TRACKING THE HIRNANTIAN GLACIATION IN THE CARNIC ALPS OF AUSTRIA

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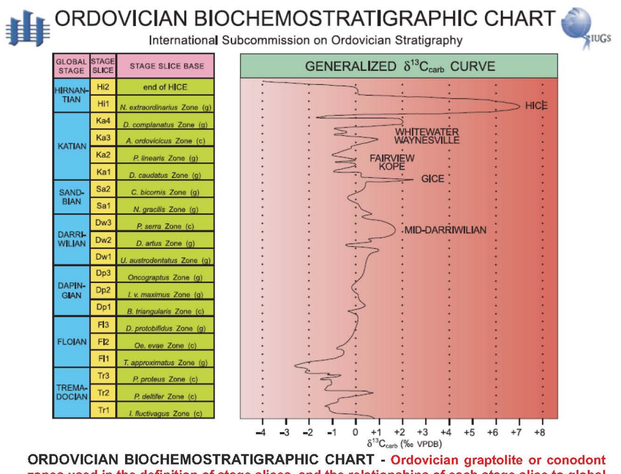
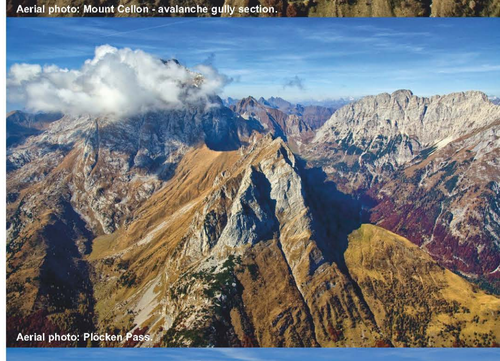
Aerial photo: Mount Cellon - avalanche gully section.

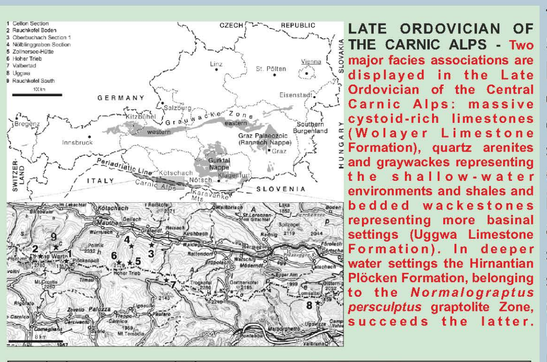
SUMMARY - The Carnic Alps of Southern Austria and Northern Italy represent one of the very few places in the world where an almost continuous biostratigraphically well-constrained succession of Lower Palaeozoic rocks is preserved and is as such a key locality along the Northern Gondwana Margin regarding Lower Palaeozoic correlation. The data from current research projects on the Late Ordovician - early Silurian interval of this middle latitude temperate sector are presented with regard to identification of global signals in the Carnic Alps. Multidisciplinary studies by our international team focussing on different aspects of lithostratigraphy, biostratigraphy, chemostratigraphy and chronostratigraphy have highlighted further evidence for the Hirnantian Stage based on the identification of the δ13C Excursion (HICE) in the Cellon Section. Evidence for palaeoenvironmental 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 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. Finally, detailed geochemical analyses for correlation and radiometric dating of interbedded volcanic layers will add precise time lines within which to collate the overall data set emerging for the Late Ordovician- early Silurian interval in the Carnic Alps. Consequently, correlation of this pivotal sector as a regional reference for the North Gondwana area is now more feasible within a global context.



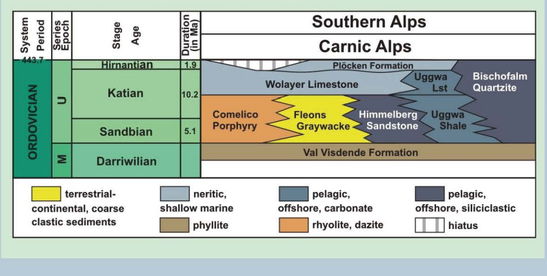
ORDOVICIAN BIOCHEMOSTRATIGRAPHIC CHART - Ordovician graptolite or conodont zones used in the definition of stage slices, and the relationships of each stage slice to global stages and a generalized composite δ13C curve (after Bergström et al., 2009).



