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

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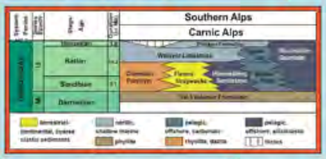
LITHOSTRATIGRAPHY



Carnic Alps: Late Ordovician sedimentation model

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 the latter the Hirnantian Plöcken Formation, belonging to the *Normalograptus persculptus* graptolite Zone, completes the sequence.

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.

Main regions of anchizonal to lower greenschist metamorphosed fossiliferous Palaeozoic strata in the Eastern Alps. Note the Periadriatic Line separating the Carnic Alps and the Karawanke Mountains (Southern Alps) from other Alpine Palaeozoic remnants belonging to the Eastern Alps.. Enlarged map shows the localities being studied. Variety of aerial phosos of the Carnic Alps.

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

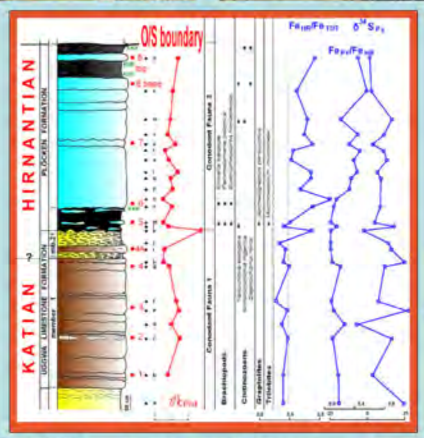
the standard *Normalograptus persculptus* graptolite Zone,

the *Amorphognathus ordovicicus* conodont Zone,

the *Tanuchitina elongata* chitinozoan Zone

and the diagnostic *Hirnantia* brachiopod fauna.

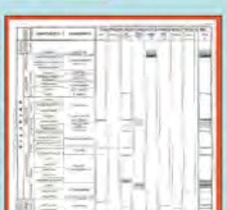
Trilobite faunas are also indicative of this interval.



Periglacial deposits which clearly reflect the diamictite nature of part of the Plöcken Fm. provide unequivocal evidence of the Hirnantian glaciation in this region. Dropstones from Rauchkofel South Section below: field and thin section photo.

CHRONOSTRATIGRAPHY

The K-bentonite levels found in the Upper Ordovician-Lr. Devonian of the Carnic Alps (see figure from Histon *et al.*, 2007) 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. Further geochemical analyses and radiometric dating are in progress.



Cellon Section: K-bentonite level bed 6, resorbed zircon from sample

CHEMOSTRATIGRAPHY

Iron and Sulfur

Geochemical signals reveal a dynamic ocean chemistry during the Hirnantian in the Cellon Section (see Figure). 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, 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 not only at the Cellon Section, but globally.

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. (see Figure). If confirmed by high-resolution sampling this excursion coincides with the prominent peak in carbonate-δ13C at the Katian-Hirnantian boundary (HICE - Bergström *et al.*, 2009).

BIOSTRATIGRAPHY

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) or that the index graptolite zone for the basal Hirnantian is encompassed in the unconformity at this level.

GRAPTOLITES

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.

Wassertall Section, all specimens from bed 1 except for f from bed 2. Thick scale bar equals 1 mm.

Persculptus Biozone

Hirnantian graptolites of Plöcken Formation.

a-d *Normalograptus persculptus* (Elles and Wood, 1907):

a, b – Feistritzgraben; a – transversally stretched specimen, b – longitudinally stretched specimen,

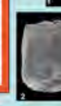
c, d – Cellon; c – above bed 5, d – 85 cm above bed 4A.

e – *Normalograptus* ex gr. *normalis* (Lapworth, 1877): Oberbuchach.

Thick scale bar equals 1 mm.

CHITINOZOA

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:
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.
Fig. 6:
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.



CONODONTS

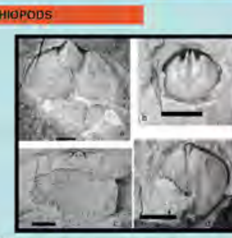
All conodont elements from the Cellon Section, except those indicated with RB (Rauchkofel Boden Section) or SK (Seekopf Base Section). Scale bar: 0,1 mm. Modified after Ferretti & Schonlaub (2001).

BRACHIOPODS

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 is 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 is 2 mm on all photographs.