Shark Eggs in the Lower Jurassic of Northern Bavaria

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Only approximately 30% of today's sharks lay eggs, which consist of coarse, sometimes interestingly shaped, capsules. Although one of the fathers of palaeobotany, Brongniart, described fossil structures in the form of a DNA strand as *Palaeoxyris* as early as 1828, they were placed as fructifications of plants until finally, in 1888, Bernhard Renault and Charles René Zeiller correctly identified these structures as eggs laid by sharks. Excavations at the Pechgraben, Sandpit Küfner (Bavaria), uncovered layers with hundreds of well-preserved capsules (*Palaeoxyris muensteri)* from the Lower Jurassic (Hettangan) period, shedding light on the nesting habitats of ancient sharks amidst preserved plants.

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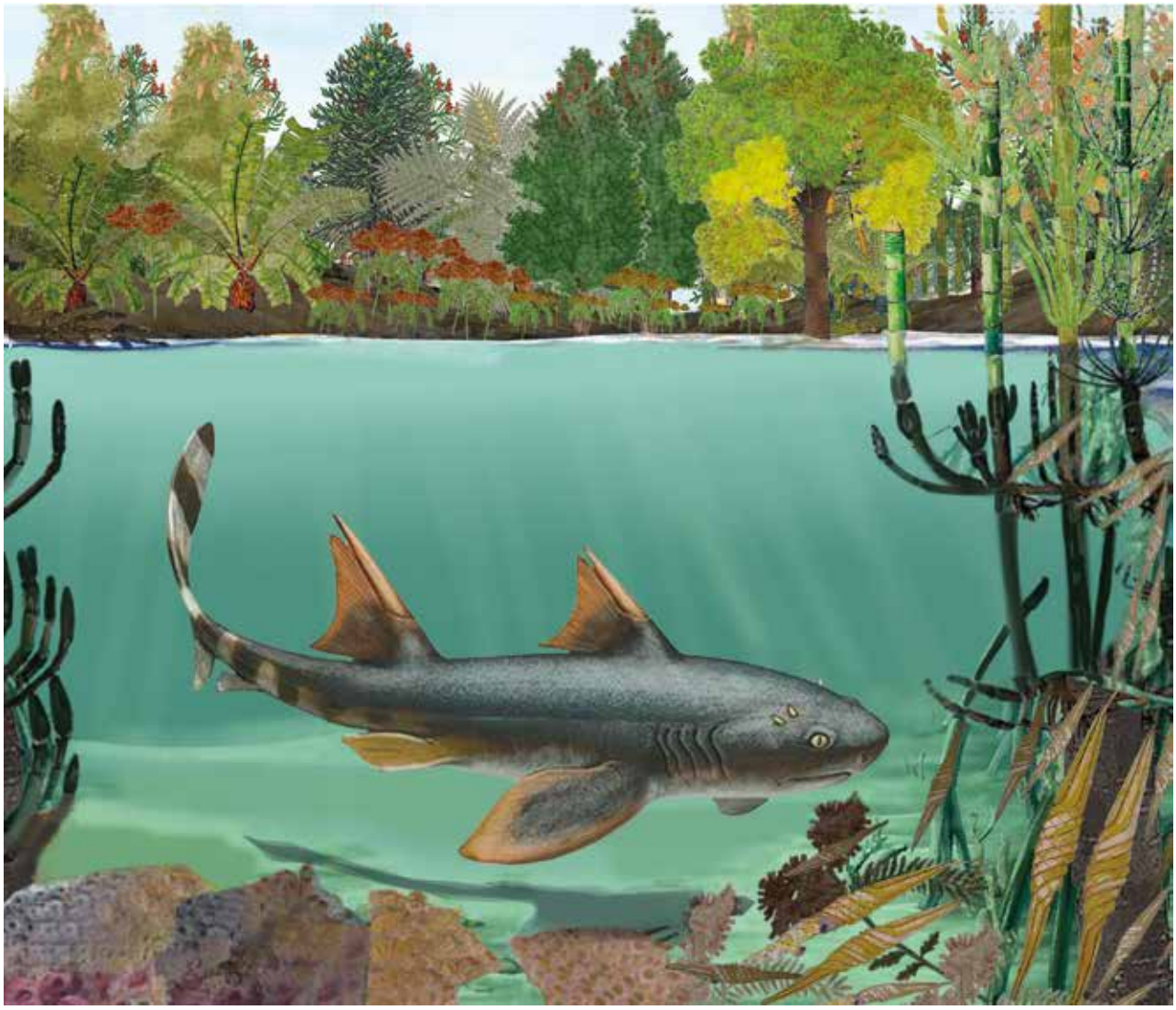
Key words: Lower Jura, Hettangian, Shark capsules, *Palaeoxyris muensteri*



