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Lower Devonian Hunsrück Slate of Germany

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ROOFS AND TILES

Visitors to this part of Germany cannot fail to notice the dark grey slate roofs and walls in the picturesque towns along the rivers Rhine and Moselle. The Hunsrückschiefer belongs, together with the Lower Jurassic Posidonia Shale and the Upper Jurassic Solnhofen Lithographic Limestone, to those sediments that have been exploited since ancient times for building purposes. The discovery of a large number of world-famous fossils in these strata is, therefore, due to the observation and skilled manual work of quarrymen preparing the slabs and tiles. Fossils wrested from the dark grey Hunsrück Slate are mostly small and, therefore, may not be quite so spectacular as those from some other sites, but they open a fascinating window onto the development of life in these early times.

DECLINE OF A CRAFT

The Hunsrückerschiefer is exposed in the Rheinisches Schiefergebirge between Koblenz, Trier and Mainz. The best localities for well-preserved fossils are the communities of Bundenbach and Gemünden. The slates were widely quarried in former times (slates for roofs, etc.); and during the 19th and present centuries, more than 600, mostly small, pits were exploited. Today, only one quarry remains open in the main fossiliferous region of Bundenbach. Unlike other famous *Lagerstätten*, the Hunsrück Slate has not undergone detailed sedimentological examination with modern techniques.

THICK SEDIMENTS FROM THE REMAINS OF AN OLD CONTINENT

The slates are of Early Devonian age and were deposited from the Late Siegenian (Late Pragian) Stage and ceased towards the end of the Early Emsian Stage (age about 390 million years). The sediments were deposited in a number of offshore basins separated by swells. Downwarping allowed the Hunsrück Slate to reach thicknesses that were estimated to be as much as 4,000 m but were probably considerably less (see Bartels *et al.* 1998). The Hunsrückschiefer proper (also called 'Dachschiefer' for its use as tiles for roofs) was laid down during the early Lower Emsian. A main belt of Hunsrückschiefer runs southwest to northeast for about 150 km (Fig. 121); smaller areas occur west and southeast of Koblenz. To the north and west the facies of the slates passes into sandy sediments with a shallow-water fauna dominated by brachiopods; the crinoids here are mostly sturdier (Schmidt 1942). To the south the thickness of the Hunsrückschiefer is reduced to about 200 m, and to the east open marine sediments were laid down (Mittmeyer 1980). Thus, deposition of the Hunsrückschiefer occurred in subsiding basins that were separated by swells

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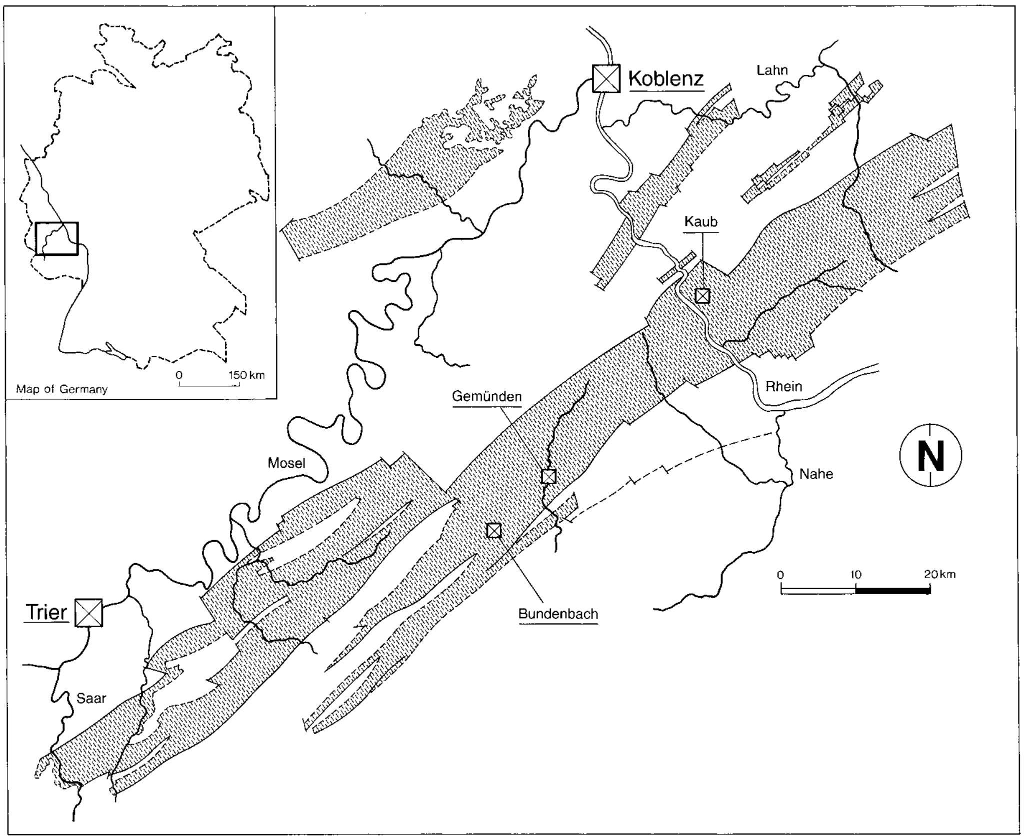


