FORAMINIFERA AND OSTRACODA FROM THE NORTHERN CALCAREOUS ALPS AND THE END-TRIASSIC BIOTIC CRISIS.

Axel von HILLEBRANDT [1] & Max URLICHS [2]

[1] Institut für Angewandte Geowissenschaften, Technische Universität, Ernst-Reuter-Platz 1, Berlin, D-10587
hil10632@mailbox.tu-berlin.de
[2] Staatliches Museum für Naturkunde, Rosenstein 1, Stuttgart, D -70191
urlichs.smns@naturkundemuseum-bw.de

Depositional and Regional Background

Three west-east directed sedimentary basins existed in the NCA around the Triassic-Jurassic boundary: Allgäu Basin in the north, Eiberg Basin in the middle part and Hallstatt/Zlambach Basin in the south. The Allgäu Basin was – at least in part – connected with the NW-European platform. The Eiberg Basin was in Rhaetian time an intraplatform depression, which can be traced over 200 km from the Salzkammergut (Austria) in the east to the Lahnewiesgraben valley in the west (NW Garmisch-Partenkirchen, Bavaria). The Hallstatt/Zlambach Basin was located south of the wide Dachstein lagoon and open towards the Tethyan Ocean.

The worldwide end-Triassic sea-level fall caused a biotic crisis in most fossil groups; it is recorded in the Northern Calcareous Alps (NCA) as a stepwise process that resulted in an end-Triassic sea level fall of at least 100 m as evidenced on the Steinplatte margin of the Eiberg Basin (KRYSTYN et al. 2005). The regression was fast and culminated near the end of the late Rhaetian, it was followed by a slow long-term sea-level rise that started in the latest Rhaetian, continued through the Hettangian and exceeded the Rhaetian highstand relatively late in the Upper Sinemurian (HILLEBRANDT et al. 2007). Caused by the sea-level fall, the Triassic carbonate platforms emerged. This is the reason why a hiatus exists between Triassic and Jurassic sediments in many shallow-water sections of the NCA. Sedimentation was continuous in the deeper part of the basins across the Triassic-Jurassic boundary but an abrupt lithological change from basinal carbonates of the Eiberg Mb. (Koessen Fm.) to marls and clayey sediments of the Tiefengraben Mb. (Kendlbach Fm.) occurred in the Allgäu- and Eiberg Basins. Within the Eiberg Basin and also parts of the Allgäu Basin all sections show the same sedimentary facies across the T-J boundary. A locally varying carbonate vs. clay content depends on the more marginal or more distal depositional position within the basins and has influenced also the microfossil content and composition. The boundary between the Eiberg and Tiefengraben Mbs. is lithologically recognizable all over the Eiberg basin. The topmost bed (bed T in HILLEBRANDT et al. 2007, Fig. 23a, b) differs by darker colour and platy weathering. The top of this bed is thin-bedded, bituminous and black, indicating an anoxic event and the lowstand of the regression (= Top-Koessen Event). The lowermost marls of the Tiefengraben Mb. are grey to yellowish (thickness < 50 cm) and may be called as Grenzmergel s. str. Above are following the Schattwald Beds which are mostly dark red coloured and sometimes laminated. Their type locality is found in the Allgäu mountains (Tannheim valley, Tyrol) in the west and can be traced over 300 km to the Restental (Enns valley, Upper Austria) in the east. The marls are more or less clayey, of variable thickness and have often been described to be of nonmarine origin. In the Eiberg Basin of the western Karwendel syncline a rhynchonellid brachiopod has been recorded from the lower part of the Schattwald Beds. Fragments of pectinid bivalves have been found in its middle and upper part. Intercalations of greyish marls contain complete pectinid bivalves. Therefore, at least parts of the Schattwald Beds of the Eiberg basin must have been deposited under marine conditions. The above following marls of the Tiefengraben Mb. are grey and more or less clayey with an increasing fraction of silt and fine sand in the middle, and limestone beds in the upper part.

