *Nd. bifurcus* of Chinese provenance is new to Europe.

At the Rauchkofel South Section, barely identifiable monograptid rhabdosomes were found in heavily cleaved black slates just above the diamictite succession. Either a tectonic contact, prominent stratigraphic unconformity, or both separate the two units. Therefore, the Rhuddanian and at least a substantial part of the Aeronian are likely omitted in the succession.

Conodonts

In the Late Ordovician of the Carnic Alps the conodont biostratigraphy is based on the pioneering study of Walliser (1964) at the Cellon Section who documented elements from the “Bereich I” (bed nos. 1 to 8) and on that of Serpagli (1967) on the “Tonflaserkalk” at the Rifugio Nordio and Monte Zermula Sections in the Italian Carnic Alps. Both works give a complete overview of the Late Ordovician conodont fauna from the area. Subsequent papers dealing with the Upper Ordovician successions of the Carnic Alps did not include age-diagnostic conodonts. Ferretti and Schönlaub (2001) documented the *Amorphognathus ordovicicus* conodont Zone both in the Uggwa Limestone and Wolayer Limestone Formations with the finding of the "holodontiform element", critical for species differentiation within the genus. Together with *Amorphognathus ordovicicus* Branson and Mehl, elements of *Amorphognathus lindstroemi* (Serpagli) were also documented within the Uggwa Limestone Fm. Faunas from both formations yielded abundant representatives of *Hamarodus europaeus* (Serpagli) and *Scabbardella altipes* (Henningsmoen), as well as of *Walliserodus amplissimus* (Serpagli) in some levels, and belong to the HDS (*Hamarodus europaeus, Dapsilodus mutatus, Scabbardella altipes*) biofacies of Sweet and Bergström (1984). The latter has been documented to date along the peri-Gondwana sector only in Sardinia (Ferretti and Serpagli, 1999) and in lower latitude areas of Avalonia and Baltica.

A slightly younger fauna occurs in the overlying Plöcken Fm. at the Cellon Section (Fig. 3 – Conodont Fauna 2), representing the only Hirnantian conodont fauna described to date along the northern Gondwana area. The fauna has a moderate diversity being composed of some twenty species. The association consists of small and fragmentary elements, documenting the first appearance of *Sagittodontina* Knüpfer and *Istorinus* Knüpfer, taxa common in older horizons of colder regions in the Mediterranean Province (such as Thuringia, Spain, NW France and Libya). Elements of "*Dichodella-Birksfeldia*", which possibly correspond to the Gamachian genus *Gamichignathus* McCracken, Nowlan and Barnes, are abundant. *Amorphognathus* cf. *Amorphognathus ordovicicus* Branson and Mehl and *Amorphognathus lindstroemi* (Serpagli) were documented by Ferretti and Schönlaub (2001).

High resolution sampling from the Cellon Section, initially limited to bed 4 of the Uggwa Limestone Fm. and to beds 7 and 8 of the Plöcken Fm., will facilitate a more precise conodont based biostratigraphic control of the Late Ordovician interval.

Palynomorphs

At the Cellon Section 16 samples ranging through the Late Ordovician interval from the base of the Uggwa Limestone Formation to the top of the Plöcken Formation were prepared palynologically and examined for palynomorphs and the results are outlined briefly here. Analyses of samples from the Nölblinggraben Section are in progress.

Acritarchs

Ten of the analysed samples yielded only poorly preserved acritarchs that could not be determined (Priewalder, 1987).

Chitinozoans

The chitinozoans, in most cases similarly badly damaged, are present in only four samples from the Plöcken Formation: the first association occurs in siltstones just below bed 5, the second in bed 7, the third in bed 8 and the fourth community is derived from sandy shales above bed 8, i.e., just below the Ordovician/Silurian boundary (Priewalder, 1997).

Besides representatives of the genera *Calpichitina* Wilson and Hedlund, *Conochitina* Eisenack, *Rhabdochitina* Eisenack and *Spinachitina* Schallreuter, and a few Ancyrochitininae, three stratigraphically important taxa could be identified on the basis of several unequivocal specimens: *Armoricochitina nigerica* (Bouché) (late Katian - Hirnantian), *Tanuchitina elongata* (Bouché) (terminal Katian - Hirnantian) and *Desmochitina minor* Eisenack (long-ranging, but not crossing the Ordovician/Silurian boundary).

