Fossils Explained 84

The Hunsrück Slate Konservat-Lagerstätte

The Lover Devonian Hunsrück Slate in western Germany is world-famous for its exceptionally preserved and beautiful fossils. What makes this Konservat-Lagerstätte so fascinating is its unique style of pyritization that has perfectly captured an entire ecosystem, from delicate echinoderms with preserved soft tissues to the Lovecraftian *Mimetaster*.

Jack T. R. Wilkin
Camborne School of Mines,
University of Exeter,
Penryn, UK
jack.wilkin@btinternet.com

For centuries, the Rheniisches Schiefergebirge (slate mountains) of the Rhine and Mosel valleys have been an important source of roof slates. Mining operations started in Roman times, but the earliest major mining operations became in the fourteenth century. Extensive mining continued throughout the succeeding centuries but was expanded in the late eighteenth century during the industrial revolution.

The slate industry in the Rhineland collapsed during the German Depression (1846–1849) but was revived during the surge of German nationalism during the Franco-Prussian war (1870–1871) that led to the formation of the German Empire, and thus slate exports increased. The development of rail networks and deeper shafts kept the Hunsrück mines economically viable until the emergence of cheaper synthetic slates and imports forced the many mines to close, with the last mine ending production in 1999.

Slate mining was vital to discovering fossils, with quarry workers often keeping specimens back to sell to fossil collectors and museums. The first scientific paper to be written on the Hünsruck fossil was by German geologist Ferdinand von Roemer in 1862, who described some asteroids and crinoids. Scientific descriptions of the fossils continued throughout the nineteenth and twentieth centuries, with extensive work conducted by Lehmann between the 1920s and 1950s. Research slowed down following Lehmann's death in 1959 and the decline in the slate industry.

But all was not lost. Although very few new specimens were being discovered, new photographic techniques were developed by chemical physicist Wilhelm Stürmer. Stürmer used X rays to produce stunning radiographs used soft X-rays (25–40 KV) and stereoscopic exposures combined with high-resolution film and image processing of uncut slates to reveal intricate details hitherto unseen of soft tissues revolutionising how we examine these fossils (Fig. 1).

Stratigraphy of the Hunsrück Slate

The Hunsrück Slate is part of the Rhenohercynian Zone, a Lower to Middle Devonian back-arc basin part of the Rheic Ocean whose formation and deformation were caused by the formation of Pangea at the end of the Phanerozoic. The Rheic Ocean separated the continents of Laurussia and Gondwana following the closure of the Iapetus Ocean (which resulted from the Caledonian Orogeny). As the Rhetic began to close, mountain ranges formed along the Laurussian continental shelves (Variscan Orogeny). The closure of the Rhetic Ocean merged the two continents of Laurussia and Gondwana, forming Pangaea during the Upper Carboniferous. The basins that formed offshore would have created ideal sediment traps.

The Hunsrück Slate is a thick sequence of Lower Devonian muddy marine sediments subsequently altered into slates by low-grade metamorphism. The Hunsrück is not a stratigraphical unit but rather should be regarded as a facies dating from the Late Pragian through to the early Emsian ~407 Ma. The outcrop spans a belt about 150 km long a covering an area of 400 km^2 along the Hunsrück Hills of western Germany (Fig. 2). The total thickness of the Hunsrück Stale was estimated to have been roughly 3750 m, but this includes several different formations.

The Hunsrück Slate can be dated using biostratigraphy (goniatites, tentaculites, brachiopods and trilobites) and Pb/Pb dating from magmatic zircons found within stratiform volcaniclastic layers intercalated in

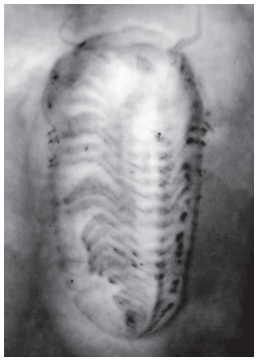


Fig. 1. Radiograph of the trilobite *Chotecops ferdinandi* showing soft tissues (antennae and legs) which can only be seen using X-rays. (Image: James St John CC-BY-SA 4.0.)

the Hunsrück Slate Formation. Both methods agree that the Hunsrück Slate Formation dates to the Lower Emisian Stage at the Lower Devonian–Upper Devonian boundary.

