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Middle Jurassic of Northern Switzerland

HANS HESS

A SCHOOLBOY'S DELIGHT

In the surroundings of Basel, four different and unique crinoid beds occur. These fossils fascinated the author of this chapter when he was a young boy. The description of *Paracomatula helvetica* was also his first publication (Hess 1950).

The crinoid beds with four different species are exposed in the Jura Mountains of northwestern Switzerland (Fig. 207). One species also occurs in eastern France and ranges as far as England. Four different horizons, each characterized by its fauna, can be distinguished (Fig. 208):

1. Beds with well-preserved specimens of the isocrinid *Chariocrinus andreae* occur within an area of about 200 km^2 in the canton of Baselland. A small slab with *C. andreae* was mentioned and figured in Bruckner's monumental description of historical and natural sights (*Merkwürdigkeiten*, curiosities) of the Basel countryside, published between 1748 and 1763. At that time, the true nature of the *Chariocrinus* remains was unknown, and they were referred to as plants.
2. Beds with *Pentacrinites dargniesi* occur at several sites in the Swiss Jura and in eastern France; the species was first described in 1869 from the Moselle region. This species had a wider range than previously assumed, as documented by specimens from the Forest Marble of Wiltshire, now housed in the Natural History Museum in London, and from the Bajocian of Department Isère, France.
3. A lens with the comatulid *Paracomatula helvetica* was exposed in a trench dug in 1940 as a defensive measure by the Swiss Army near Hottwil, on a strategic hill not far from the Rhine. A few individuals of this species have also been found in the Schinznach Quarry mentioned in the next section.
4. A lens with the isocrinid *Hispidocrinus* (formerly assigned to *Chariocrinus) leuthardti* was discovered on a shooting range near Liestal and exploited between 1892 and 1903 by Franz Leuthardt (1904), a schoolteacher and renowned naturalist. This is the youngest of the four beds and the only one that the author has not seen in the field. So far this species has not been found elsewhere.

CELTIC PLATFORM AND SWABIAN REALM

All localities are of Middle Jurassic age, about 165 million years before present. At the beginning of this period, dark mudstones of Early Aalenian age were deposited in northern Switzerland under uniform, partly anoxic conditions. This Opalinum Clay is overlain by Late Aalenian and Early Bajocian shales, sandstones, sandy limestones and iron oolites. To the west, bioclastic (mainly crinoidal) limestones formed in the Late Bajocian. These belong to the western part of a shallow-

Hans Hess, William I. Ausich, Carlton E. Brett, and Michael J. Simms, eds., *Fossil Crinoids*.