Continuous Triassic-Jurassic sections up to now are not known from the Hallstatt/Zlambach Basin. Rhaetian sediments are strongly faulted and folded in the Zlambach area near Bad Goisern (Salzkammergut, Austria). Marly sediments predominate in the late Rhaetian and are rarely exposed. The ammonoid bearing early Hettangian was up to now found in morainic erratic blocks and only Middle and Late Hettangian are known from outcrops. A recently discovered section of clayey marls rich in mica resembles the more marly to clayey Tiefengraben Mb. of the western Eiberg basin, it may span the latest Rhaetian and earliest Hettangian and follows above late Rhaetian marls with *Choristoceras* of the *marshi* group.

Biostratigraphy of the T-J boundary in the NCA

In the last decades the T-J boundary in the NCA was commonly lithologically and variously drawn: sometimes between Kössen and Kendlbach Fm. but more often at the base of the Calliphyllum Bed which up to this time was considered in the NCA as oldest Jurassic ammonite horizon, within the upper Kendlbach Fm. The T-J boundary has now been fixed to the basal Tiefengraben Mb. (lower Kendlbach Fm.) a few metres above the Schattwald Beds after a recent international agreement to define it by the first appearance of *Psiloceras spelae*, declared as the earliest Jurassic psiloceratid. This species is also found in North America (Nevada) and South America (Peru). A section in the western part of the Eiberg Basin (Kuhjoch, Karwendel syncline) was proposed as candidate GSSP for the base of the Jurassic by HILLEBRANDT et al. (2007) where *P. spelae* occurs in the lower part of the marly Tiefengraben Mb., approx. 18 m below the Calliphyllum Bed. It thus is possible to distinguish a late Rhaetian containing the last *Choristoceras* (and conodonts), a latest Rhaetian without ammonites (5,8 m thick in the proposed candidate GSSP) and an earliest Hettangian below the Calliphyllum Bed of late early Hettangian age.