Fig. 121. Palaeogeography of the Hunsrückschiefer facies (stippled) in the Rhenish Massif. (Redrawn from Mittmeyer 1980.)

with reduced and partly sandy sedimentation. Mass occurrences of pelagic tentaculitoids in certain layers suggest the influence of an open ocean; water depth in the offshore setting of the slates has been estimated to be 40–60 m (Bartels & Blind 1995). This is considerably less than a depth of more than 200 m derived from sedimentary structures and trace fossils (Seilacher & Hemleben 1966), but is more in line with the occurrence of well-developed eyes of arthropods and vertebrates (Stürmer & Bergström 1973); see the section titled 'A Wealth of Fossils').

The Hunsrückschiefer, with a thickness of up to 1,000 m in the Bundenbach area, was deposited from clay and silt swept in by rivers from land situated to the northwest. The sedimentation rate varied in the Hunsrück Basin. The mudstone (made up of clay and silt) was transformed into slate under pressure during later Variscan mountain-building and thereby compressed to a tenth of its original thickness. Unfortunately, the bedding planes and, therefore, most fossils do not lie parallel to the cleavage planes of the slates.

PYRITE AND X-RAYS

The fossil remains are usually covered by a pyritic surface layer. When burial was rapid, the fossils, such as the delicate crinoids, were commonly completely replaced by pyrite, in which case preservation is excellent. Pyritized fossils can be examined in 0.5- to 1-cm-thick slabs by X-ray technique before preparation (Fig. 122); see Bartels and Blind (1995) for a discussion of pyritization and X-ray technique. This is of considerable help because the fossils cannot easily be separated from the fine-grained sediment matrix. Museum collections give the impression that intact fossils are the rule. However, the Hunsrück Slate contains mostly disarticulated remains, intact specimens being more common for sturdily built organisms, such as trilobites and their moulted carapaces. Due to the dissolution of thin calcareous shells (brachiopods, lamellibranchs, gastropods and cephalopods), such organisms were not well preserved, so that the number of fossils gives a biased picture of the original communities. Also, because the slates be-