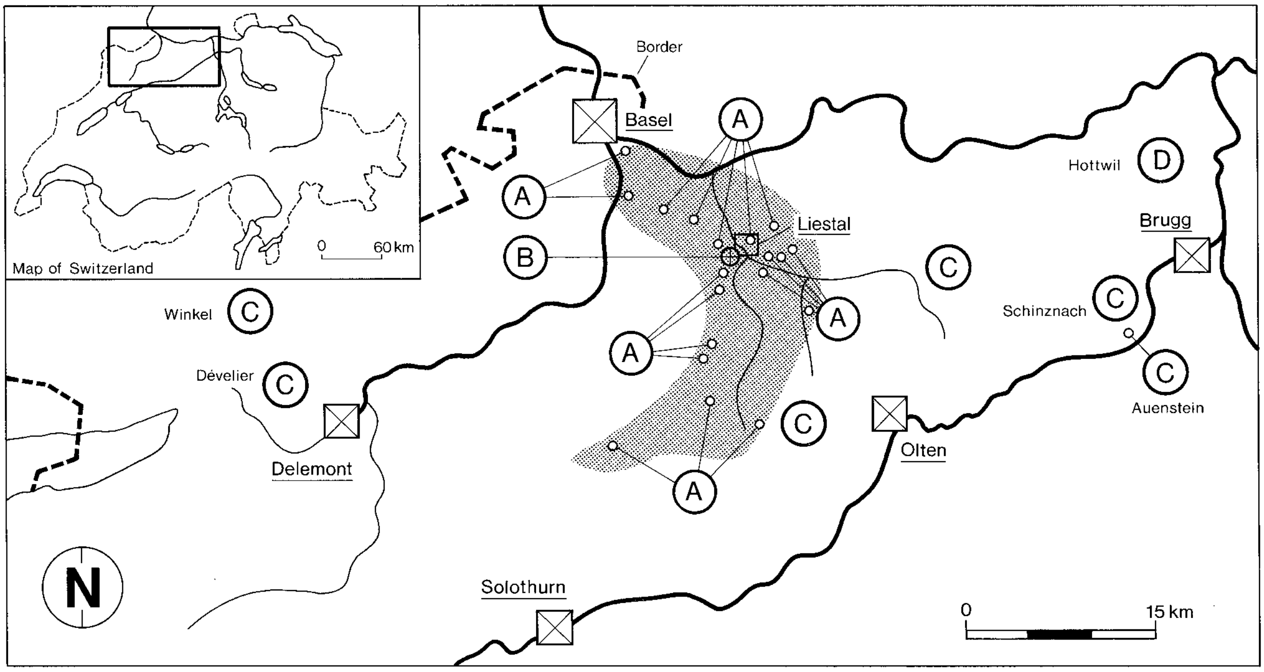


Fig. 207. Crinoid locations in northern Switzerland. (A) *Chariocrinus andreae* (Bajocian); (B) *Hispidocrinus leuthardti* (Bathonian); (C) *Pentacrinites dargniesi* (Bajocian); (D) *Paracomatula helvetica* (Bajocian).

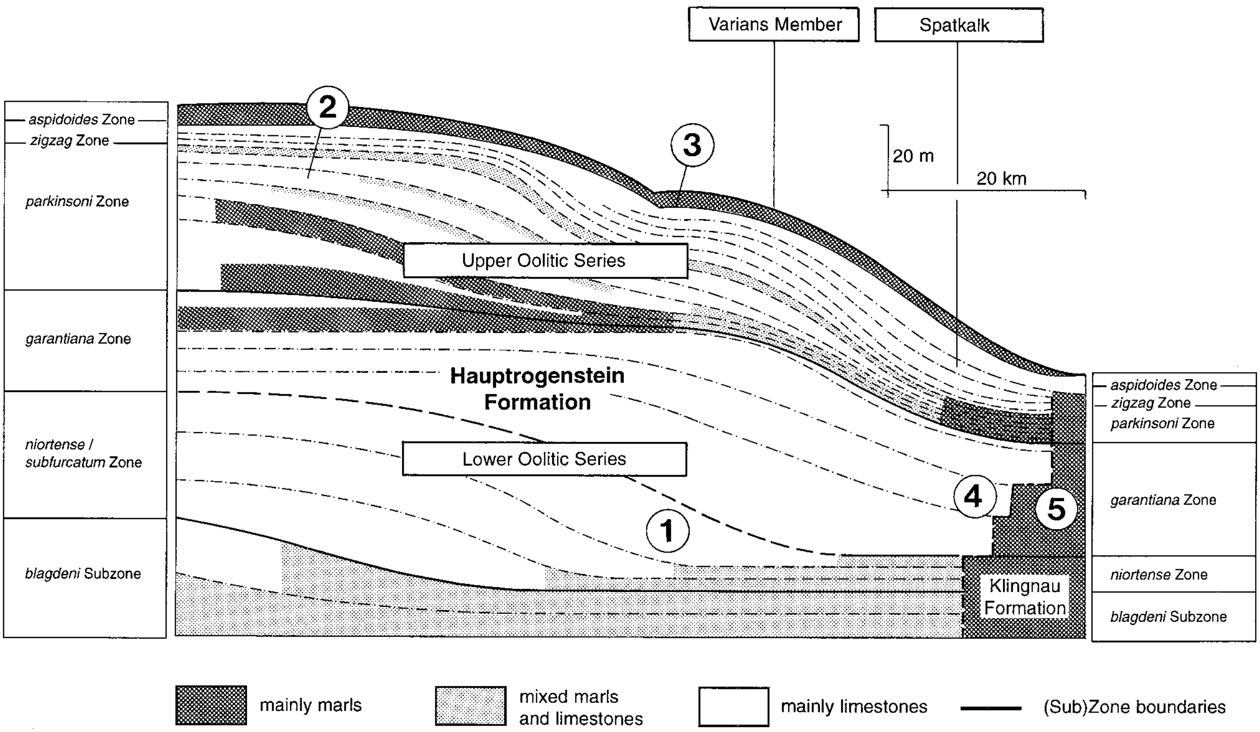


Fig. 208. Schematic cross section through the Hauptrogenstein and Klingnau Formations of northern Switzerland, with some of the main crinoid beds. (1) *Chariocrinus andreae*, Liestal; (2) *Pentacrinites dargniesi*, Develier and Winkel; (3) *Hispidocrinus leuthardti*, Liestal; (4) *Pentacrinites dargniesi* and *Isocrinus nicoleti*, Schinznach; (5) *Paracomatula helvetica*, Hottwil. Age of 4 and 5 is uncertain; see text. (After Gonzalez & Wetzel 1996.)

marine carbonate platform, the 'Burgundy Platform' (Celtic facies), covered by an epicontinental sea. In the central and eastern areas of the platform, a broad oolitic belt developed. To the south and east of the platform, tempestites and basinal calcareous mudstones (marls) of the Swabian facies accumulated under low-energy conditions; the boundary between the two facies types was just to the west of the Aare River (Gonzalez & Wetzel 1996, Fig. 1). The first two crinoid beds discussed in this chapter lie within the oolitic belt in the southeastern part of the Burgundy Platform, and the third bed (*Paracomatula helvetica*) was just east of the Celtic–Swabian facies boundary.