The mud was deposited in a narrow offshore marine basin between the recently uplifted Old Red Sandstone continent to the north and the Mitteldeutsche Schwelle to the south. Large volumes of sediment were transported into the oceans by rivers eroding down the recently formed Caledonian Mountains to the north. The area was then uplifted during the Variscan Orogeny, and the mudstones were latter subjected to low-grade metamorphism producing the characteristic slatey cleavage. The animals of the Hunsrück lived within the phototic zone as shown by photosynthetic algae, solitary rugose corals, and the well-developed eyes of fishes and arthropods.

Taphonomy of the Hunsrück fossils

The Hunsrück fossils are exceptionally well preserved with both mineralized skeletons and soft tissues, including arthropod limbs, eyes and intestines.

Pyritization of soft tissues is incredibly rare in the fossil record. The pyritization of soft tissues requires rapid burial in fine-grained sediments and very specific sediment chemistry when there is low organic content but a high concentration of dissolved iron. After burial organics are broken down by sulphur reducing bacterial to produce sulphide, the high concentration of iron converts the sulphide into iron monosulphide. Aerobic bacteria then, via oxidation, turn this into iron pyrite.

The most spectacular fossils come from the area surrounding the charming villages of Bundenbach and Gemünden in the Hahnenbach and Simmerbach valley southwest of the city of Koblenz. The Hunsrück is one of the few marine Devonian Lagerstätten to preserve soft tissues. Such preservation is extraordinarily rare in the fossil record as it is believed to require not only rapid burial but burial in sediments low in organic matter and high in sulphur and iron. Such quality of pyritization is only present in a handful of other localities worldwide, such as the Maotianshan Shales in China, the oldest Konservat-Lagerstätte of the Cambrian.

The fossil biota

The Hunsrück Slates provides an unrivalled picture of the diversity of Early Devonian fishes. More than 270 animal species have been described from this deposit. The only group of modern fish not present is the chondrichthyan because they have not yet evolved. Most of the fishes are agnathans and the now extinct placoderms. The presence of photosynthetic red algae and the well-developed eyes of fishes and arthropods suggests that the water was relatively shallow, <200 m.

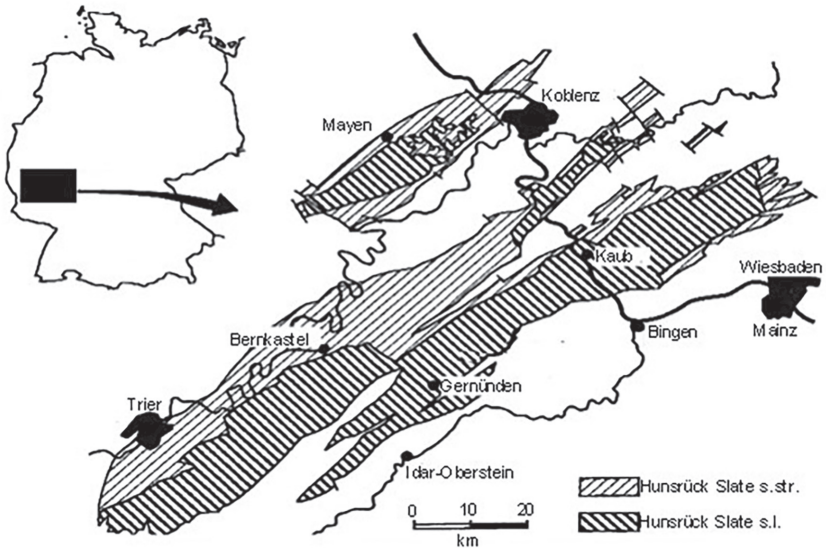


Fig. 2. Geography of the Hunsrück Slate. Redrawn from Stoup (2018).

Fishes

The agnathan, jawless, *Drepanaspis* is locally abundant and may suggest brackish conditions. This genus belongs to a group called the heterostracans, one of the groups that evolved to have armoured heads. The heterostracans were filter-feeders, using their dental plates covered in denticles. In 2002, Mark Purnell reported no signs of wear and tear on these dental plates, so he concluded that they must have been used for filter feeding. The flattened shape of *Drepanaspis* (Fig. 3) shows that it was nektobenthic as-well-as the evidence of scaping on the ventral shields. This would explain the relative abundance of this genus as a nektobenthic organism would be more likely to have been caught up in turbidity flows and thus would have been readily preserved. Therefore, the abundance of *Drepanaspis* fossils may represent a taphonomic bias.

Gemuenduna is an excellent example of convergent evolution—the process by which organisms from different taxonomic groups evolve to look similar due to selective pressure—superficially resembling a ray.

