The Jurassic Begins in Karwendel! The Triassic/Jurassic GSSP and New Advances on the End-Triassic Mass-Extinction

Der Jura fängt im Karwendel an! Der Trias-Jura-GSSP und neue Erkenntnisse über das Massensterben am Ende der Trias

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The Kuhjoch section northeast of Hinterriss (Karwendel, Tyrol, Austria) was ratified in April 2010 as GSSP for the base of the Hettangian Stage and, as such, the base of the Jurassic System. Sedimentary successions across the Triassic/Jurassic boundary which are expanded and highly fossiliferous in the Northern Calcareous Alps are restricted to the Eiberg Basin, and can be traced over 200 km from the Salzkammergut (Kendlbachgraben, Upper Austria) in the east to the Lahnewiesgraben valley (northwest of Garmisch-Partenkirchen, Bavaria) in the west. With a thickness of more than 20 m, the Karwendel Syncline exposes the most expanded Triassic-Jurassic boundary succession within the Eiberg basin as well as worldwide. The well-exposed section displays a high and continuous sedimentation rate with a constant facies trend across the boundary level. The continuously subsiding Eiberg basin reached 150–200 m water depth in late Rhaetian time and was, therefore, less affected by the end-Triassic sea level drop which led to widespread and longer-lasting emersion of the surrounding shallow water areas. The distinct and abrupt lithological change from basinal carbonates of the Koessen Fm. (Eiberg Mb.) to marls and clayey sediments of the lower Kendlbach Fm. (Tiefengraben Mb.) is interpreted as a result of this sea level fall. This drastic change in lithology was interpreted during the last decade as the T-J boundary because it coincides with the disappearance of typical Triassic fossils such as ammonoids and conodonts. New studies demonstrate, however, that the lowermost metres of the Tiefengraben Mb. (= "Rhaetische Grenzmergel" sensu FABRICIUS, 1960 – including also the reddish Schattwald Beds) still yield a surviving Triassic micro- and nannofauna before they turned extinct as well. The section contains well preserved and frequent fossils and an abundant microflora allowing a cross-correlation with the continental realm.

The exact boundary level is 5.80 m above the top of the Koessen Formation and corresponds to the FO of the ammonite *Psiloceras spelae tyrolicum* HILLEBRANDT & KRYSTYN. This taxon relates to the group of *Psiloceras tilmanni* that is considerably older than other Northwest European psiloceratids (i.e. *Psiloceras erugatum*, *Psiloceras planorbis)* and is comparable with the oldest *Psiloceras* in North America (Muller Canyon, Nevada, USA) but is much better preserved (aragonitic shell, whorl section and complete suture line). The ammonite event correlates to the FO of *Cerebropollenites thiergartii*, a widely distributed palynomorph and Early Jurassic marker in continental successions. Additional boundary events are the FO of the aragonitic foraminifer *Praegubkinella turgescens* and of the ostracod *Cytherelloidea buisensis* 60 cm below the proposed stratotype point and the disappearance of the ostracod *Eucytherura sagitta* immediately above the point. The $\delta^{13}C_{org}$ record shows an initial strong negative excursion near the boundary between the Koessen and Kendlbach Formations that may be correlatable worldwide. The stratotype point coincides with a shift to more positive $\delta^{13}C_{org}$ values shortly above this negative peak.

The mass-extinction occurring around the Eiberg Mb./Tiefengraben Mb. lithological boundary is clearly stepwise but altogether represents the extinction of more than 80 % of all marine invertebrates. The extinction of marine and terrestrial biota is increasingly linked to the outgassing of large volumes of CO_2 and SO_2 during the emplacement of the Central Atlantic Magmatic Province. New multidisciplinary data, including organic geochemical proxies, isotope (C, N), and palynological data, from Kuhjoch and different cores in Luxemburg and Germany provide evidence for changes in type of black shale deposition that reflect major environmental perturbations across the T-J boundary. Prior to the T-J extinction, the Uppermost Rhaetian in Germany contains black shales that are rich in dinoflagellate cysts, and show high amplitude nitrogen isotope excursions. Because cyst-building dinoflagellates require oxygenated bottom waters, Rhaetian organic-rich sediments were deposited through

high-productivity in well mixed shallow marine basins. Following the major overturn of terrestrial vegetation (fern spike) and the marine extinction level, black shales in the lowermost Hettangian reveal extremely low dinoflagellate cyst abundance, but high abundance of prasinophyte green algae and acritarchs. These black shales also show elevated quantities of the biomarker isorenieratane. Isorenieratane derives from the brown strains of photosynthetic green sulphur bacteria (Chlorobiaceae) that require both light and free hydrogen sulfide in the water column. The presence of abundant isorenieratane and its diagenetic products suggests that marginal marine basins in NW Europe became salinity stratified and developed intense Photic Zone Euxinia (PZE) after the mass extinction event. This change in low oxygen conditions is consistent with the long-term effects of CO_2 release, greenhouse warming and post-extinction productivity breakdown. Isorenieratane occurs repeatedly in Hettangian and Sinemurian organic rich sediments. Hence, repeated PZE in epicontinental seas bordering the Tethys Ocean may have contributed to the slow recovery of shallow marine ecosystems after the Triassic-Jurassic boundary.