

studied time slice, one of the emerging branches, together with all intermediate forms, becomes extinct.

These morphological developments could be related to changes in the paleoenvironment, as documented by a comprehensive set of isotope, stratigraphic and geophysical data. These give about constant environmental conditions for the interval of stasis, promoting the action of stabilizing selection on the morphological traits. Coinciding with the appearance of new phenotypes, a massive rise in lake level is documented. This surely had a strong effect on the availability of habitats and distribution of nutrients. The strong correlation between environmental parameters and appearance of several new phenotypes is interpreted as an adaptive radiation. The following morphological bifurcation is thought to reflect successively evolving discrepancies of ecological requirements, hence the establishment of isolated ecological niches. Probably, this ecological separation promoted divergent natural selection and, given the widely separated morphologies, finally led to the establishment of reproductively isolated species, a process known as ecological speciation. In the final interval, Lake Pannon faced drastic environmental changes, with strong seasonal fluctuations of lake level and nutrient supply, lake stratification and algal blooms. This resulted in the extinction of the major part of the gastropod fauna.

### S8 – Predatory vs. non-predatory boreholes in fossil and Recent echinoids

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Drilling predation is important among many fossil and Recent invertebrates and since the fossil record of boreholes is excellent, drilling predation has been the subject of many key studies dealing with predation in deep time. Whereas molluscs and brachiopods are mainly drilled by muricid and naticid gastropods, the main drilling predators of echinoids are cassid snails (helmet conchs) which specialized on echinoids as prey. The fossil record of the Cassidae dates back to the Late Cretaceous but not until the radiation of the family in the Eocene, cassid predation became increasingly important. Based on actualistic observations, studies on cassid predation on echinoids follow two assumptions: (i) circular boreholes in echinoid tests are of predatory origin and (ii), if the borehole completely penetrates the echinoid test, the predatory attack is considered lethal and thus, successful.

However, some non-predatory organisms produce borings in echinoid tests and many of these are not lethal. Especially parasitic ascothoracid crustaceans and eulimid

gastropods produce traces which can be easily confused with predatory borings. In addition, dwelling structures of endolithic foraminifers and copepods, produced either in vivo or post mortem, can be similar to cassid drillings. The proper interpretation of boreholes found in echinoid tests is therefore crucial for unbiased studies of interactions among echinoids and their drilling antagonists (predatory or parasitic) or bioeroders.

### S25 – First record of chambered hexactinellid sponges from the Palaeozoic

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Most chambered sponges (the polyphyletic group of „Sphinctozoa“) are hypercalcified types and most of them probably belong to the Demospongia. „Spinctozoa“ occur from the Cambrian to the Recent and are the most abundant sponges in Late Palaeozoic and Triassic reefs and shallow water limestones. Among hexactinellid sponges, chambered forms are very rare including taxa only from the Late Jurassic and the Late Triassic of Europe, Russia, Tadjikistan, Iran or China. There are five genera described *Casearia* Quenstedt, *Caucasocoelia* Boiko, *Dracolychnos* Wu & Xiao, *Pseudoverticillites* Boiko and *Innaecoelia* Boiko, the latter of which is synonymised with *Casearia* by most authors.

To date, there are no reports on chambered hexactinellid sponges before the Mesozoic. Moreover, the first representatives of the order Hexactinosida apparently occurred in the Ordovician, but well preserved and diversified representatives of the order Hexactinosida were thought to evolve not before the Late Devonian.