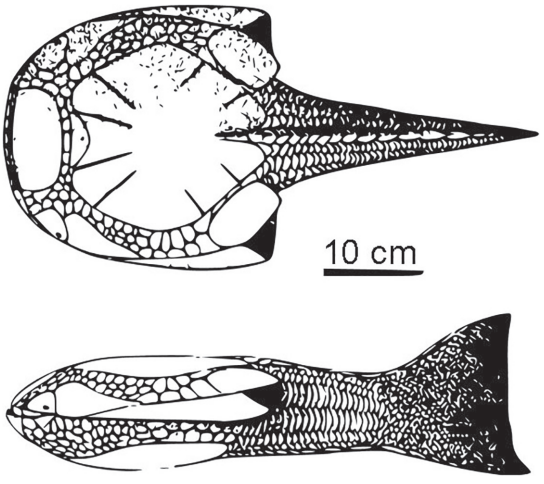


Fig. 3. Reconstruction of *Drepanaspis*. Redrawn from Delsate *et al.* (2004).

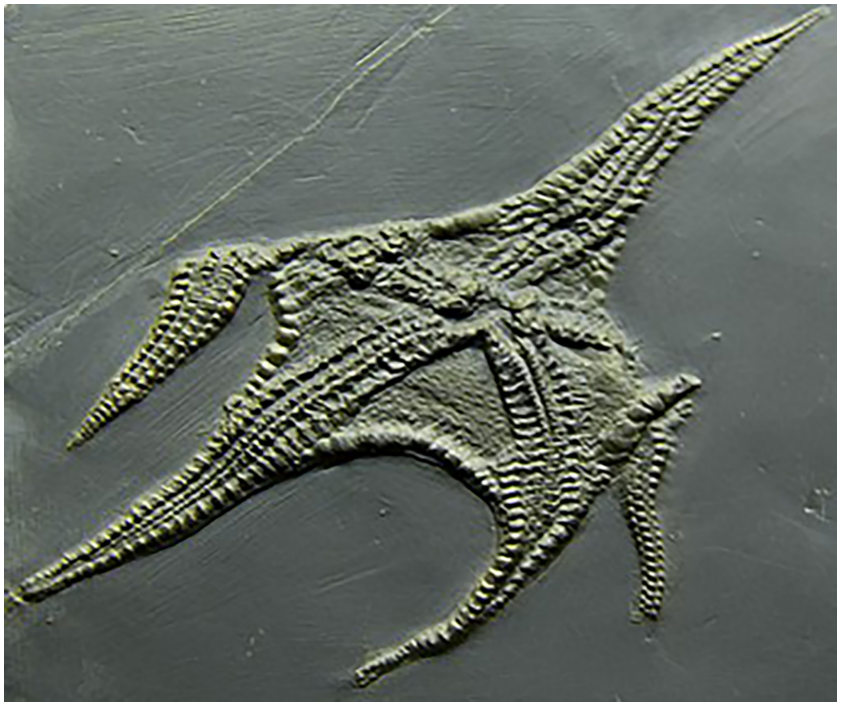
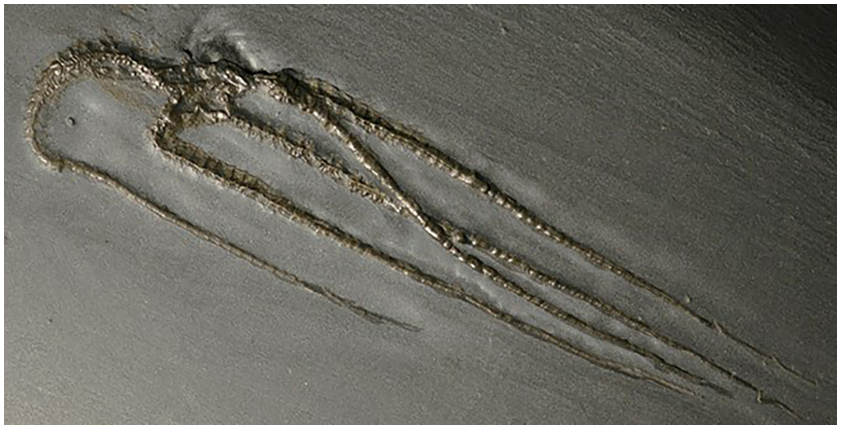


Fig. 4. The starfish *Euzonosoma tischbeiniana* still showing its soft-tissue webbing between its arms. (Image: Dwergenpaartje CC-BY-SA 4.0.)