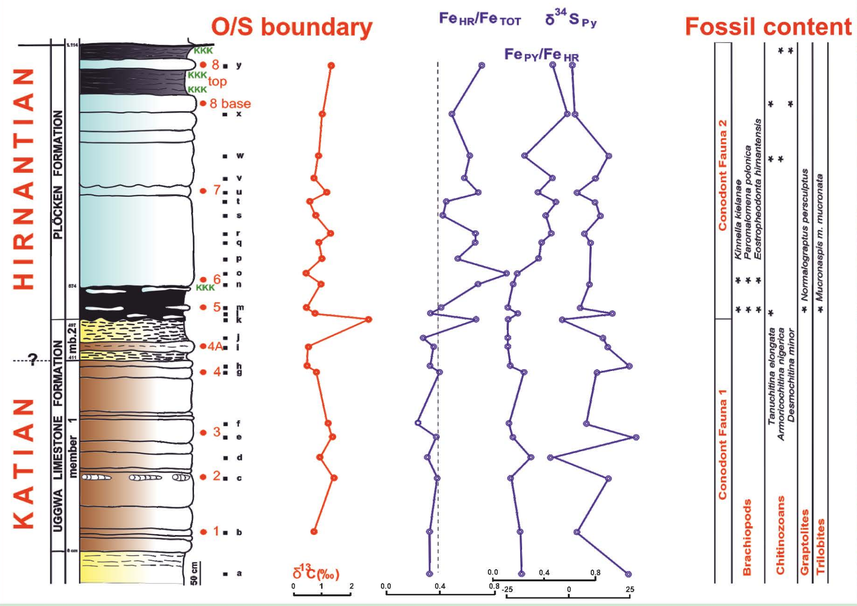
Aerial photo: Plöcken Pass.



LATE ORDOVICIAN OF THE 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.



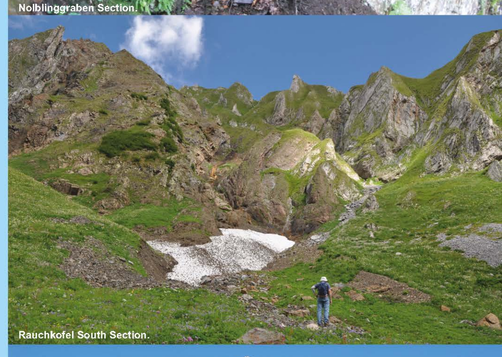
The new chronostratigraphic classification of the Ordovician System recently proposed by Bergström et al. (2009) has highlighted again the necessity of integrating different aspects of lithostratigraphy, biostratigraphy, chemostratigraphy and chronostratigraphy in order to identify with precision subdivisions of stratigraphical intervals. Regarding the Late Ordovician in particular, it is becoming apparent that identification of the δ13C excursion (HICE) for recognition and subdivision of the Hirnantian Stage is essential. 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. (see Figure). If confirmed by high-resolution sampling this excursion coincides with the prominent peak in carbonate δ13C at the Katian-Hirnantian boundary (HICE).Geochemical signals reveal a dynamic ocean chemistry during the Hirnantian in the Cellon Section (figure to the right). 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. The late Katian and earliest Hirnantian has unequivocal values, around the conventional threshold for anoxic values at 0.38, however above the Paleozoic mean for sediments deposited under oxic conditions. Moving into the Hirnantian and the Plöcken Fm., there is a clear enrichment of reactive iron. In the end-Hirnantian an increasing part of the reactive iron consists of pyrite. It seems that the Plöcken Fm. and *Normalograptus persculptus* interval of the Hirnantian had a reducing water column, with increasing concentrations of sulfide.