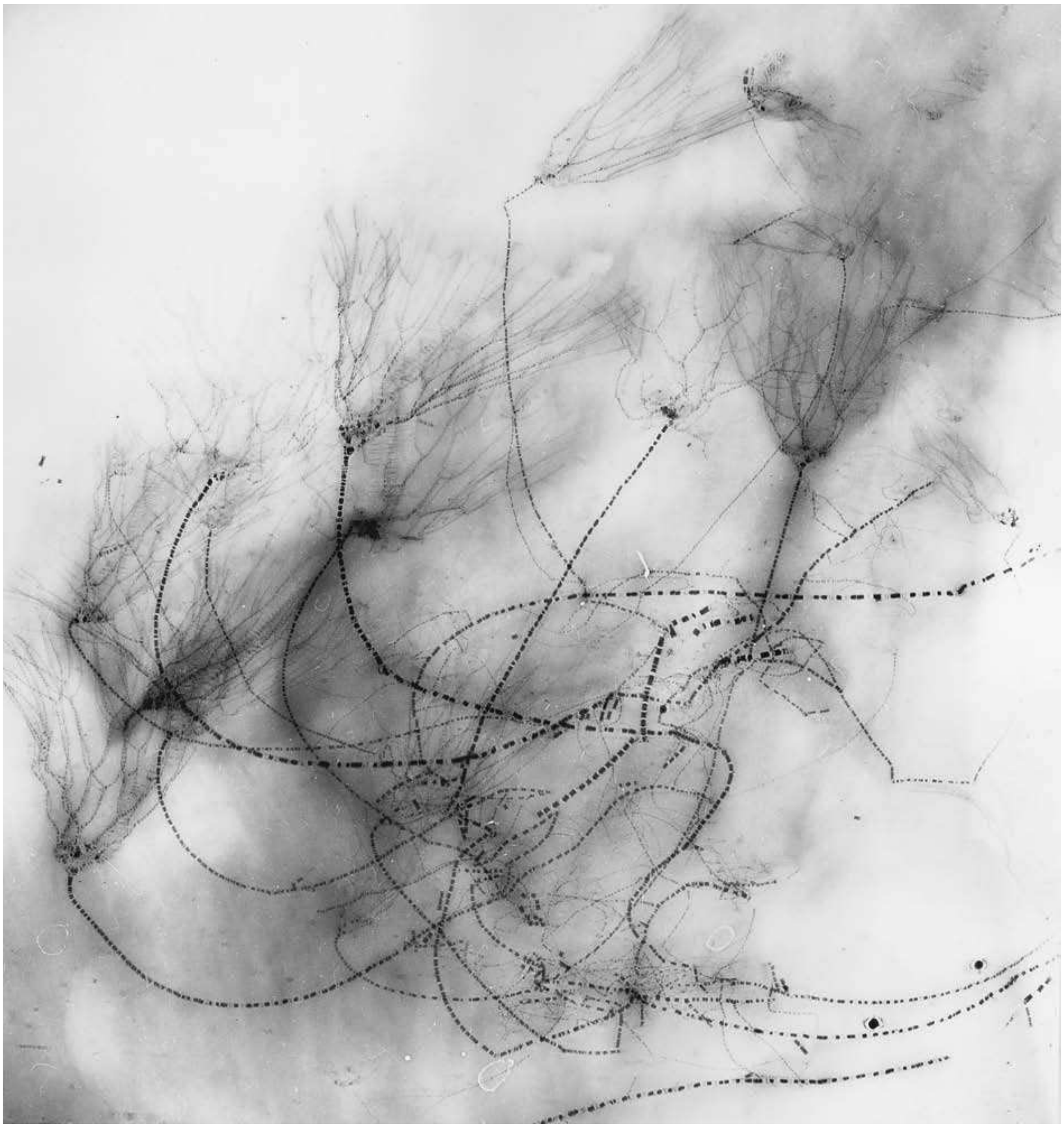


Fig. 122. X-ray photograph of a group of *Parisangulocrinus zeaeformis* with radicular cirri. Hunsrückschiefer, Bundenbach. (Staatliches Museum für Naturkunde Stuttgart; original photograph by W. Stürmer, whose contributions to the X-ray photography of Bundenbach fossils are outstanding; courtesy M. Urlichs.) ×1.

came famous for their arthropods and echinoderms, quarrymen ignored less spectacular fossils. It must be realized that excellently preserved fossils are confined to localized patches, mainly around Bundenbach and in some other localities from the Rhine valley to the middle part of the Hunsrück, where they are restricted to a few horizons. Soft-body preservation is quite exceptional.

A WEALTH OF FOSSILS

To date, at least 264 different species and subspecies of animal fossils have been described from the Hunsrück Slate, which also includes 6 species of plants and 46 species or subspecies of land-based spores (Bartels *et al.* 1998). In the main depositional basin (localities of Kaub, Bundenbach and Gemünden), echinoderms are concentrated in the southwestern part around Bundenbach, whereas the northeastern part is rich in brachiopods. Corals and trilobites with well-developed eyes are in sediments from the more shallow environments as well as from the central basin areas. This suggests moderate water depths of considerably less than 200 m (Mittmeyer 1980; Bartels 1995). Breaks in sedimentation in the shallow-water areas indicate sporadic emergence. However, remains of land plants (*Psilophyton*) and spores are found only rarely.

Animal fossils include rare sponges and jellyfish, corals and, more commonly, conularians, brachiopods, gastropods (frequent in silty and sandy layers), lamellibranchs and cephalopods (*Orthoceras* and early ammonoids). Traces of worms are abundant in places. Certain horizons are filled with tiny tentaculitoids, pelagic inhabitants of the open ocean to the south. The main attractions, as demonstrated in numerous museum and private collections, are the arthropods (trilobites and others) and echinoderms, as well as the rather rare vertebrates. About 50 species of asterozoans have been described. Other echinoderms, such as holothurians (mostly isolated sclerites and parts from the calcareous mouth ring), echinoids, homalozoans, cystoids and blastoids are present, but only crinoids are very common, especially as disarticulated ossicles. The vertebrates include flattened jawless and other fishes, which were living on or near the bottom in the Bundenbach area. From other regions numerous remains of sharks have been reported. For a complete overview see Bartels *et al.* (1998).