Palaeoxyris muensteri. **Shark eggs.** Shore area in the Lower Jurassic in Bavaria with an egg-laying hybodont shark (*Lissodus*)

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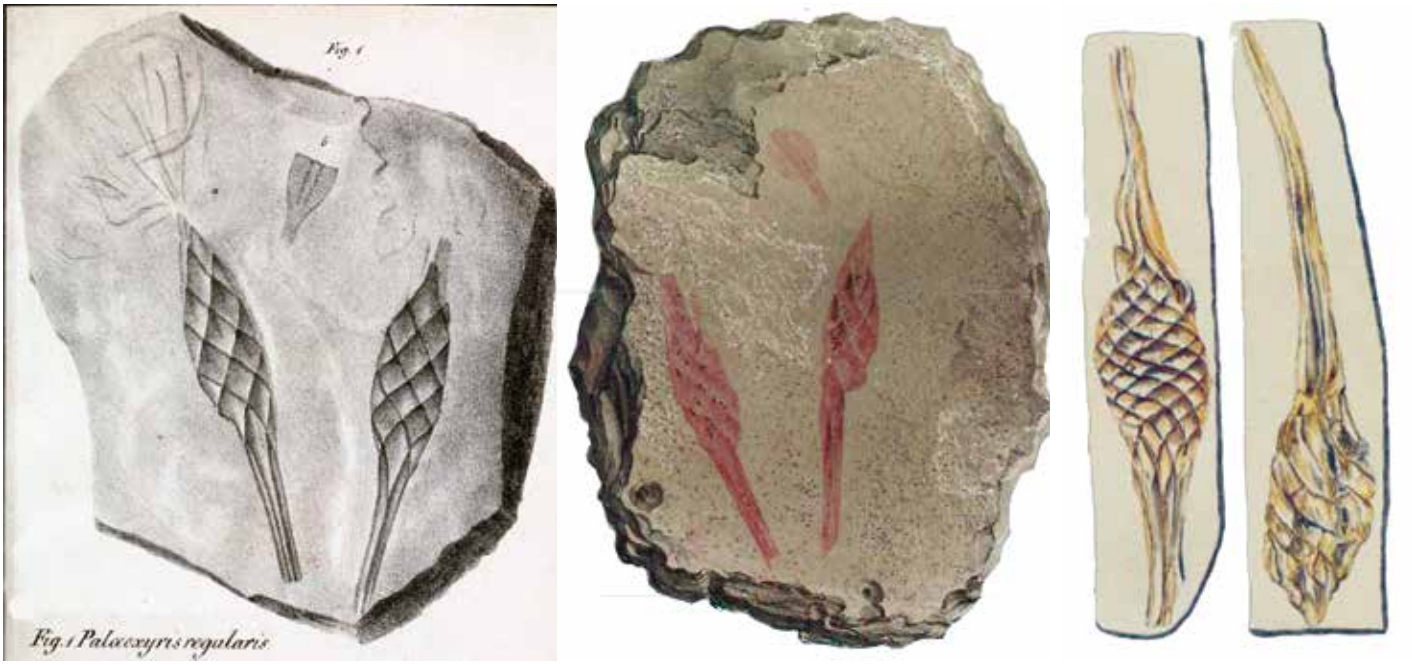
Over many decades, beginning in 1828, when Brongniart described the first shark capsules from the Anisian (Middle Lower Triassic) of Alsace through C. Presl (1838, in Sternberg) to Schenk (1867), the strange structures sometimes found between plant deposits led to the various classifications. They were mostly attributed as fructifications (Brongniart, 1828; Presl, 1838) of cycads or horsetails (Schenk, 1867; Brignon, 2021).