The eastern (Swiss) part of the Burgundy Platform is dominated by the shallow-marine oolitic barrier system that was controlled by tidal currents. The back-barrier system to the west includes micrites, oncolites and patch reefs; the off-barrier sediments to the east are characterized by tempestites and marls. In response to sea level changes, these facies belts migrated three times from west to east during Middle Bajocian to Middle Bathonian times, forming three shallowing-upward successions with a hardground on top (Gonzalez & Wetzel 1996).

The oolitic limestones of the platform belong to the Hauptrogenstein Formation ('main oolitic limestone' because of its wide distribution; *Rogen* = roe). The lower part of the Hauptrogenstein Formation, or 'Lower Oolitic Series', represents the first shallowing-upward succession. It reaches a thickness of 70 m in the western and 30 m in the eastern Jura Mountains. The accumulation of the rather thick sediments was made possible by a relatively slow rise in sea level combined with a steady subsidence (Gonzalez & Wetzel 1996). Oblique stratification (cross-bedding) indicates the presence of tidal sand waves on a shoal with a water depth estimated to be 1–10 m; the broad oolitic barrier was affected by north–south currents. At the same time, marly sediments of the Klingnau Formation accumulated in deeper water to the east. The second shallowing-upward succession started with sedimentation of calcareous mudstones and bioclastic limestones during a sea level highstand. A subsequent fall in sea level re-established ooid production, leading to the 'Upper Oolitic Series' with a thickness of up to 30 m in the western Jura. The facies change from the western oolitic limestones of the Hauptrogenstein Formation to the eastern marly basinal sediments of the Klingnau Formation occurs in the area west of the lower Aare River and is quite abrupt. The section of the Schinznach Quarry with beautiful sand waves is thus located in an area of significant changes in thickness, from 30 m to 6 m within a distance of a few kilometres. It has been placed by Hess (1972a) in the Upper Oolitic Series on the basis of the echinoderm fauna, which compares well with that of the western localities near Delémont clearly belonging to the upper part of the Upper Oolitic Series. According to Gonzalez and Wetzel (1996), the oolitic sediments of the western Upper Oolitic Series pass into marly deposits in this area, so that the Schinznach fauna appears to be in the Lower Oolitic Series. However, the exact age of the sediments at the Schinznach Quarry has not been determined; they may have been deposited later than indicated in Fig. 208.

The marly Klingnau Formation (formerly Parkinsoni Beds) locally includes crinoidal limestones such as the bed with *Paracomatula helvetica* near Hottwil (Fig. 209). *Chariocrinus andreae* is restricted to the Lower Oolitic Series. *Pentacrinites dargniesi* is characteristic of the similar facies of the Upper Oolitic Series in the western part of the Swiss Jura; but the comatulid *Paracomatula helvetica* and the stalked *Isocrinus nicoleti* (Fig. 214) cross the boundary from the basinal Klingnau Formation into the oolitic facies at the Schinznach Quarry, noted for its spectacularly diverse echinoderm fauna, which includes a lens with *Pentacrinites dargniesi*.

The third shallowing-upward succession was formed during the Bathonian, which follows stratigraphically above. On top of this sequence lie the marly limestone beds of the Varians Member deposited at a depth of 40–70 m (Meyer 1990); they have furnished the unique *Hispidocrinus leuthardti* lens.

BEDS WITH *CHARIOCRINUS ANDREAE*

Fragile Sea Lilies, Densely Packed

The beds with *Chariocrinus andreae* occur within the Celtic Hauptrogenstein facies, oolitic limestones that are partly cross-bedded but that also contain layers of mudstone. The crinoids appear near the base of the Lower Oolitic complex. More or less complete specimens have been found at about 30 sites in nearly the same stratigraphic position. *Chariocrinus andreae* commonly occurs in lenticular beds. In a number of sites, crinoids reach a density of 400 individuals per square metre and show excellent preservation, especially on the lower surface of the beds (Fig. 210). The crinoidal limestones are usually underlain by fine-grained sediments such as clay or marl (Fig. 211). As a rule, the upper surfaces contain only disarticulated fossils. Beds are