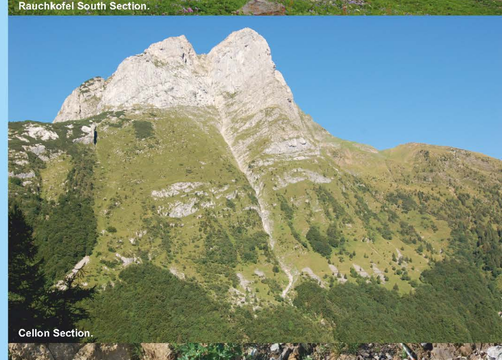
LATE ORDOVICIAN INTERVAL OF THE CELLON SECTION - Lithostratigraphic column based on new field measurements by HPS and AF. Vertical trends in key geochemical parameters (iron, sulphur and carbon isotopes) across the Hirnantian glacial event are shown; letters a-y indicate sampling points. Letters KKK 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 indicated (after Schönlaub et al., 2011).

Aerial photo: Carnic Alps.

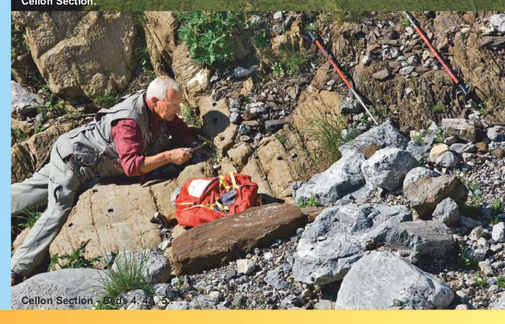
Nolbliggraben Section.



Rauchkofel South Section.



Cellon Section.



Cellon Section - Beds 4, 4A, 5.

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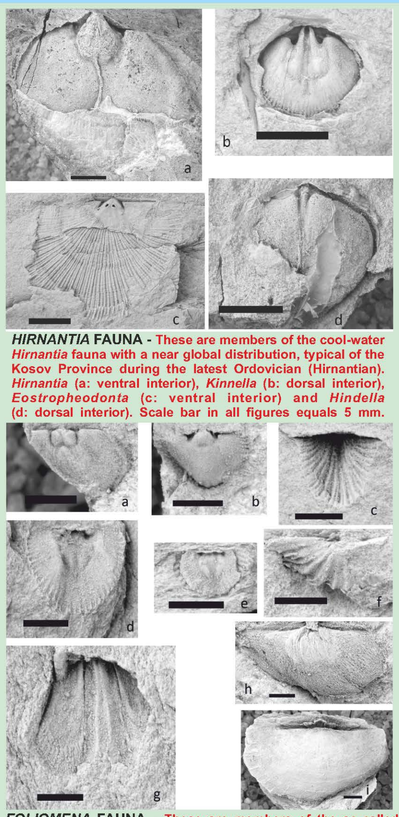
Schönlaub H.P., Ferretti A., Gaggero L., Hammarlund E., Harper D.A.T., Histon K., Priewalder H., Spötl C., Štorch P. 2011. The Late Ordovician glacial event in the Carnic Alps (Austria), In: Gutiérrez-Marco J.C., Rábano I. & García-Bellido D. (eds.), Ordovician of the World. Cuadernos del Museo Geominero, 14. Instituto Geológico y Minero de España, Madrid, 515-526.



***HIRNANTIA* FAUNA** - These are members of the cool-water *Hirnantia* fauna with a near global distribution, typical of the Kosov Province during the latest Ordovician (Hirnantian). *Hirnantia* (a: ventral interior), *Kinnella* (b: dorsal interior), *Eostropheodonta* (c: ventral interior) and *Hindella* (d: dorsal interior). Scale bar in all figures equals 5 mm.