It is a testament to the greatness of Schenk that in 1888, he changed his views and assumed that they belonged to Pisces. This was after the eggs of other fish such as *Fayolia* and *Vetacapsula* became known, which were associated with heterodont bullhead sharks. Renault and Zeiller (1888) solidified this claim and brought these fossils from the plants to the animal kingdom. They compared both *Fayolia* and *Palaeoxyris* with egg-laying marine animals such as rays, sea cats (Chimaeriformes), and various sharks from the group of bullhead or zebra sharks (Fischer & Kogan, 2008). Even Salfeld (1906), in his detailed publication on the Jurassic plants of southern Germany, expressed doubts about this classification and maintained it in the context of a plant origin.

During a prospecting expedition at the southwest end of the Küfner sandpit (50°00‘04. 1“N 11°32‘26. 4“E), Thomas Gerasch succeeded in finding a shark capsule in 2022. Subsequent systematic excavations by Fuchs and Wachtler revealed hundreds of shark capsules at the deepest layer of a location rich in fossil plants. They all belonged to the same species, *Palaeoxyris muensteri*, and imparted valuable insights into the breeding behaviour of hybodont sharks in the Lower Jurassic, about 200 million years ago.

An area of about 40 sq m was systematically examined. The shark capsules were concentrated on a fine, but unfortunately fragile, thin layer at the very bottom of the site, directly in contact with massive fossilised sandstone banks. Surprisingly, they were found in hundreds, partly in association with larger vegetal parts, loosely embedded in fine clay or alongside well-preserved sporophylls and fronds from the fern *Thinnfeldia rhomboidales.* While *Podozamites* leaves, which appeared in abundance in the upper strata, were present, they were less common. Other flora elements took a secondary role in the findings.

Thanks to the fine mud deposits, all details of both the plants and *Palaeoxyris* capsules

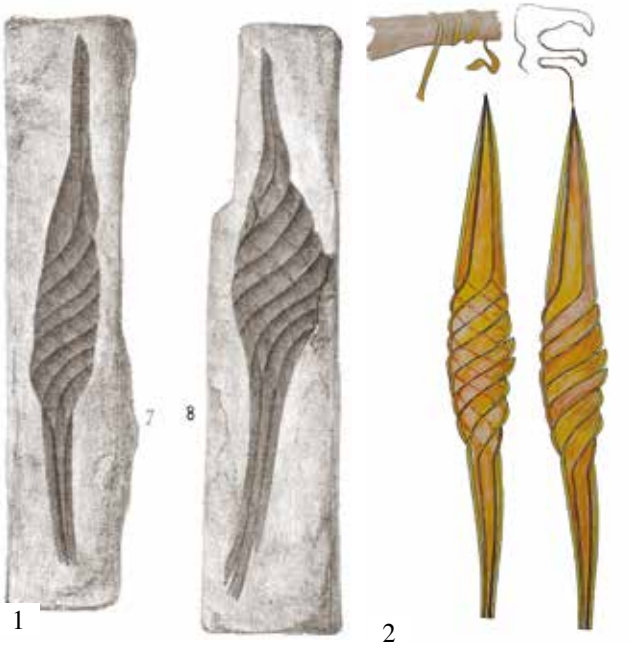


Research history of shark eggs: *Palaeoxyris regularis.* Original specimen of Brongniart, 1828, pl. 20, Fig. 1, Soultzles-Bains, (Anisian, Middle Lower Triassic); middle: chromolithography of the same specimen, by Schimper and Mougeot, 1841, pl. 23, Fig. 3; right: *Palaeoxyris muensteri.* First description drawing of Presl in Sternberg, 1838, vol. II, 7/8, pl. 59, Fig. 1–11 from the Lower Jurassic of Bamberg.

were excellently preserved. However, it is worth noting that embryos have never been found until now. It is assumed that hybodont sharks manoeuvred into hard-to-reach, partly enriched with freshwater, lateral arms, which were not too deep, and attempted to anchor the shark capsules with their filamentous outgrowths to protruding trunks or washed-in land plants.