The Placodermi, the class that contains the massive Dunkleosteus, are heavily armoured fishes represented by several genera, such a Gemuenduna, are significantly rarer than agnathans. Both groups, though unrelated, share several morphological features, including a flattened body with wing-like pectoral fins. The eyes, however, of *Gemuenduna* face upwards, and the position of the mouth suggests that it sucked in prey that swam overhead rather than feeding on the sediment as modern rays do today.

The acanthodian fish *Machaeracanthus* was very successful during the Early to early Late Devonian, having a wide distribution in the southern hemisphere from muddy bottom environments. These fossilized pectoral spines could reach up to 40 cm and are thought to have helped prevent the fish from sinking into the mud while they rested on the seafloor.

Fig. 5. The brittle star *Furcaster paleozoicus*. All five of its arms are pointing in the face direction which shows the direction of the current before burial. (Image: James St John CC-BY-2.0.)



Echinodermata

The best known of the Hunsrück fauna are the echinoderms, which are often found articulated with the fragile skin between the arms still persevered (Fig. 4). Most groups of echinoderms (echinoids, blastoids, cystoids and even sea cucumbers) are rare though amazingly preserved. Both asteroids (true starfish) and ophiuroids (brittle stars; Fig. 5) are known as both groups being represented by four genera.

The preservation of the Hunsrück echinoderms is so good that the incredibly delicate pyritized tube feet—extensible tentacles connected to the water vascular system used for locomotion, feeding and respiration echinoderms—have been found in six specimens of the brittle star *Bundenbachia beneckei*. This remarkable discovery, only made possible due to improved abrasive techniques developed by German fossil collectors, represents the first report of fossilized ophiuroid tube feet in the fossil record. Crinoids (sea lilies) are very common, with almost all the 65 species present being sessile forms attached to the substrate.

Arthropods

The Hunsrück arthropods are very diverse, with all three major aquatic groups (trilobites, crustaceans and chelicerates) known. The quality of the pyritization allows for the preservation of appendages and internal organs. Some of the more enigmatic forms include one of the earliest known examples of sea spiders in the fossil record and the star-shaped taxon *Mimetaster*.

Sea spiders (pycnogonids) are rare in the fossil record with three genera known from the Hunsrück Slate: *Palaeoisopus*, *Palaeopantopus* and the tiny *Palaeothea*. *Palaeoisopus* has some unusual features for sea spiders: the swimming legs are of an alternating size. In contrast, modern pycnogonids have equal length limbs. The abdomen of *Palaeoisopus* is also very long and segmented but are reduced in modern sea spiders. The large eyes and paddle-like legs of *Palaeoisopus* suggest that they were active nektonic predators and likely preyed on stalked crinoids (Fig. 6). *Palaeothea* was, at the time of its description, the only known fossil representative of the extant order Pantopoda, implying that entirely modern forms were in existence already in the Early Devonian.

Mimetaster is the most common non-trilobite arthropod from the Hunsrück. This bizarre animal had a star-shaped dorsal shield with a pair of powerful walking limbs on its head and a short trunk of up to 30 segments each with a pair of biramous—meaning that they divide to form two branches—limbs. *Mimetaster* and the small Vachonisia have a body plan reminiscent of the earlier Burgess fauna of the Middle Cambrian and have been referred to the clade Marrellomorpha.

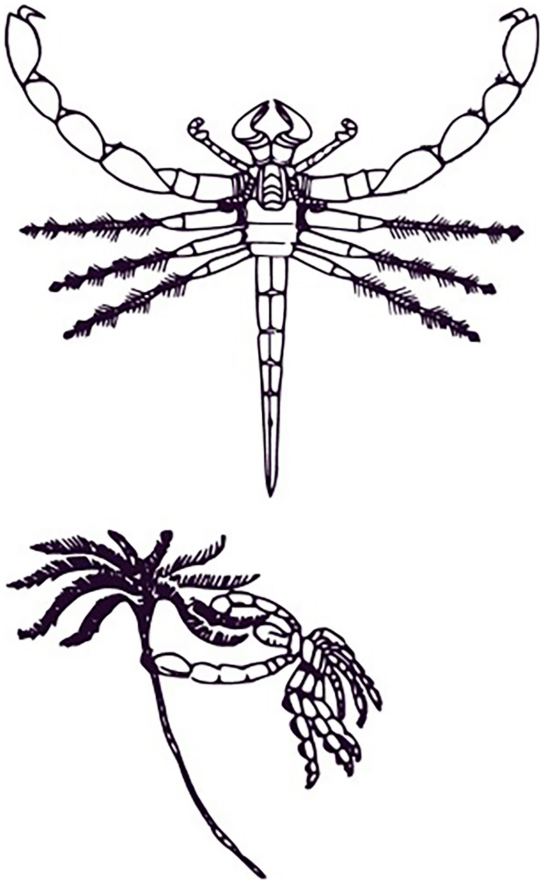


Fig. 6. Reconstructions of *Palaeoisopus* (top) and *Palaeoisopus* attacking a crinoid (bottom). Redrawn from Bergström *et al.* (1980).