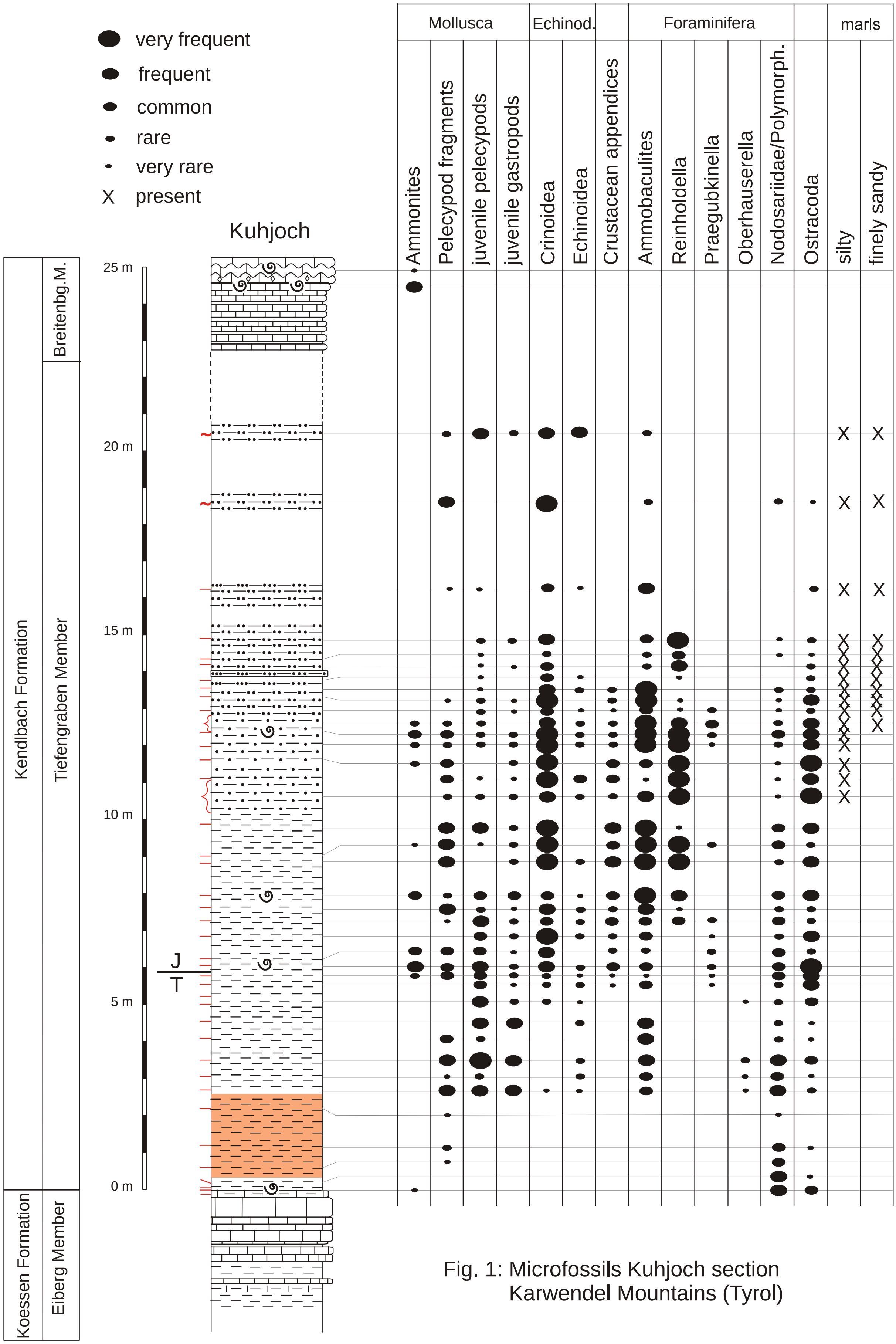

Fig. 1: Microfossils Kuhjoch section
Karwendel Mountains (Tyrol)

a. Foraminifera

The emersion of the carbonate platforms was the first step of the regression. The lagoonal facies of the Norian-Rhaetian carbonate platforms was dominated by *Triasina hantkeni*. This foram, like other Involutinidae (*Coronella, Semiinvoluta, Angulodiscus, Arenovidalina, Auloconus*), do not recur in Liassic sediments deposited under similar ecologic conditions (e.g. platforms of Southern Alps and Dinarids) after the top-Triassic emergence of the carbonate platforms and must have gone extinct. Other Involutinidae like *Involutina liassica* and *Trocholina* which were also adapted to basinal marly facies (e.g. Zlambach marls) survived the TJB biotic crisis.

The Rhaetian Zlambach marls are yielding a highly diverse fauna of Foraminifera. KRISTAN-TOLLMANN (1964) described 54 genera with 245 species which maybe taxonomically oversplitted. Nodosariacea predominate with 14 genera and 136 species. Agglutinated forams (Textulariina) are represented with 19 genera and 39 species. Miliolina are found with eight genera and 13 species. More than 50% of the Triassic Nodosariacea are also known from the Jurassic. 53 species of the other groups are restricted to the Triassic and 21 species also known from younger strata. The last representatives of the Paleozoic Tetrataxidae and Palaeonodosariidae are found in the Rhaetian. The last *Tetrataxis* occur in the latest Rhaetian, above the Top-Koessen Event. The Foraminfera of the Koessen Beds are not yet described in detail but are less diverse than those from the Zlambach Beds. URLICHS (1972) reports nine genera of Nodosariacea. *Ammobaculites* (agglutinated test) and *Nodosaria* can be very frequent. The Duostominacea (with aragonitic test and trochospirally enrolled) are mainly found in the Zlambach Fm. and less common in the Koessen Fm.. The late Triassic biostratigraphy of the Duostominidae was established by KRISTAN-TOLLMANN (1963) and that of the Oberhauserellidae by FUCHS (1967). Both families are of biostratigraphic importance, the Duostominidae are taller and the Oberhauserellidae smaller. The Duostominidae became extinct at the end of the Triassic, only one questionable species survived the Top-Koessen Event and is found in the latest Rhaetian. The Oberhauserellidae survived not only this event but also the T-J boundary. They are the source for the Jurassic Robertinina which gave way in middle Jurassic time to the planktonic Foraminifera.