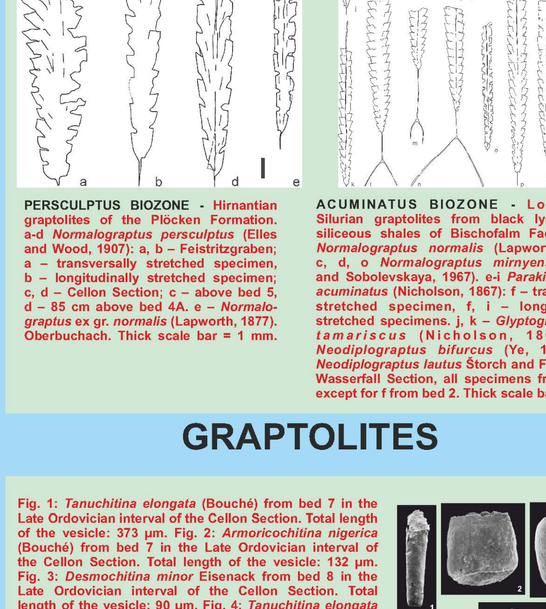
***FOLIOMENA* FAUNA** - These are members of the so-called *Foliomena* fauna, generally minute, thin-shelled brachiopods that occupied the deep sea, during the Late Ordovician (Katian) and that have a wide spread distribution around most of the palaeocontinents at the time: *Dedzetina* (b: ventral interior, c: ventral exterior, d and e: dorsal interiors), *Leptestiina* (a: ventral interior), *Skenidioides* (f: ventral interior), *Christiania* (g: dorsal interior) and *Kozlowskites* (h: ventral interior, i: dorsal exterior). The scale bar corresponds to 2 mm on all photographs.

BRACHIOPODS

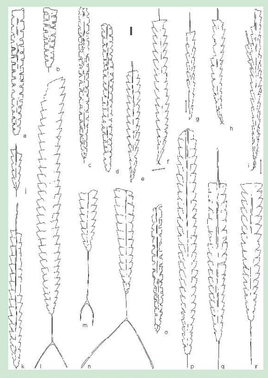
New collections of graptolites, conodonts and chitinozoans have identified the index fossils for the global standard biostratigraphic zonations, are complimentary to the faunal record documented previously and add a further recalibration of the latter biostratigraphic data. To date, the index graptolite 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 (see Figure above) or that the index graptolite zone for the basal Hirnantian is encompassed in the unconformity there. Periglacial deposits which clearly reflect the diamictite nature of part of the Plöcken Fm. provide unequivocal evidence of the Hirnantian glaciation in this region. Further geochemical analyses and radiometric dating are in progress.

The *Amorphognathus ordovicicus* conodont Zone has been documented both in the Uggwa Limestone and Wolayer Limestone formations (Conodont Fauna 1) with the finding of the «holodontiform» element, critical for species differentiation within the genus. A slightly younger fauna occurs in the overlying Plöcken Fm. at the Cellon Section (Conodont Fauna 2), representing the only Hirnantian conodont fauna described to date along the northern Gondwana area. 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 & Barnes, are abundant in this younger Conodont Fauna 2.

CONODONTS



PERSCULPTUS BIOZONE - Hirnantian graptolites of the Plöcken Formation. a-d *Normalograptus persculptus* (Elles and Wood, 1907): a, b – Feistritzgraben; a – transversally stretched specimen, b – longitudinally stretched specimen; c, d – Cellon Section; c – above bed 5, d – 85 cm above bed 4A. e – *Normalograptus* ex gr. *normalis* (Lapworth, 1877). Oberbuchach. Thick scale bar = 1 mm.



ACUMINATUS BIOZONE - Lowermost Silurian graptolites from black lydites and siliceous shales of Bischofalm Facies. a, b *Normalograptus normalis* (Lapworth, 1877), c, d, o *Normalograptus mirnyensis* (Obut and Sobolevskaya, 1967). e-i *Parakidograptus acuminatus* (Nicholson, 1867): f – transversely stretched specimen, f, i – longitudinally stretched specimens. j, k – *Glyptograptus* aff. *tamariscus* (Nicholson, 1868); l-n *Neodiplograptus bifurcus* (Ye, 1978), p-r *Neodiplograptus lautus* Štorch and Feist, 2008. Wasserfall Section, all specimens from bed 1 except for f from bed 2. Thick scale bar = 1 mm.