The eggs reached lengths of 5 to 25 cm. The resistant membrane protected the yolk-rich contents, which served as a food source for the following weeks or months. Upon reaching a high degree of maturity, the young sharks hatched, offering them greater chances of survival. This behaviour has been documented at least since the Carboniferous period, and the development is likely to go back even further. However, fossilised shark capsules belong to the great rarities, so this mass discovery from the Küfner sandpit in Pechgraben is unique and contributes to a better understanding of the life of the Lower Jurassic.

The comprehensive exploration of the area by only two people, Fuchs and Wachtler, facilitated a thorough investigation of the deposition conditions and meticulous excavation of the thin layer on a large scale to obtain the most coherent findings possible. Due to the layers being as thin as millimetres at times, the desired result was not always achieved. Nevertheless, this endeavour resulted in one of the most intriguing discoveries globally.



After Schenk, 1867. *Palaeoxyris muensteri,* plate XLV. Fig. 7-8, locality Strullendorf near Bamberg); 2. *Palaeoxyris muensteri.* Reconstruction based on the new finds (Michael Wachtler) with typical tripartite and twisted collarette.

Manfred Fuchs in spring 2023 at the shark capsule rich horizon at the Küfner sandpit in Pechgraben. They were found in mass burial grounds, especially in the lowest layer at the transition to coarse-grained sandstone sediments. Rarely, however, were they found in the middle ranges. An area of approximately 40 sq m was systematically examined.

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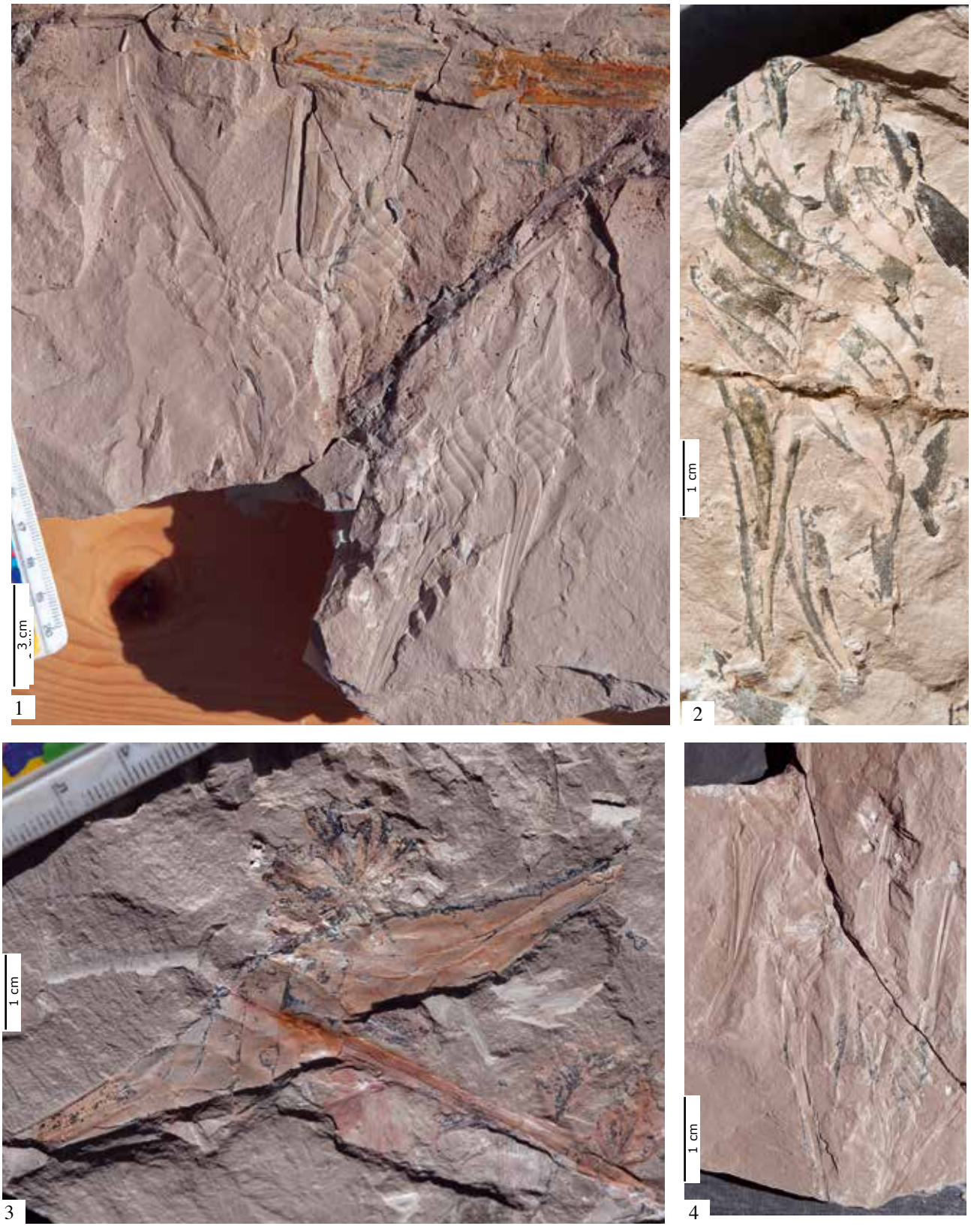