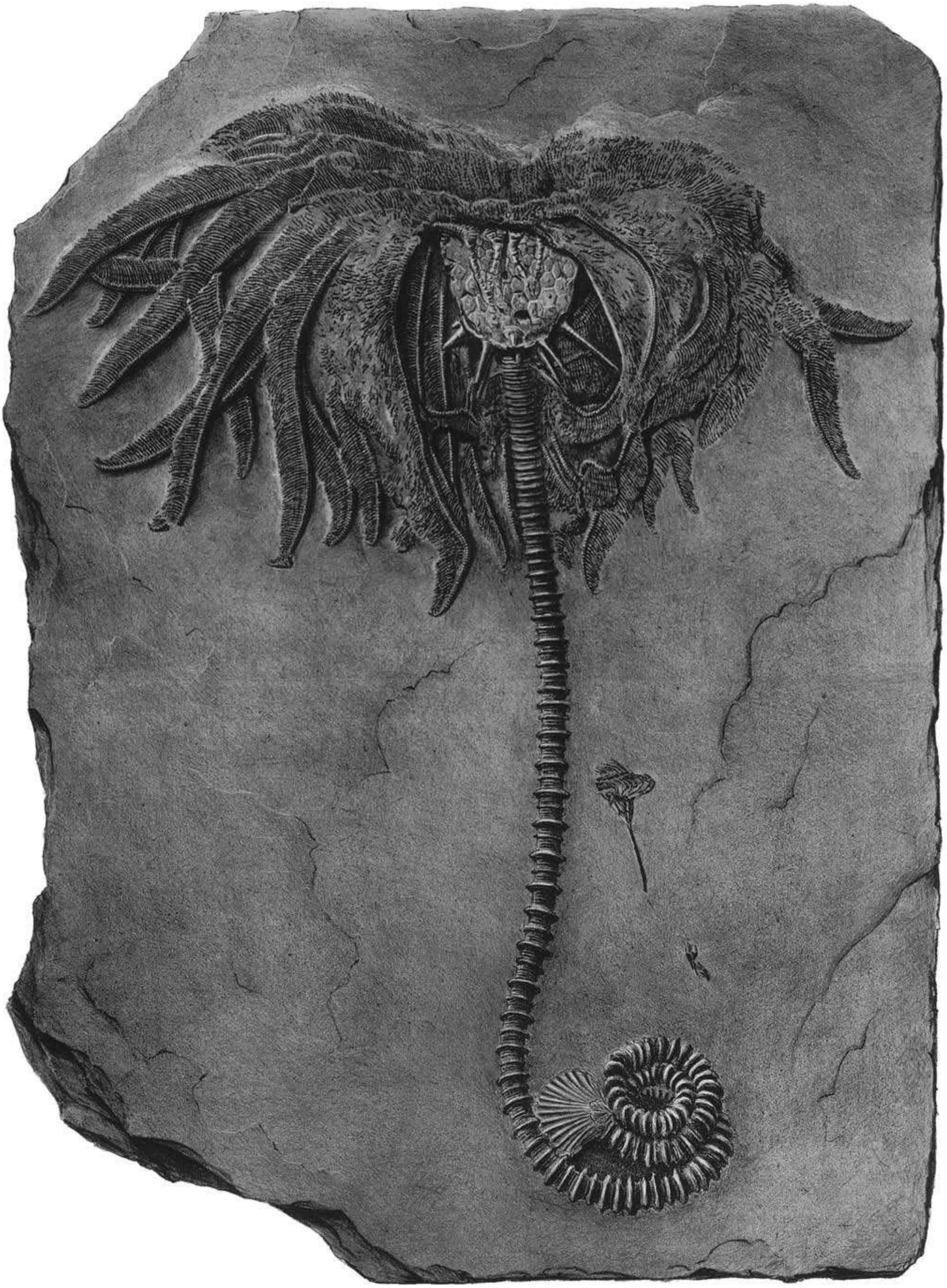
THE DELICACY OF MOST CRINOIDS

According to Bartels *et al.* (1998), the 63 crinoid species from the Hunsrückschiefer belong to 30 genera. All the main Palaeozoic groups are represented, most commonly with the cladid genera *Codiacrinus*, *Imitatocrinus* and *Parisangulocrinus*, the disparid genera *Calycanthocrinus* and *Triacrinus* and the camerates *Hapalocrinus* and *Thallocrinus*; the flexible *Eutaxocrinus* is somewhat less common (Südkamp 1995). Crinoids vary from heavily branched forms with numerous arms to *Triacrinus* with only five long arms (Fig. 129). Some species have long anal tubes with protective spines; on others such spines are missing. This is also true of the cup (see Fig. 124 for a cup with spines). According to Schmidt (1934), almost half of the species show some development of spines. Animals that might have fed on the crinoids appear to be uncommon. The snail *Platyceras* has been found on the cup of only two species. Stem lengths vary considerably, but the stems are generally rather long in comparison with the crown (Figs. 122, 125–127); those of *Eutaxocrinus* may reach a length of more than 1 m. Most of the crinoid species are unique to the Hunsrückschiefer, whereas these strata share about half of the genera with the sandy Lower Devonian facies. It appears that the different crinoids occupied separate niches by collecting food at different elevations above the sea floor. Most crinoids in the Hunsrücker Slate are lightly built with small cups, in contrast to the sturdy animals in the nearby contemporaneous sandy facies. This points to a rather sheltered life on the muddy bottom, protected from regular wave action. Even under higher magnification, the Hunsrückschiefer crinoids do not readily show detailed structures of stem and crown, but they beautifully illustrate the different lifestyles of an extraordinary assemblage. We have therefore chosen, for discussion in the following section, a set of complete individuals and groups with different modes of attachment.

ATTACHMENT STRATEGIES ON A MUDDY SEA FLOOR

Crinoids attached themselves with radicular cirri or roots, commonly to hard objects lying on the muddy bottom, such as shells of *Orthoceras* (Figs. 123, 126), brachiopod valves (Fig. 128) or corals (Fig. 125). In many instances, crinoids attached themselves to stems, some of them lying on the sea floor, of other crinoids. Juvenile individuals particularly preferred the stems of adult individuals (Figs. 125, 127). Crinoids that were rooted in the muddy sea floor by radicular cirri growing