The chambered sponges studied herein stem from the famous Lower Devonian (Emsian) locality of Colle in the Cantabrian Mountains of northern Spain. The Colle outcrops have been well known for their well preserved and abundant invertebrate fossils since the 19<sup>th</sup> century. The studied interval within the Valporquero Formation includes coral biostromes and small bryozoan-crinoid mud mounds. The latter grew in an outer ramp setting just below the storm wave base. The mud mound fauna includes the hexactinellid sponge fauna. The sponges are characterized by cylindrical to conical, frequently branched multi-chambered bodies with an axial spongocoel. The

outer morphology reflects the internal segmentation. Stacked annular chambers show variable size and shape with some chambers fully encasing the previous chamber. The cortex on the dermal surface is formed by a single layer of hexactines with spherically enlarged multiradiate nodes producing triangular meshes. On the gastral surface, within the spongocoel, the fused hexactines exhibit polygonal to rounded meshes, representing possible exhalant canal openings. Chamber fillings show a dictyonal hexactine network with rectangular meshes.

The general characters of the Colle hexactinosidan hexactinellids fit the diagnosis of *Casearia*. Based on the irregular shape and size of the chambers, the lack of dermalia and gastralia above single cortical layer as well as the absence of proper skeletal canals, the material has been classified as a new species.

The oldest representative of *Casearia* is also the first chambered hexactinellid sponge from the Palaeozoic. Moreover, it is the first record of hexactinosidan sponges from the Early Devonian partly filling the long gap between Late Ordovician and Late Devonian hexactinosidan record.

## S2 – Habitat breadth and geographical range predicting evolutionary rates in Mesozoic bivalves

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Numerous environmental and intrinsic biotic factors have been sought to explain patterns in diversity and turnover. In the current study we utilized taxonomically vetted and sampling-standardized data sets of more than 50,000 taxonomic occurrences in the PaleoDB to test (1) whether habitat breadth predicts genus durations and diversity dynamics of marine Mesozoic bivalves, and (2) whether this effect is independent of the well-known positive relationship between geographical range and longevity.

Bivalve genera were categorized as narrowly or broadly adapted according to their proportional occurrence counts within different settings of lithologic and bathymetric categories. Habitat breadth was then defined as a combined measure of those proxies. Our analysis showed that mean values of Foote's extinction and origination rates are significantly higher for narrowly adapted taxa compared to broadly adapted taxa in various environmental categories and likewise decrease with increasing habitat breadth. These differences are evident in all analyzed stratigraphic intervals. Further, linear models and respective model rankings showed that geographical range and habitat breadth both have a significant effect on genus durations and on diversity dynamics. These results reaffirm

the role of geographical range and furthermore suggest that habitat breadth is an equally important key predictor of extinction risk and origination probability in Mesozoic marine bivalves. Thus, habitat generalists, regardless of their geographical range, exhibit longer genus durations and are generally less prone to extinction. This shows that being widespread alone does not prevent taxa to become extinct – widely distributed taxa that are more specialized may be more endangered than one would expect.

In addition, the slopes ('partial' coefficients) of the linear models were used to visualize selectivity patterns in origination and extinction with respect to habitat breadth through time. Whereas there is no pronounced ecological selectivity in origination throughout much of the Triassic and Jurassic, in the Cretaceous origination of specialized taxa is favoured. As generic bivalve diversity increases throughout the Mesozoic the observed pattern may best be explained by diversity-dependence. In contrast, extinction rates are generally higher for specialized taxa. Furthermore, extinction selectivity during times of mass extinction is indistinguishable from background levels (end-Triassic), or only slightly elevated for environmentally restricted genera (end-Cretaceous). This suggests that the underlying mechanisms do not change in times of global crisis and that broad adaptation buffers against both background and mass extinctions.

## S3 – The Cassian biota – Ecology and geobiology of the Triassic diversity hotspot

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The famous Cassian Formation (Late Triassic, N Italy) provides unique insights into an early Mesozoic tropical ecosystem. Various palaeo-environments with different fossil assemblages have been reported. Basically carbonate platforms and reefs are present and interfinger with basins filled by marls and mass flow deposits. Climate was tropical warm but with a high seasonality as is indicated by high resolution  $\delta^{18}\text{O}$  records from megalodontoid bivalve shells consisting of pristine aragonite.

More than 1000 invertebrate species have been described from the Cassian Formation – no other early Mesozoic fauna is as rich. Gastropods are by far the most