The chitinozoans therefore indicate a Hirnantian age for the Plöcken Fm. (Fig. 3). The poor state of preservation of the chitinozoans (as well as the acritarchs), however, indicate a high energy sedimentary environment which probably led to selective preservation of the identified chitinozoan taxa. Hence, the *Tanuchitina elongata* chitinozoan biozone (base - late Hirnantian) is stated with some reservation. Finally, *Armoricochitina nigerica* (Bouché) and *Tanuchitina elongata* (Bouché), two typical North Gondwanan taxa and for the first time described from Niger, suggest a close relationship between the two depositional areas.

In the Nölblinggraben Section, a few badly preserved representatives of the Conochitinidae are present in the impure bioclastic intervals of the Plocken Fm., which are quite similar to those documented from the same interval at the Cellon Section.

Brachiopods

Faunas occur at three key horizons within the Upper Ordovician succession. An abundant and diverse brachiopod fauna has been described from the Himmelberg Sandstone and Uggwa Shale (Havlíček et al., 1987). The fauna is unusual, being characterized by a number of typical Gondwanan taxa, with links to Bohemia and Morocco, but with immigrants from Avalonia and possibly elsewhere. Higher in the succession, green siltstones within the upper member of the Uggwa Shale contain elements of the wide-spread deep-water *Foliomena* fauna (Harper et al., 2009; Rong et al., 1999). The terminal Ordovician *Hirnantia* fauna (Fig. 3) has been recorded from the Plöcken Formation (Jaeger et al., 1975). The fauna is typical of the Kosov brachiopod province (Rong and Harper, 1988) and there is clearly a depth gradient across the region from shallower-water facies at Hoher Trieb to deep water at the Cellon Section.

CHEMOSTRATIGRAPHY

Iron and Sulfur

Geochemical signals reveal a dynamic ocean chemistry during the Hirnantian in the Cellon Section (Fig. 3). By using the ratio of highly reactive iron over total iron contents in the sediment we get an estimation of the reducing conditions in the water column (Raiswell and Canfield, 1998; Poulton and Canfield, 2004). The late Katian and earliest Hirnantian has unequivocal values, just below the conventional threshold for anoxic values at 0.38. Unless turbidities affected the clastic input and diluted an iron signal of anoxic conditions, the Uggwa Limestone appears to have been deposited within an oxic water column. However, moving into the Hirnantian and the Plöcken Fm., there is a clear enrichment of reactive iron. The pyrite content, in the reactive iron, is at first, present but modest and increases towards the end-Hirnantian. It seems that the Plöcken Fm. and *Normalograptus persculpus* interval of the Hirnantian had a reducing water column. The conditions were at first ferruginous and later on richer in sulphide, however, not euxinic. We also note a heavy composition of sedimentary pyrite sulphur in the late Katian and presumably early Hirnantian. This could be an indication of low sulphate concentrations (Habicht et al., 2004) not only at the Cellon Section, but globally. A limited and depletable sulphate pool in the global ocean might give us

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an indication that euxina has increased in deeper parts of the ocean, burying excessive carbon and pyrite. This would contradict that deep ocean ventilation increased in the early Hirnantian. It would also demand a process that can mute the effect from cooling in terms of the sea water hosting more dissolved oxygen, as increased euxinia would mean less oxygen at least in some parts of the ocean.

Carbon Isotope Chemistry

The stable isotopic values of carbon at the Cellon Section straddle around +1‰ throughout the Uggwa Limestone (increased from a value of -1.1 for carbonate in the underlying Uggwa Shale) and show a prominent excursion of +2.8‰ precisely at the unconformity with the overlying Plöcken Fm. (Fig. 3). If confirmed by high-resolution sampling this excursion coincides with the prominent peak in carbonate-$\delta^{13}C$ at the Katian-Hirnantian boundary (HICE - Bergström et al., 2009). The remainder of the Plöcken Fm. shows again consistently low values with a slight trend toward increasing values upsection.