Fig. 123. (*On facing page*) *Hapalocrinus elegans* (upper right, with 10 pinnulate arms) and several *Parisangulocrinus zeaeformis*, a form without pinnules, growing out of the body chamber of an empty *Orthoceras* shell. On the outer surface of the shell, small crinoid roots are preserved whose stems and crowns were presumably torn off the shell while it was scraping or rolling along the bottom before burial. Hunsrückschiefer, Bundenbach. (Geologisch-Paläontologisches Institut, Johann Wolfgang Goethe-Universität, Frankfurt a.M.; figured by Seilacher 1961; courtesy K. Vogel.) ×0.6.



from the distal end of the stem appear to be exceptional (Fig. 129). Rare discoidal holdfasts are found only in the Eifel region, where hard substrates occur. The rare *Acanthocrinus rex* used the strategy of a coiled distal stem for fixation, as shown by the famous type specimen (Fig. 124). It is interesting that the same species may vary considerably in the development of its stem (length, occurrence of radicular cirri). In a few instances, crinoids were attached to rarely occurring sponges, rooted in the soft sediment by means of root tufts. By virtue of its attachment to the sponge, a specimen of *Dictenocrinus semipinnulatus* figured by Südkamp (1992) seems to have needed only a short stem (3 cm) for elevating the crown high enough into the current, whereas other specimens of this species have much longer stems. The calceocrinid *Senariocrinus maucheri* (Fig. 30) has a rudimentary, tapering stem. The anal sac is articulated to the cup and, therefore, could be moved like an arm, perhaps to release waste material downcurrent. Schmidt (1934) thought that *S. maucheri* with its rudimentary stem was free-living and could even swim. As already discussed, we think it more probable that this animal lived on the muddy bottom, used the stem for attachment and raised the crown for feeding.

BOTTOM LIFE WITH CURRENTS AND OCCASIONAL MUD SLIDES

Hunsrückschiefer fossils represent mainly sessile and vagile benthic organisms and include numerous trilobite tracks. This is proof of a rich bottom life on the muddy sea floor. The Hunsrück Slate was deposited in several environments (Bartels *et al.* 1998). The shallower parts of the submarine fan above storm level basis were fully oxygenated; the shelly bottom fauna was therefore not pyritized. Density currents from channel distributories reached the lower parts of the fan; the current-transported sediment was initially oxygenated and supported an infauna. The classic fossil sites of Bundenbach and Gemünden are preserved in interchannel areas with oxygenated bottom water that allowed the establishment of bottom communities. Occasional density currents buried the animals, many of them where they lived, and the thick sediment layer protected them from scavengers. The iron-rich sediment rapidly became anoxic beneath the surface, leading to conditions that promoted pyritization and further inhibited any scavengers.