***Paleoxyris muensteri.* Shark capsules. Lower Jurassic**

1. Accumulation of shark eggs hanging from a tree trunk (PECH 369); 2. Isolated shark capsules in green chlorite (PECH 335); 3. *Thinnfeldia rhomboidales*, branch with associated fructification, and a shark capsule (PECH 675); 4. Accumulation of shark eggs (PECH 333), sand pit Küfner, Pechgraben, Ex. Coll. Wachtler, Coll. Renè Kindlimann

Paleoxyris muensteri. **Shark capsules. Lower Jurassic**

1. Accumulation of shark eggs (PECH 671); 2. *Thinnfeldia rhomboidales*, branch with associated sporophylls and a shark capsule(PECH 678); 3. Isolated shark capsule with typical tripartite tip, tail and collarette twisted in the middle (PECH 332); 4. Detail of a shark capsule (PECH 292), Sandpit Küfner, Pechgraben, Coll. Wachtler Dolomythos Museum

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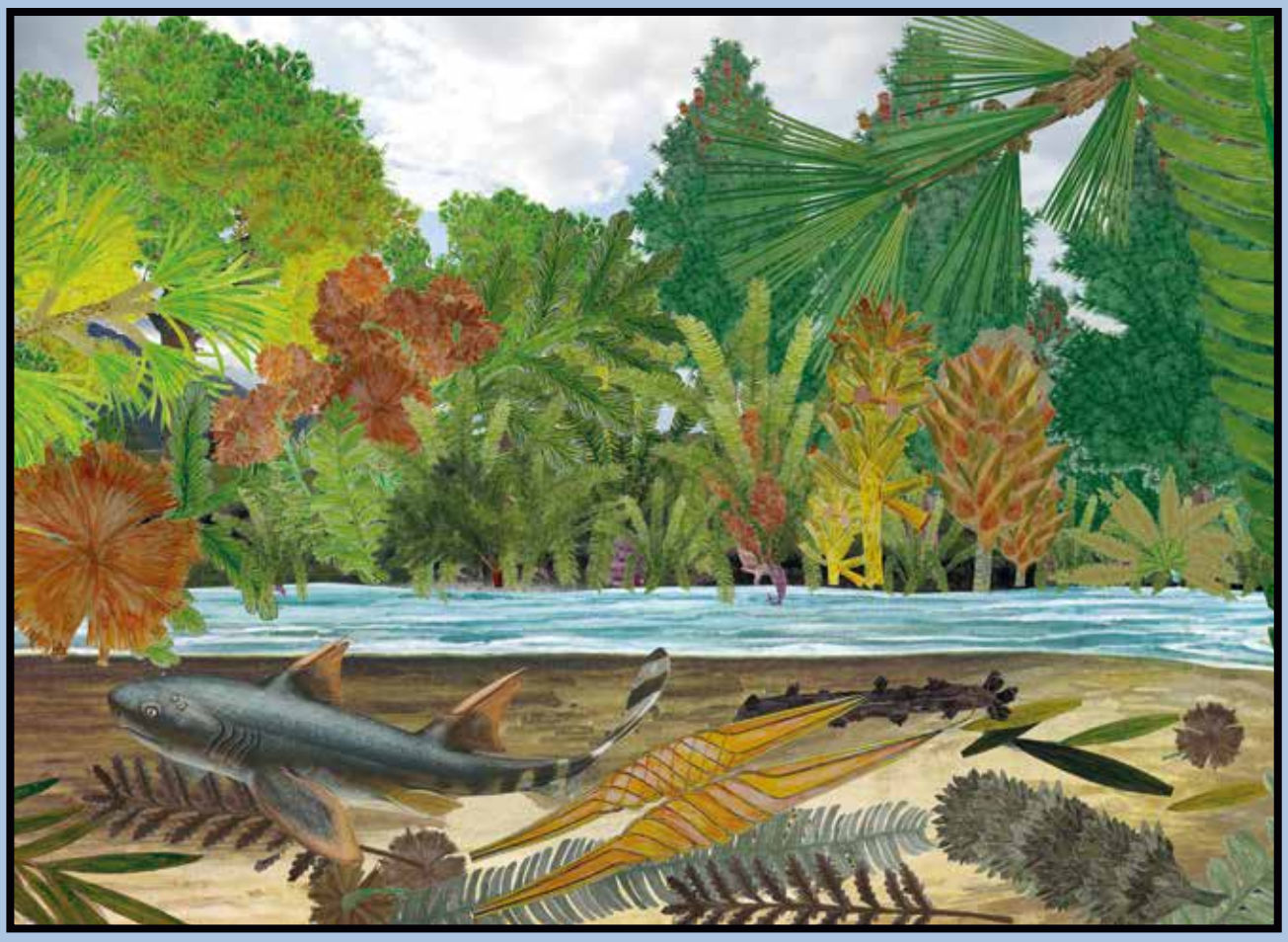
Fayolia sharovi, Capsule from a xenacanthid shark. Upper Triassic (Carnian), Dzailoucho, Madygen, Kyrgyzstan, Ex. Coll. Wachtler, Coll. Kindlimann (CH)