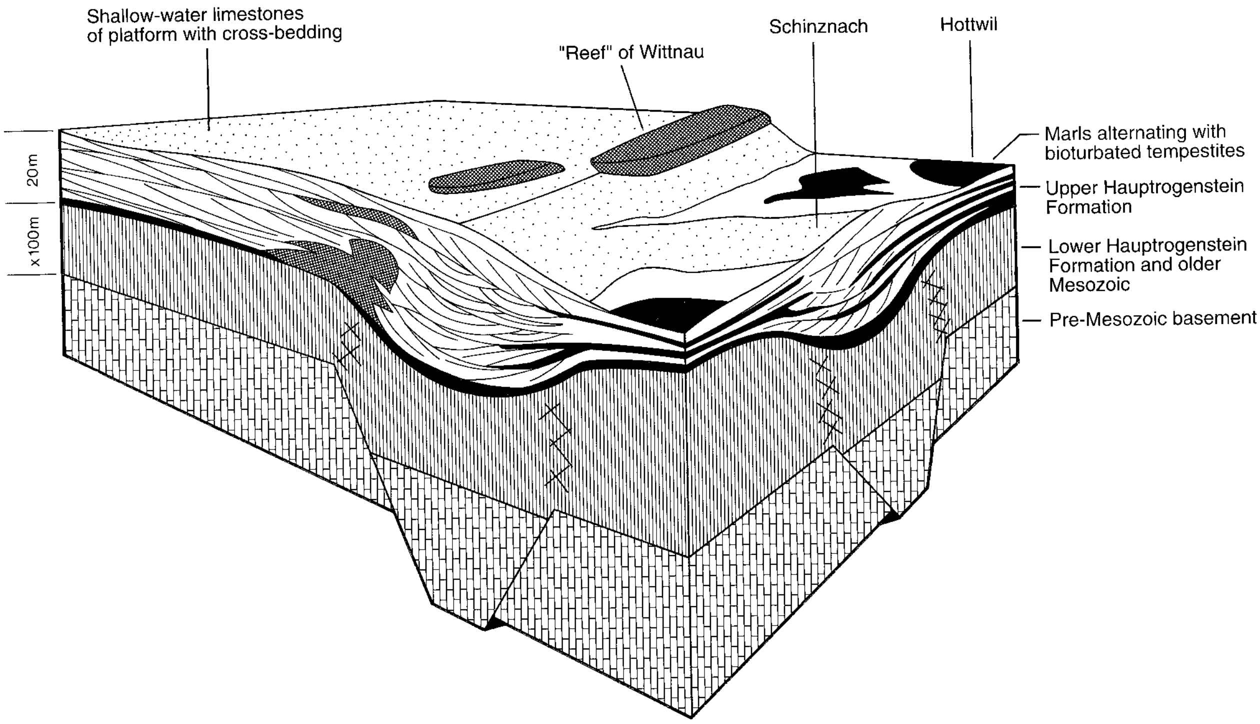


Fig. 209. Sedimentation and tectonics in the eastern Jura Mountains, showing the facies boundary between the western platform sediments and the eastern deeper water mudstones (marls) and tempestites. The facies at the eastern margin of the platform was probably influenced by a pre-Mesozoic trough. (Redrawn from Gonzalez 1993.)

composed almost exclusively of the dominant crinoid species (for a review of the fauna of this and the other beds see Hess & Holenweg 1985). A small bivalve, attached to the stems, occurs rarely, and asterozoans (mainly brittle stars) are present rarely in a few localities.

Chariocrinus andreae is a rather small species with a total height of 10–25 cm. The smallest individuals have a crown height of 3 cm; large crowns reach a height of 7 cm. Maximum stem length is difficult to determine because the stems are mostly broken between nodals and internodals. If unbroken, the stems taper somewhat distally and end with a whorl of cirri. One such stem, belonging to a nearly adult individual, reaches a length of 13 cm. The terminal cirri could have fixed the animals in the muddy bottom, but it appears more probable that, especially in environments affected by stronger currents, the distal part of the stem laid horizontally on the bottom and was held down by the terminal claws of several rows of cirri. Growth rings on a columnal indicate that the animals needed at least 4 years to reach maximum height (C. A. Meyer 1988). The size of the animals may vary considerably among localities, although larger (adult) animals are most common. In extended outcrops such as the Lausen Quarry, animals of different size occur in the different lenses up to 100 m along the quarry wall; however, in a given lens the superimposed beds (Fig. 211) usually contain individuals of similar size. Small individuals appear to be juvenile because their columnals and brachials are proportionally higher. Some of the beds have a comparatively large number of crowns on short stems, whereas others consist mainly of stems or their fragments. Because the preservation of crowns is identical, we assume that stem length varied between the different localities and that stems may have been autotomized repeatedly under less favourable conditions.