Disarticulated specimens and oriented fossils as well as ripple marks and flow marks point to the occasional presence of rather strong bottom currents (Koenigswald 1930; Seilacher 1960). Rapid burial must have occurred in the case of completely preserved crinoids as well as the many current-oriented intact asterozoans, whereas disarticulated specimens must have lain on the sea floor for some time or represent previously buried and decayed specimens exhumed and disarticulated by bottom currents. The mobile asterozoans seem to have been swept into somewhat deeper water, where the crinoids were anchored; in some instances the crinoid stems served as traps. It has been observed that the root part of crinoid stems is commonly on a lower bedding plane than the crown (Fig. 125). Larger groups may pierce up to 3 cm of slate that were compressed from 20–30 cm of mud (Bartels 1995). Such cases indicate rapid burial of the crinoids by a considerable amount of sediment from a turbidity current or a tempestite event. Arthropods (mainly trilobites) are preserved in all possible positions, including sideways, indicating that they came to rest in pasty mud (Bartels 1995). In addition, groups of crinoids of all age classes have been found, including individuals with a size of only a few millimetres, the young ones often attached to adult animals of the same or some other species (Figs. 125, 127). Such specimens were buried at or near the place of living. However, other crinoids have been detached and transported for at least a short distance before burial. Opitz (1932) pointed out that the majority of crinoids are found with broken stems. Intact specimens, as shown in our figures, are quite exceptional. The burial events with preservation of soft tissues at certain horizons were local in extent; their distribution reflects considerable relief on the sea floor within the basin (Bartels *et al.* 1998). This is in line with local differences in the composition of the Hunsrück fossils, which derive from different communities.

Fig. 124. (*On facing page*) *Acanthocrinus rex.* The specimen – certainly one of the most beautiful crinoids ever found – belonged to the collection of the Preussische Geologische Landesanstalt (Geologisches Landesmuseum), Berlin; it was lost during World War Two. Visible to the right of the stem are one larger and four small specimens of the blastoid *Pentremitidea medusae*. The shell at the coiled end of the stem may have belonged to a brachiopod. Hunsrückschiefer, Kaub. (Photograph S. Dahint from Jaekel's 1895 original lithographic plate.) ×0.8.

Fig. 125. (*On facing page*) *Eutaxocrinus stürtzii* attached to a rugose coral; fixed to the middle part of the stem is a juvenile *Hapalocrinus elegans*. The slab has been prepared from below, the stem was broken at a distance of about a third from the crown, and this proximal part is in a somewhat higher sediment layer. It must be assumed that the distal part of the stem of the *Eutaxocrinus* with its radicular cirri was lying on the sea floor while the crown and the proximal part of the stem were elevated into the water. The stem must have been broken during burial. The animal appears to have initially grown on the coral and formed its dense network of radicular cirri only later. Hunsrückschiefer, Bundenbach. (C. Bartels Collection; Deutsches Bergbau Museum, Bochum; photograph A. Opel; courtesy C. Bartels.) This photograph as well as those in Figs. 126–129 are of specimens treated with mineral oil; they therefore appear lighter than that in Fig. 123 and many Hunsrückschiefer fossils figured previously. ×0.5.

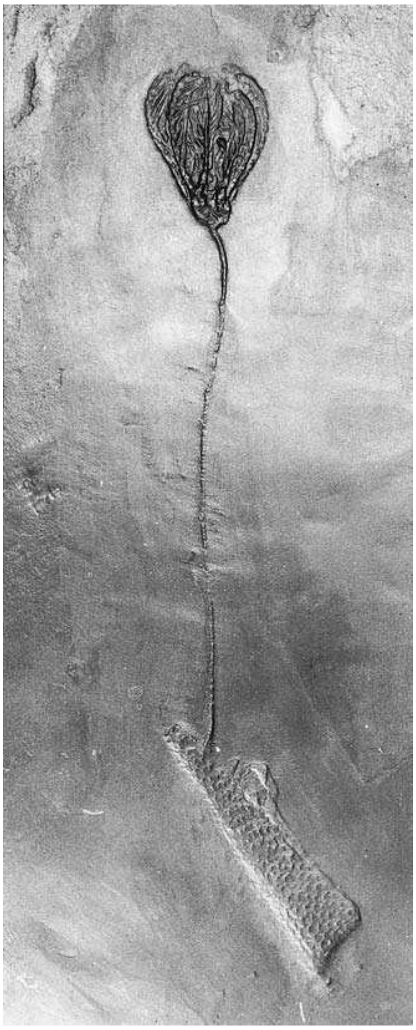


Fig. 126. *Thallocrinus procerus* anchored to the shell of a small orthocone cephalopod, which is overgrown with epizoic tabulate corals. Hunsrückschiefer, Bundenbach, Eschenbach-Bocksberg pit. (G. Brassel Collection; preparation and photograph C. Bartels; courtesy C. Bartels.) ×0.8.