A detailed study of the Foraminifera (and Ostracoda) across the T-J boundary was possible in the Eiberg basin (western Karwendel syncline and additional sections). Bed T of the Koessen Fm. yielded a diverse fauna of Nodosariidae with few Textulariina, some of them not found higher up. The diversity diminishes in the upper part of bed T in direction to the Top-Koessen Event. The beds between the Koessen event and the transition to the Schattwals Beds are characterized by small, mostly compressed, coarsely agglutinated *Trochammina* and an impoverished fauna of nodosariids often characterized by a large species of *Marginulinopsis*. *Hippocrepina* (a finely agglutinated siliceous foram with simply constructed test) dominates the Schattwald Beds of the Eiberg Basin and is accompanied by compressed *Trochammina* and an impoverished fauna of nodosariids (especially *Marginulinopsis*). The predominance of *Hippocrepina* points to unfavourable ecologic conditions most times unsuitable for the segregation of calcitic tests. Large *Ammobaculites* (species similar to that of the Koessen Fm.) are common to frequent in many samples of the marls above the Schattwald Beds where small agglutinated forams (in part attached) and an impoverished fauna of small Nodosariidae and Polymophinidae occur. The latter are more frequent in the lower part of that interval. Nodosariidae are more frequent from the first Jurassic ammonite level upwards. The Robertinina are represented by an evolutionary line that begins above the Schattwald Beds with tiny *Oberhauserella* (~ 0,06 to 0,12 mm) related to late Rhaetian species from the Zlambach Beds. *Praegubkinella turgescens* (~ 1,5 to 0,2 mm) appears in the interval around the first Jurassic ammonite horizon and a new species of *Reinholdella* (~ 0,2 to 0,3 mm; a typical Jurassic genus) can be very frequent in the middle and upper part of the Tiefengraben Mb. (HILLEBRANDT 2008) Biostratigaphically important genera like *Ichthyolaria* or species of the *Lingula tenera* plexus are missing or very rare in the lower and middle part of the Tiefengraben Mb. as a result of unfavourable ecologic conditions in the Eiberg basin at that time. This is probably due to a lower oxygen level at the sea floor favouring the aragonitic Robertinina and the occurrence of nuculid bivalves and the ostracode *Cytherelloidea*.

Only a few continuous T-J boundary sections are exposed in the Allgäu Basin. Typical Triassic Oberhauserellidae were found directly above the Top-Koessen Event and below the Schattwald Beds. The thick Schattwald Beds do not contain forams or ostracodes and a nonmarine environment can thus not be excluded. Oberhauserellidae were also found above the Schattwald Beds, similar to those below the first Jurassic ammonite horizon of the Eiberg basin.

The series of clayey marls with mica above late Rhaetian Zlambach marls near Bad Goisern, which are comparable to the Grenzmergel s. l. of the Eiberg basin, contains simply constructed agglutinated forams predominating in the lower part. The Nodosariids are much lesser diverse than those of the Zlambach marls but more diverse and taller than those of the Tiefengraben Mb. The genera and species are of Triassic appearance. The very well preserved aragonitic Oberhauserellidae exhibit the same evolutionary trend as observed in the Tiefengraben Mb. The youngest fauna of this outcrop has Oberhauserellidae with a very similar variability to those of the basal Jurassic beds of the Eiberg basin with *Praegubkinella turgescens*. Unfortunately, the section is incomplete both downward to an equivalent of the Top-Koessen Event and upward into the lower Hettangian.