Rich Food at the Bottom of Sand Waves

Chariocrinus andreae is found in up to nine superimposed beds of 0.7–5 cm thickness in certain places, separated by thin layers of mudstone that may contain isolated ossicles. Thus, the colonies must have been repeatedly

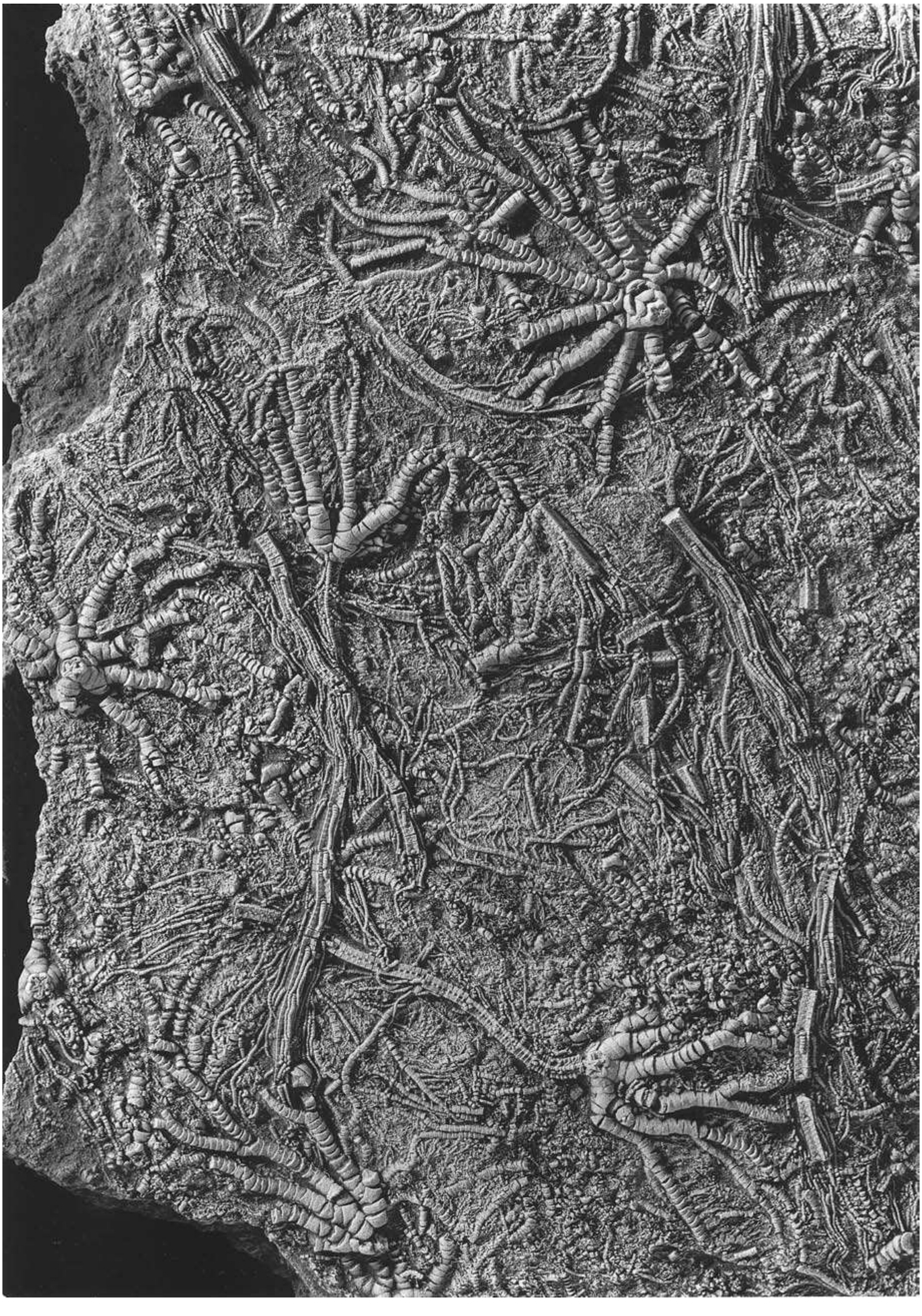


Fig. 210. *Chariocrinus andreae*. Lower Hauptrogenstein (Lower Crinoid Beds, Lower Oolitic Series, Bajocian), Liestal. Lower surface of a very dense crinoid bed with complete specimens. (Hess Collection; photograph S. Dahint.) ×1.6.