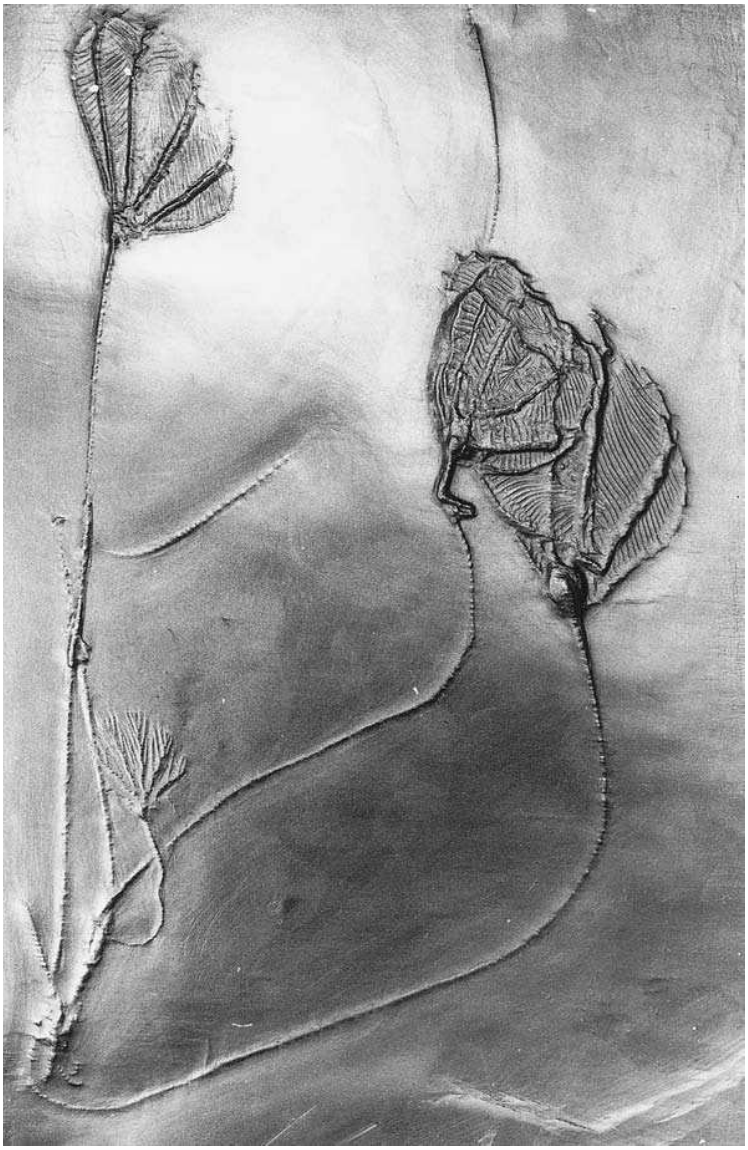


Fig. 127. Three adult and one juvenile specimen of *Hapalocrinus frechi*, anchored to the stem of a fifth, now-lost crinoid. Hunsrückschiefer, Bundenbach, Eschenbach-Bocksberg pit. (G. Brassel Collection; photograph C. Bartels; courtesy C. Bartels.) ×0.6.