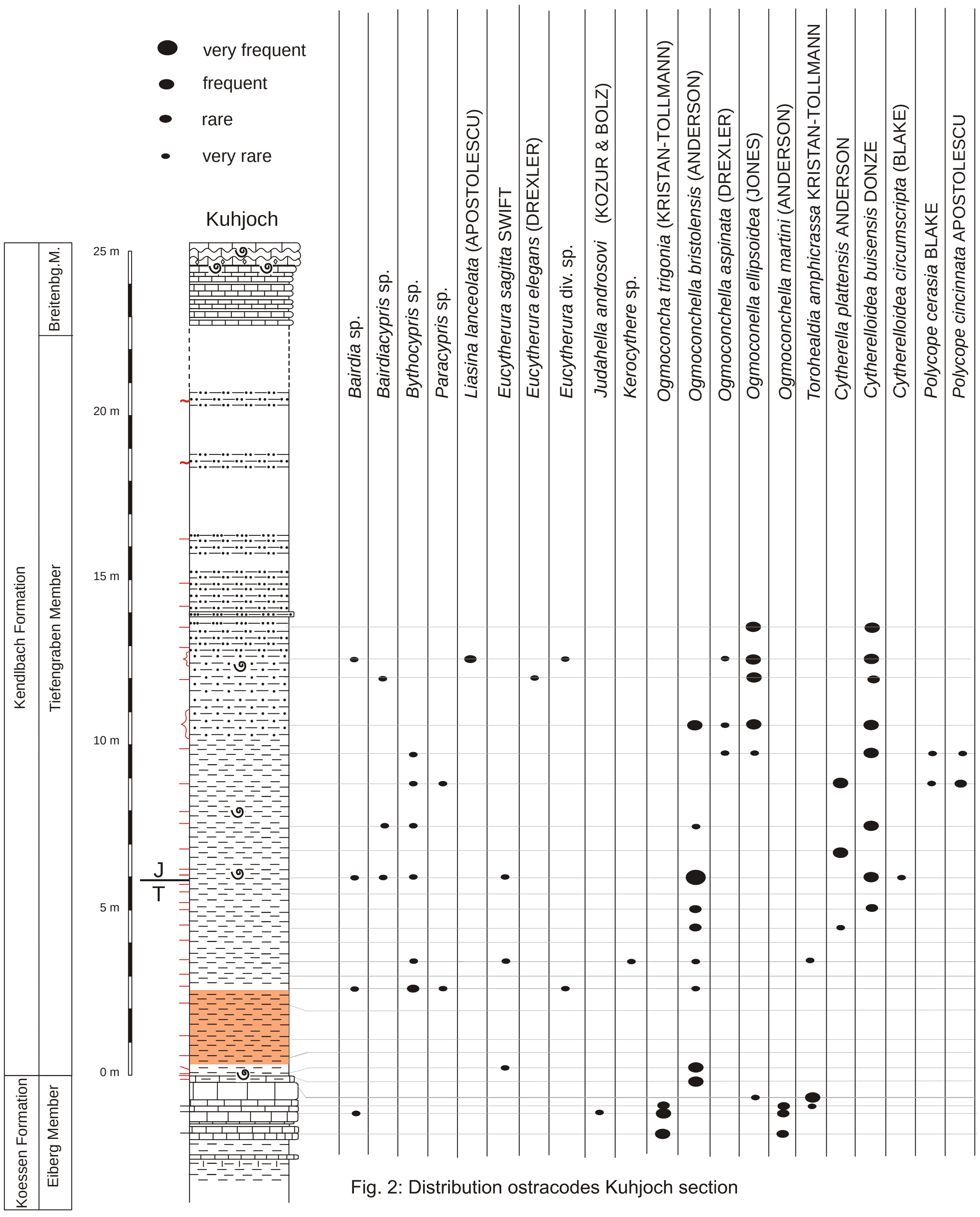

Fig. 2: Distribution ostracodes Kuhjoch section

b. Ostracoda

The late Triassic ostracodes of the NCA are well known: ostracodes of the Zlambach marls were described by KOLLMANN (1960, 1963), KRISTAN-TOLLMANN (1969, 1970) and BOLZ (1970, 1971), those of the Koessen Formation by URLICHS (1972). Less well known are the early Jurassic ostracodes of the NCA. Some species were published by KOLLMANN (1960, 1963) and KRISTAN-TOLLMANN (1990). HARLOFF & JÄGER (1994) described 77 species from the Liassic of the NCA. Latest Rhaetian and earliest Hettangian ostracodes are now under study by Urlichs (URLICHS in HILLEBRANDT et al. 2007).