Fig. 211. Unweathered section with well-developed *Chariocrinus andreae* Beds, Lower Hauptrogenstein, eastern part of quarry at the Lausen railway station. Exposed are two sets of crinoidal limestone beds interbedded with blue marl-clay and separated from oolitic limestone below and above by thicker layers of clay. In the lower set with three distinct beds (arrows), complete crinoids such as those of Fig. 210 occur on the lowest bedding plane, just above the hammer. The upper set passes into marly limestone in its upper part and into oolitic limestone to the right of the picture (not shown). The clay between the two sets has an elevated content of organic carbon (see text). The lower set of three crinoid beds thins to one bed, which wedges out at 3 m to the right of the section shown in the photograph. Clay near the top of the section is deformed through faulting. For detailed profiles in different parts of the quarry see C. A. Meyer (1988). (Photograph 1993 by H. Hess.) To view this figure in colour, see the colour plate section following page xv.

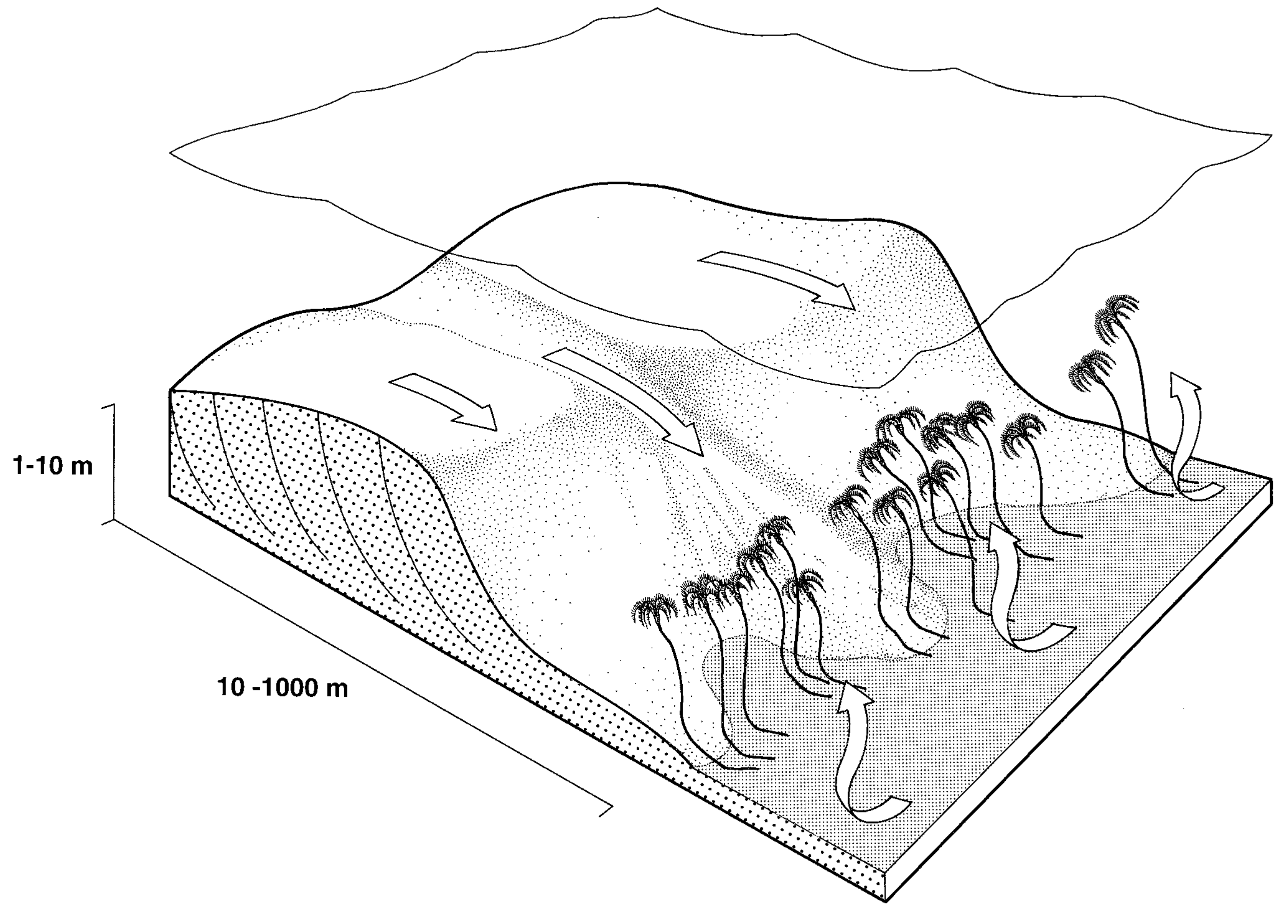


Fig. 212. Model of a sand wave with *Chariocrinus andreae* colonies on the leeward side. Arrows on top of the sand wave indicate sediment transport; arrows from bottom right represent weak currents resulting from flow separation (also depositing fine-grained material). Crinoid colonies will be displaced to similar new positions by movement of the sand wave. Size of crinoids exaggerated. (Modified from Gonzalez 1993.)