GRAPTOLITES

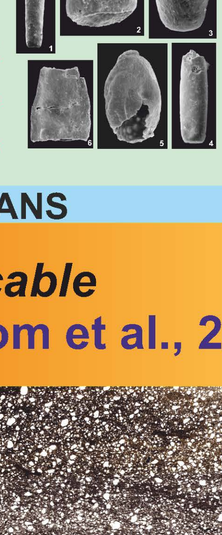
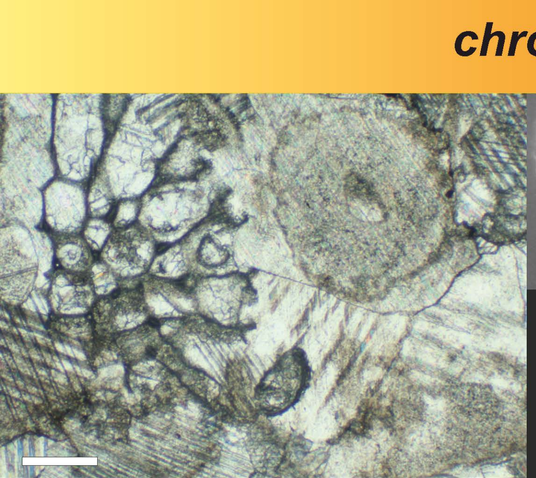


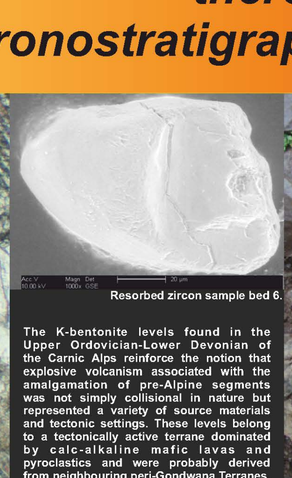
Fig. 1: *Tanuchitina elongata* (Bouché) from bed 7 in the Late Ordovician interval of the Cellon Section. Total length of the vesicle: 373 µm. Fig. 2: *Armoricochitina nigerica* (Bouché) from bed 7 in the Late Ordovician interval of the Cellon Section. Total length of the vesicle: 132 µm. Fig. 3: *Desmochitina minor* Eisenack from bed 8 in the Late Ordovician interval of the Cellon Section. Total length of the vesicle: 90 µm. Fig. 4: *Tanuchitina elongata* (Bouché) from bed 8 in the Late Ordovician interval of the Cellon Section. Total length of the vesicle: 246 µm. Fig. 5: *Desmochitina minor* Eisenack from the sandy shales above bed 8 in the Late Ordovician interval of the Cellon Section. Total length of the vesicle: 79 µm. Fig. 6: *Armoricochitina nigerica* (Bouché) from the sandy shales above bed 8 in the Late Ordovician interval of the Cellon Section. Total length of the vesicle: 159 µm.

CHITINOZOANS

"*there has been an urgent need for a globally applicable chronostratigraphic classification of the Ordovician*" (Bergstrom et al., 2009).



Rauchkofel Boden Section: Wolayer Limestone (scale: 0.5 mm).



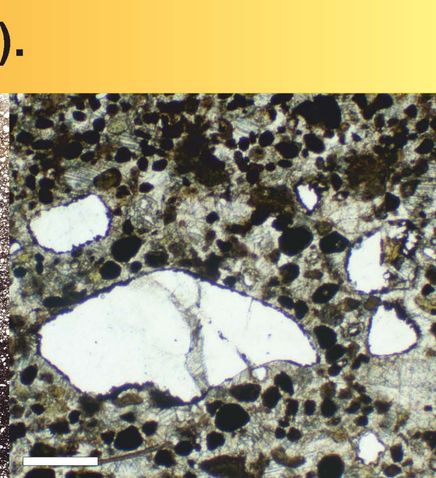
Resorbed zircon sample bed 6.

The K-bentonite levels found in the Upper Ordovician-Lower Devonian of the Carnic Alps 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. These levels belong to a tectonically active terrane dominated by calc-alkaline mafic lavas and pyroclastics and were probably derived from neighbouring peri-Gondwana Terranes.

Cellon Section: K-bentonite level.

Rauchkofel South Section: dropstones field exposure.

Rauchkofel South Section: thin-section of a diamictitic horizon (scale: 5 mm).



Cellon Section: quartz grains at the top of the Plöcken Fm. (scale: 0.5 mm).