Shark capsules from the Carboniferous to the present

1. *Palaeoxyris prendelii*, Upper Carboniferous, Mazon Creek (Coll. Renè Kindlimann, CH); 2. *Palaeoxyris friessii,* (Ladinian, Erfurt, Formation; Ilsfeld, Coll Pohl, Großbiberau); 3. *Palaeoxyris muensteri* (PECH 442, Pechgraben, Ex-Coll. Wachtler, Coll. Kindlimann); 4. *Palaeoxyris jugleri,* Lower Cretaceous (Wealden) Nienstedt/Deister (Coll. Kindlimann); 5. Recent shark capsule of the horn shark *(Heterdontus*); 6. Recent capsule of a cat shark with embryo (Both Coll. Kindlimann, CH)



The Fossil Flora of Early Jurassic

A catastrophic decline in vegetation during the Upper Triassic period was followed by a remarkable resurgence of flora in the Lower Jurassic era. However, the family of flowering plants, which is prevalent today, was clearly absent during this time. Even potential ancestors of these plants remain unidentified. During the Lower Jurassic period, conifers such as Podozamites, Swedenborgia, and Hirmeriella dominated, although they are now only found in limited areas in East Asia, represented by species like the golden larch (Pseudolarix), umbrella fir (Sciadopitys), Taiwania, and precursors of ginkgo (Ginkgoites). Cycads, including the two-seeded Nilssonia and Ctenis, as well as the multi-seeded Macrotaeniopteris, were also quite common. Interestingly, ferns that are now rare, such as Matonia (Phlebopteris, Laccopteris) and ancestors of Dipteris (Thaumatopteris, Chlathropteris, Dicytophyllum, Sagenopteris, Otozamites), played an important role during this period. Another notable fern, Thinnfeldia, which can be classified within the large Schizaeales group due to its distinct trophophyll and sporophyll fronds, was abundant. Precursors of Marattiales (Marattiopsis) were numerous. Horsetails were represented by Equisetites and Schizoneura, while strange clubmosses such as Bernettia, Bavarostrobus and Lepacyclotes also had a notable presence, with no clear descendants identified.

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Summary

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