killed and replaced. The predominance, in some beds and at some localities, of small (presumably juvenile) individuals indicates that such colonies may have been rather short-lived; arrested or reduced growth from a lack of nutrients may be another explanation. Current-aligned individuals are sometimes present on bedding planes, and such orientation is much more pronounced for stem fragments on the upper bedding planes, where fossils are commonly disarticulated. Such preservation suggests that burial of the youngest colonies of the beds occurred some time after death. The main transport direction was from north to south (C. A. Meyer 1988; Gonzalez 1993), but it may be assumed that the crinoids established filtration fans using secondary flows in the opposite direction (Fig. 212). Well-preserved individuals mostly have intact crowns on stems of different length, as already explained. Specimens with regenerated arms are rare, indicating that predators were of minor importance in these dense crinoid populations. Traces from the action of scavengers as well as bioturbation are largely missing, with the exception of ooid-filled vertical burrows, which were probably produced by sea anemones.

The excellent preservation of crowns with attached stems at many localities and the high-energy, shallow-water facies seem to be mutually exclusive at first sight, but recent work may suggest how these beds were formed. The occurrence of clay and marl at the base of many of the beds indicates their formation at the margin of large fields of sand wave complexes (Gonzalez 1993), rather than in subtidal channels cut into oolitic sands as postulated by C. A. Meyer (1988). The dense colonies occurred in somewhat deeper water below fair-weather wave base (the water depth is estimated to be 10–15 m), where clay particles accumulated (Fig. 212). The sudden appearance of dense crinoid meadows indicates luxuriant growth based on a rich supply of planktonic organisms. The corresponding nutrients may have been brought into this epicontinental sea by rivers from land to the north; this was also the source of the detrital clay swept in various amounts. After a while the favorable conditions changed and the crinoids were killed, possibly through toxins resulting from red tides (blooms of phytoplankton) (C. A. Meyer 1988). In certain localities this process was repeated several times. This hypothesis is supported by the presence of remains of phytoplankton as well as the absence of larger amounts of clay minerals within the beds. In addition, the crinoid beds and the adjacent clays are darkly coloured in an unweathered section at the Lausen locality (Fig. 211), where an elevated content (0.5%) of organic carbon (hydrocarbons) was found in the clay overlying a set of crinoid beds (A. Wetzel, pers. comm., 1995). During further accumulation of the Hauptrogenstein sediments, oolitic sand became prominent. Crinoids disappeared from these, now very shallow, waters, and the bottom became inhospitable to crinoids due to shifting tidal sediments.

The occurrence of very dense isocrinid colonies on a soft bottom is without Recent analogue. Extant isocrinids prefer hardgrounds (Fig. 235, 236). Perhaps the greatest local concentrations of isocrinids occur in the Straits of Florida at 350–430 m, where *Endoxocrinus parrae* individuals, clustered along the upcurrent brow of isolated boulders, form groups of up to 39 in an area of 0.5 by 2 m, with a maximum density of 15 individuals in 0.25 m^2 (C. Messing, pers. comm., 1997). On unconsolidated sediment bottoms they attach to low outcrops, small bits of rubble and shell (Messing *et al.* 1990). One species (*Isocrinus blakei*) with delicate cirri has also been found on unconsolidated biogenic sand, but it is thought to be attached to hard surfaces buried underneath.

BEDS WITH *PENTACRINITES DARGNIESI:* STURDY MATS

This species occurs in the uppermost part of the Upper Oolitic Series of the Hauptrogenstein complex at a number of localities in northwestern Switzerland and across the border in France. It has also been found farther to the northwest near Toul and to the southeast near Tournus, in possibly contemporaneous strata. Bedding and preservation at the Swiss localities are comparable to the beds with *Chariocrinus andreae*, but *Pentacrinites dargniesi*, being a larger species than *Chariocrinus andreae*, achieves a density of only about 80 individuals per square metre. Near Delémont, where the beds are particularly well developed, one may count up to four complete individuals or generations lying on top each other (Fig. 213). Some of the beds contain echinoids (a species of *Acrosalenia* with very long spines). The Schinznach Quarry with its rich and diverse echinoderm fauna (Hess 1972a) included a lens of about 2 by 5 m with *P. dargniesi; Isocrinus nicoleti* (Fig. 214) and very rare specimens of mostly juvenile *Paracomatula helvetica* are not in this lens but occur in other parts of the quarry.

