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Final results on the Jurassic-Cretaceous boundary in the Gresten Klippenbelt (Austria): Macro-, micro-, nannofossils, isotopes, geochemistry, susceptibility, gamma-log and palaeomagnetic data as environmental proxies of the early Penninic Ocean history

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Jurassic to Lower Cretaceous pelagic sediments are well known to form a major element of the northernmost tectonic units of the Gresten Klippenbelt (Lower Austria). The Penninic Ocean was a side tract of the Central Atlantic Oceanic System intercalated between the European and the Austroalpine plates. Its opening started during the Mid Jurrasic, as rifting of the of the oceanic crust between the European and the Austroalpine plates. The turnover of the deposition on the European shelf (Helvetic Zone) from deep-water siliciclastics into pelagic carbonates is correlated with the deepening of this newly arising ocean. Within the Gresten Klippenbelt Unit, this transition is reflected by the lithostratigraphic boundary between the Tithonian marl-limestone succession and the Berriasian limestones of the Blassenstein Formation. This boundary is well exposed in a newly discovered site at Nutzhof, in the heart of Lower Austria (Kroh and Lukeneder 2009, Lukeneder 2009, Pruner, Schnabl, and Lukeneder 2009, Reháková, Halásová and Lukeneder 2009).
Biostratigraphy. According to microfossil (calcareous dinoflagellates, calpionellids) and palaeomagnetic data, the association indicates that the cephalopod-bearing beds of the Nutzhof section belong to the Carpistomiosphaera tithonica-Zone of the Early Tithonian up to the Calpionella Zone of the Middle Berriasian. This interval corresponds to the ammonoid zones from the Early Tithonian Hybonoticeras hybonotum-Zone up to the Middle Berriasian Subthurmannia occitanica-Zone.
Ammonoids. Late Jurassic to Early Cretaceous ammonoids were collected at the Nutzhof locality in the eastern part of the Gresten Klippenbelt in Lower Austria. The cephalopod fauna from the Blassenstein Formation, correlated with micro- and nannofossil data from the marly unit and the limestone unit, indicates Early Tithonian to Middle Berriasian age (Hybonoticeras hybonotum Zone up to the Subthurmannia occitanica Zone). According to the correlation of the fossil and magnetostratigraphic data, the entire succession of the Nutzhof section embraces a duration of approx. 8 million years (approx. 150-142 Ma). The deposition of the limestones, marly limestones and marls in this interval occurred during depositionally (e.g. tectonics) unstable conditions.The ammonite fauna comprises 6 different genera, each apparently represented by a single species. The occurrence at the Nutzhof section is dominated by ammonites of the perisphinctid-type. Ammonitina are the most frequent component (60 per cent; Subplanites and Haploceras), followed by the Phylloceratina (25per cent; Ptychophylloceras and Phylloceras), and the Lytoceratina (15 per cent; represented by Lytoceras and Leptotetragonites). The ammonite fauna consists solely of Mediterranean elements.
Crinoids. Only the Tithonian part of the section proved suitable for bulk sampling. Four crinoid taxa (Margocrinus cf. pentagonalis, Saccocoma tenella, Crassicoma ? sp., and Phyllocrinus belbekensis could be documented. Among these only S. tenella and probably Crassicoma ? sp. appear to be autochthonous, the others are interpreted as transported based on preservation and size range. Observed changes in lithology and microfauna may be reflect