CHRONOSTRATIGRAPHY

K-bentonites

The K-bentonite levels found in the Upper Ordovician of the Carnic Alps are quite rare and have relatively few equivalents elsewhere in Europe with the exception of beds reported from the British Isles, Baltoscandia, Poland and Lithuania (Histon et al., 2007). One of the four horizons (base Bed no. 6) noted in the Cellon Section occurs within the *Hirnantia* fauna interval (Fig. 3) and this level is also found at the Hoher Trieb Section. Three levels (Bed 8) occur higher in the *Normalograptus persculptus* graptolite Zone at the Cellon Section, one of which may be correlated with the single horizon noted at the Oberbuchach Section within this interval. Two lower levels at the Oberbuchach Section may be correlated with that found in the *Amorphognathus ordovicicus* conodont Zone at the Valbertad Section.

These data reinforce the notion that explosive volcanism associated with the amalgamation of pre-Alpine segments was not simply collisional in nature but represented a variety of source materials and tectonic settings. The K-bentonites belong to a tectonically active terrane dominated by calc-alkaline mafic lavas and pyroclastics in the Late Ordovician, Silurian and Early Devonian which was either situated north or south of the Carnic Alps but separated from the latter by an oceanic realm or at least an open sea of unknown width. However, the K-bentonite horizons in the Carnic Alps range from a few millimeters to 2-3 centimeters in maximum thickness indicating that the volcanic source area must have been quite distant. Histon et al. (2007) concluded that the majority of the K-bentonites found in the Carnic Alps were derived from neighbouring peri-Gondwanan terranes rather than from far distant sources at the eastern margin of the closing Iapetus Ocean.

Radiometric dating

Initial sampling of the K-bentonite levels identified from the Upper Ordovician successions of the Cellon Section and Nölblinggraben Section for further analyses and radiometric dating was carried out in September 2010. The levels consist of yellow to dark brown clays, in general with a putty-like texture; the mineral composition is dominated by authigenic clay minerals and goethite, together with quartz, albite, ilmenite, magnetite, Ca-F apatite, F-apatite, indicating that a pristine igneous component is preserved.

According to the preliminary data in Histon et al. (2007), the andesite bulk composition of the K-bentonite levels indicates that U-Pb radiometric dating by SHRIMP on zircons is feasible. The phase separation is currently in progress.

On the whole, the radiometric dating will constrain the volcanic processes at the Ordovician – Silurian boundary, and may allow geotectonic inferences at a regional scale to be drawn.

DISCUSSION

The new chronostratigraphic classification of the Ordovician System presented by Bergström et al. (2009) with biostratigraphical standard zonations has made it essential to identify the $\delta^{13}C$ excursion (HICE) with precision in the Upper Ordovician interval of the Carnic Alps; this will permit recognition and subdivision of the Hirnantian Stage. Data integrated from multidisciplinary studies by our international team focussing on different aspects of lithostratigraphy, biostratigraphy, chemostratigraphy and chronostratigraphy as outlined briefly above have highlighted further evidence for the Hirnantian Stage based on the identification of the $\delta^{13}C$ Excursion (HICE) in the Cellon Section, although additional high resolution sampling is required to fully confirm this during the next field season. Evidence for paleoenvironmental and climatic/oceanic signals from a variety of isotope analyses has improved our knowledge of small scale perturbations within the marine succession which will allow high resolution correlation with other sectors. Sedimentological evidence recording the cold water influx of the Hirnantian glaciation event in the form of diamictites within the Upper Ordovician successions at the Rauchkofel South and at Nölblinggraben sections is now precisely constrained biostratigraphically thus adding further data for the timing of this event along the North Gondwana Margin.

New collections of graptolites, conodonts and chitinozoans have identified the index fossils for the global standard biostratigraphic zonations from a variety of sections and correlation of brachiopod faunas has documented distinct facies related assemblages recognized globally. These new results are complimentary to the faunal record documented previously and add a further recalibration of the latter biostratigraphic data. To date, the index graptolite for the lower Hirnantian, *Normalograptus extraordinarius* has not been found in the Carnic Alps. We conclude, however, that the siltstones of Member 2 of the Uggwa Limestone Fm. at the Cellon Section may correspond to this level (Fig. 3). The other possibility is that the unconformity separating Member 2 and the Hirnantian Plöcken Fm. encompasses the index graptolite zone for the basal Hirnantian. Finally, radiometric dating of interbedded volcanic layers will add precise time lines within which to collate the overall data set emerging for the Late Ordovician interval in the Carnic Alps. Thus, correlation of this pivotal sector as a regional reference for the North Gondwana area is now more feasible within a global context.

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