Other Hunsrück arthopods include the anomalocarid *Schinderhannes bartelsi* (Fig. 7). Anomalocarids are large predators thought to have gone extinct during the Cambrian. The famous *Anomalocaris* from the Burgess Shale of Canada could reach a metre in length and have grasping appendages on their heads and circular mouthparts. Some species were even adapted for filter feeding, their frontal appendages resembling the baleens of modern whales. *Schinderhannes* shows that these enigmatic animals survived for at least 100 Ma after the end of the Cambrian, and together with the marrellomorphs, suggest that the lack of Burgess-type fauna may be a preservation bias.

Other invertebrates

Several other groups of invertebrates are recognized from the Hunsrück Slate. Polychaete worms ('bristle worms') are entirely soft-bodied, and as such, their fossil record is very sparse because the tissues of polychaetes decay readily after death. In total four species of annelid (*Hunsrueckochaeta hohensteini*, *Ewaldips feyi*, *Crocancistrius lutzi* and *Scopyrites magnus*), have been described from the Hunsrück Slate. The diversity of Hunsrück annelids represented is similar to that in the other major Palaeozoic Konservat-Lagerstätten that yield them, including the Cambrian Burgess Shale in Canada and the Late Carboniferous Mazon Creek biota in the United States.

Other groups include siliceous sponges, cnidarians (including the first known fossil comb jellies), corals, molluscs (goniatites, orthoconic nautiloids and gastropods) with some specimens with preserved tentacles emerging from their shells, and even brachiopods with preserved soft tissues including the pedicle.

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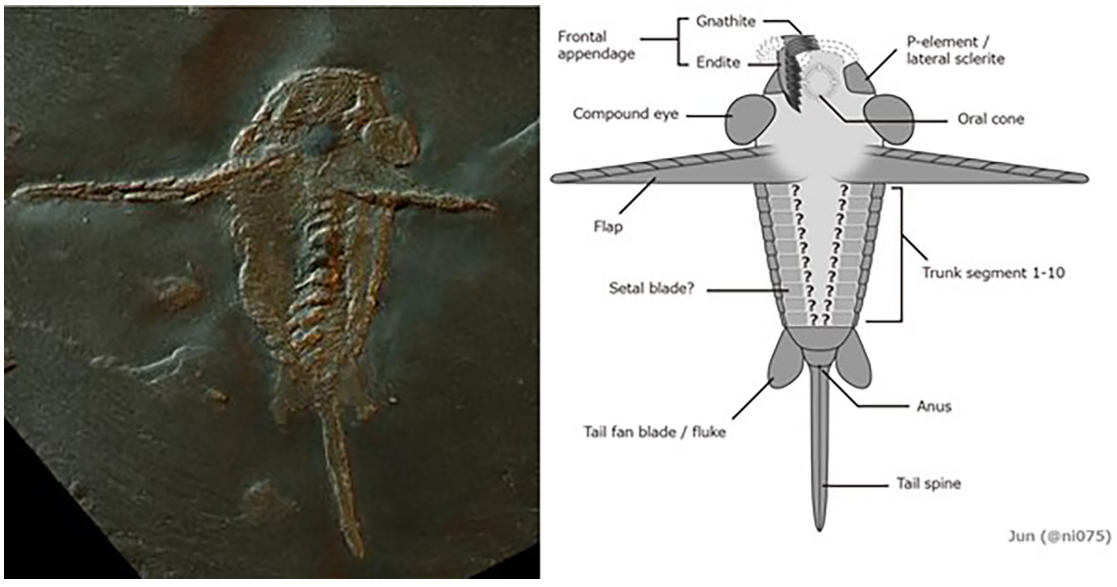

Fig. 7. Fossil (left) and reconstruction (right) of *Schinderhannes*. (Image: Junnn11—CC-BY-SA 4.0.)

Suggestions for further reading

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