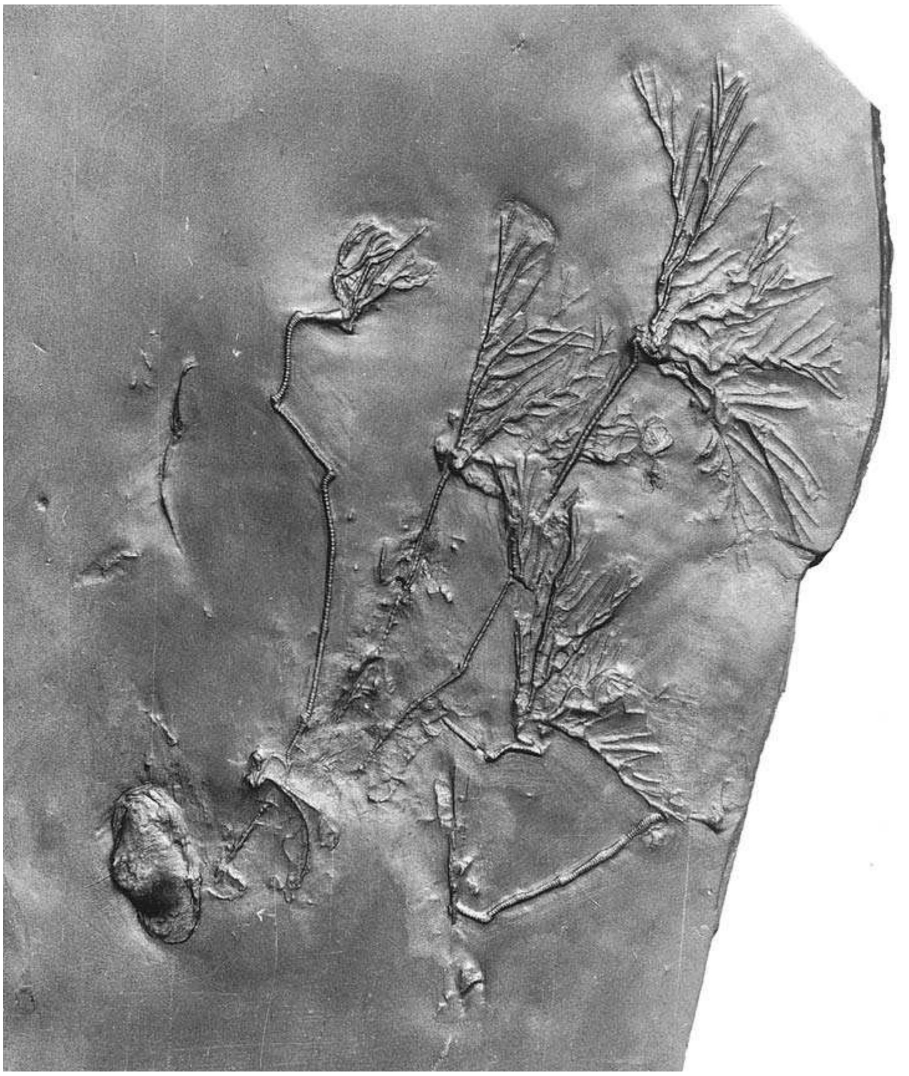


Fig. 128. Group of three *Rhadinocrinus* sp. (right) and one *Bactrocrinites jaekeli* (left), anchored to a brachiopod shell; stem and cup of another specimen of *Bactrocrinites* are visible at lower right. Hunsrückschiefer, Bundenbach, Eschenbach-Bocksberg pit. (G. Brassel Collection; preparation and photograph C. Bartels; courtesy C. Bartels.) ×0.9.

IMPORTANT COLLECTIONS IN GERMANY

Bayerische Staatssammlungen für Paläontologie und historische Geologie, Munich. This contains a large collection of Ferdinand Broili with many specimens described from the Hunsrückschiefer; in addition, important private collections (Maucher, Rievers) were deposited here.

Humboldt University, Berlin. This has taken over the collection of the former Reichsstelle für Bodenforschung with specimens collected by F. Kutscher before World War Two. Many of W. E. Schmidt's originals are deposited here.

Museum am Besucherbergwerk Bundenbach (started in 1993). The collection of the community shows a cross section of the local Hunsrückschiefer fauna.

Natur-Museum Senckenberg, Frankfurt a.M. This important museum contains a large part of the Opitz Collection, as well as the Rudolf and Emma Richter Collection. The classic X-ray films of Stürmer are

also preserved here, as will be in the near future G. Brassel's collection, one of the most important ones accumulated since World War Two.

Schlossparkmuseum Bad Kreuznach. This contains parts of the collection of Opitz as well as the Herold Collection with numerous type specimens. Opitz and Herold accumulated the most important collections made between 1920 and 1939.

University of Bonn, Geological Institute. This collection contains many of the beautiful asterozoans described by Lehmann (1957), and was accumulated between 1930 and 1959.

Deutsches Bergbau Museum, Bochum. This houses the unique Bartels Collection, with an almost complete documentation of the Bundenbach area and other, largely unknown Hunsrückschiefer sites in the southeast Eifel region.

Fig. 129 *Triacrinus koenigswaldi*, specimen with dense tuft of root radicular cirri at the end of the stem. This form has three basals and five long, unbranched arms. Hunsrückschiefer, Bundenbach, Eschenbach-Bocksberg pit. (Collection, preparation and photograph C. Bartels; Deutsches Bergbau Museum, Bochum; courtesy C. Bartels.) ×1.