geodynamically induced palaeogeographic changes and/or basinal deepening.
Microfossils. The biostratigraphic study based on the distribution of calpionellids allowed us to distinguish the Boneti Subzone of the Chitinoidella Zone in the Nutzhof section. The J/K boundary in this section is situated between the Crassicollaria and Calpionella Zone (interval limited by samples 7.0-5.6). This base is defined by the morphological change of Calpionella alpina tests. The base of the Crassicollaria Zone approximately coincides with the onset of Tintinnopsella remanei and the base of the standard Calpionella Zone, with the monospecific calpionellid association being dominated by Calpionella alpina. Two further Subzones (Ferasini and Elliptica) of the standard Calpionella Zone were recognized in radiolarian-calpionellid and calpionellid-radiolarian wackestones in the overlying topmost part of the investigated sequence.
Nannofossils. Calcareous nannofossils from the Nutzhof section belong to low poorly diversified, because of the lithology. Nonetheless, the appearance of several important genera was determined, allowing the studied deposits to be attributed to the Early, Middle and Late Tithonian, the approximation of the Tithonian-Berriasian boundary, and the definition of the Early Berriasian nannofossil zones. The results show the major role of the coccoliths of the family Watznaueriaceae and nannoliths of the genera Conusphaera, Nannoconus and Polycostella in the assemblage composition. The interval between the FAD of Nannoconus wintereri co-occurring with small nannoconids in sample No 9 (the uppermost Tithonian) and the FAD of Nannoconus kamptneri minor in sample No 5 (lowermost Berriasian; 143.92 Ma after Hardenbol et al. 1998) is interpreted as the Tithonian-Berriasian boundary interval. The nannoconid dominance ("Nannoconus world") starts, also in Nutzhof profile, in the lowermost Berriasian.
Palaeomagnetic data. The principal aim of detailed magnetostratigraphic and micropalaeontological investigation on the Jurassic/Cretaceous (J/K) boundary is precisely determine the boundaries of magnetozones and narrow reverse subzones, and find global correlation across the J/K boundary. A high resolution study focusing on the detailed biostratigraphy of the limestone-, marly limestone- and marl succession at Nutzhof has been carried out. Eleven magnetic polarity zones, six reverse (R) and five normal (N) polarity - are included in the whole interval (18 m) around J/K boundary of Nutzhof section. The J/K boundary (the Berriasian Stage base), located near Calpionella Zone base roughly corresponds to magnetozone M19N a succession of M-zones correlative with M17N to M22R. Low-field magnetic susceptibility (k) ranges from -5.9 to 94.9$\times$10-6 SI and the intensity of the natural remanent magnetization (NRM) varies between 31 and 615$\times$10-6 A/m. The samples display a two- to three-component remanence. The average sampling density for the whole section was around two samples per 1 m of true thickness of limestone strata in these preliminary results. The next step of investigation will be to precisely determine the boundaries of magnetozones M19 and M20 including narrow reverse subzones with the high resolution sampling density for the whole section.
Stable isotope data (C, O, Sr). High-resolution reconstruction of the carbon cycle, by isotope stratigraphy, is the key for drawing conclusions on the palaeooceanography of the Nutzhof area. The approach using oxygen isotope analysis, by constraining diagenesis impacts, will yield a picture of the Lower Cretaceous palaeoclimatology here. The investigations on istopes will be rigorously linked and networked with measurements and results of cyclostratigraphy and lithostratigraphy. C-istopes are extremely important calibration tools between ammonoids and magnetostratigraphy (Henning et al. 1999). Cyclostratigraphy is crucial in comparing the lithologic appearance of different units and the carbon isotope records. A detailed cyclostratigraphic reconstruction of the record will be carried out by comparing (1) the results obtained by time series analysis of the collected faunal and isotope proxy records with (2) the reconstructed lithologic cycle patterns of the studied sedimentary sections. A first-order floating cyclostratigraphy will be refined using a tentative calibration of the record to the available numerical solutions of the insolation curve. This approach should provide an absolute age for the different stratigraphic events recognised throughout the record.
Gamma-log and Geochemistry. We conducted geochemical analyses of the carbonate, sulphur and organic carbon content in the limestones and marls of the different lithological units. The gamma log measures the radioactivity of the rock and represents a direct function of its clay-mineral content. Higher radioactivity reflects a higher clay content. The gamma-log curve supports the biostratigraphic data very well. The gamma response becomes gradually weaker in the upper, undisturbed part of the section (Nu10-Nu0, Berriasian). The lower part (Nu18-Nu10, Tithonian) of the section shows the highest gamma responses. The gamma curve pattern at Nutzhof therefore shows decreasing values what corresponds well with decreasing values of susceptibility as well with the contrastingly, increasing values in carbonate content (from 50 per cent up to 95 per cent CaCo3) and increasing grey scale values (up to 250).

The above reported results strongly suggest that the section mirrors a change of the depositional position of the Nutzhof section from a shallower into a deeper region, and a more stable environment on the European Helvetic shelf to slope during the Late Jurassic to Early Cretaceous time.

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