The Zlambach marls are yielding a high diverse fauna of ostracodes. BOLZ (1971, p. 245) found in these marls 173 species. The Bairdiidae dominate with approx. 100 species and the Healdiidae with approx. 30 species. Some species of the Bairdiidae are very tall (length up to 2 mm). URLICHS (1972) described 25 species of ostracodes from the Koessen Beds where only few Bairdiidae are known and Healdiidae are more frequent. Small Eucytheruridae are more frequent in species in the Rhaetian than in the early Hettangian. Typical Rhaetian ostracodes (different species of Bairdiidae and Healdiidae) are represented in bed T of the Koessen Beds (various localities) and in the Grenzmergel s. str. directly above. Many species of the Cytheracea disappear above the Koessen event, especially most of the Bairdiidae and many Healdiidae. The faunal change between the Rhaetian and Hettangian is very distinct though some species occur from the Rhaetian up to the Hettangian. *Cytherelloidea* and *Polycope* survived the biotic crisis and new species were developed. Ostracodes are very rarely found in the Schattwald Beds and may eventually be reworked. The ostracode fauna is poor in species in the basal Tiefengraben Mb. between the Schattwald Beds and the first Jurassic ammonite. Smooth ostracodes of the Healdiidae are usually the most frequent ostracodes in the Tiefengraben Mb. and *Cytherelloidea* can be frequent in the middle and upper part of it. This genus is indicating unfavourable oxygen conditions. New species of small *Eucytherura* appear during the earliest Hettangian. The survivors from the Rhaetian to the Hettangian indicate that the ecologic conditions have been unchanged euhaline, probably with exception of the Schattwald Beds. The ostracod species of the Tiefengraben Mb. are found later in NW Europe, at first in younger Hettangian beds.

Conclusions

In the NCA the biotic crisis at the T-J boundary was taking place step-by-step probably through a time-interval of some hundred thousand years and paralleled a stepwise change in lithology. The crisis started in the well-studied Eiberg Basin with the Top-Koessen Event and ended gradually during the upper part of the Early Hettangian. The Top-Koessen Event was caused by the abrupt sea level fall which resulted in a very important marine biotic extinction. Many groups of forams and ostracodes are affected by this event, especially those specialized to restricted and/or specific ecologic conditions. Some species survived the Koessen event. A fauna poor in species remained within the Grenzmergel s. str. between the Koessen event and the Schattwald Beds. The ecologic conditions once more got worse during the sedimentation of the Schattwald Beds where eventually nonmarine conditions predominated in the Allgäu Basin. Abnormal marine conditions prevailed in the Eiberg Basin and at times segregation of calcitic tests must have been impeded, probably caused by acidification of the sea. The ecologic drawback also occured in the Hallstatt/Zlambach Basin at that time. The ecologic conditions improved above the Schattwald Beds during the lower Tiefengraben Mb. Many survivors reappeared and new species evolved. This recovery came from the Tethyan Realm and reached the NCA basins from South continuing to the North and finally to NW Europe.

The end-Triassic biotic crisis seems to have mainly been caused by the relatively quick and strong sea-level fall. Climatic changes from arid to more humid mainly are reflected in a sedimentary change from carbonatic to more siliciclastic and the ecologic conditions changed. The calcification potential probably was affected by the beginning of the CAMP volcanism and an acidification by a to high concentration of carbon dioxide. The temporarly change to anoxic sea floor conditions also can have been important.

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