Pentacrinites dargniesi is a robust crinoid with highly branched, heterotomous arms (height of crown up to 10

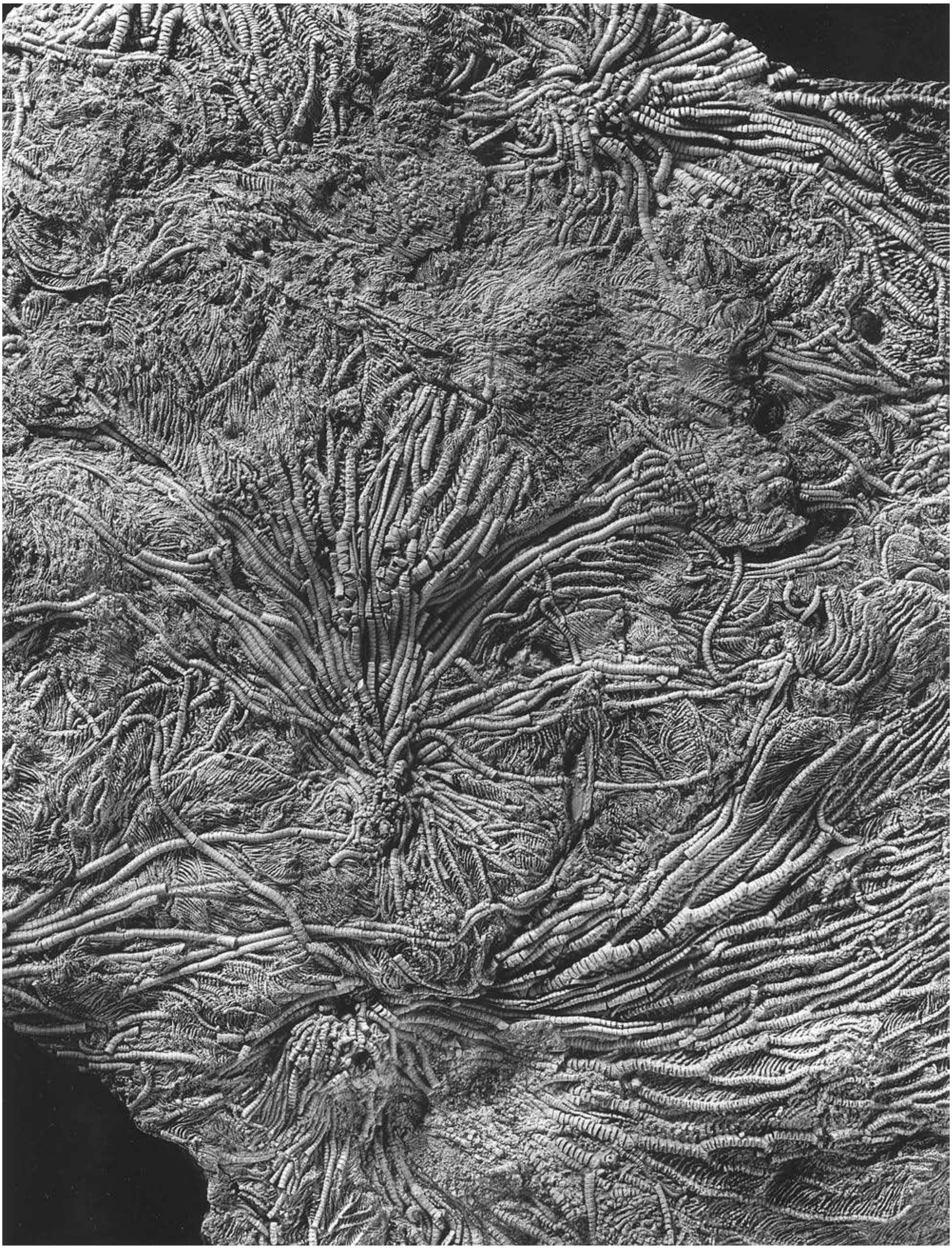


Fig. 213. (*On facing page*) *Pentacrinites dargniesi*. Upper Hauptrogenstein (Upper Oolitic Series, Bajocian), Develier. Lower bedding plane covered with complete specimens. The subadult individual in the centre has a complete stem, densely covered with long cirri. This oblique bedded slab with the crinoids in the lower part and oolitic limestone in the upper part rested on a layer of bluish clay. (Natural History Museum, Basel; photograph S. Dahint.) ×0.85.

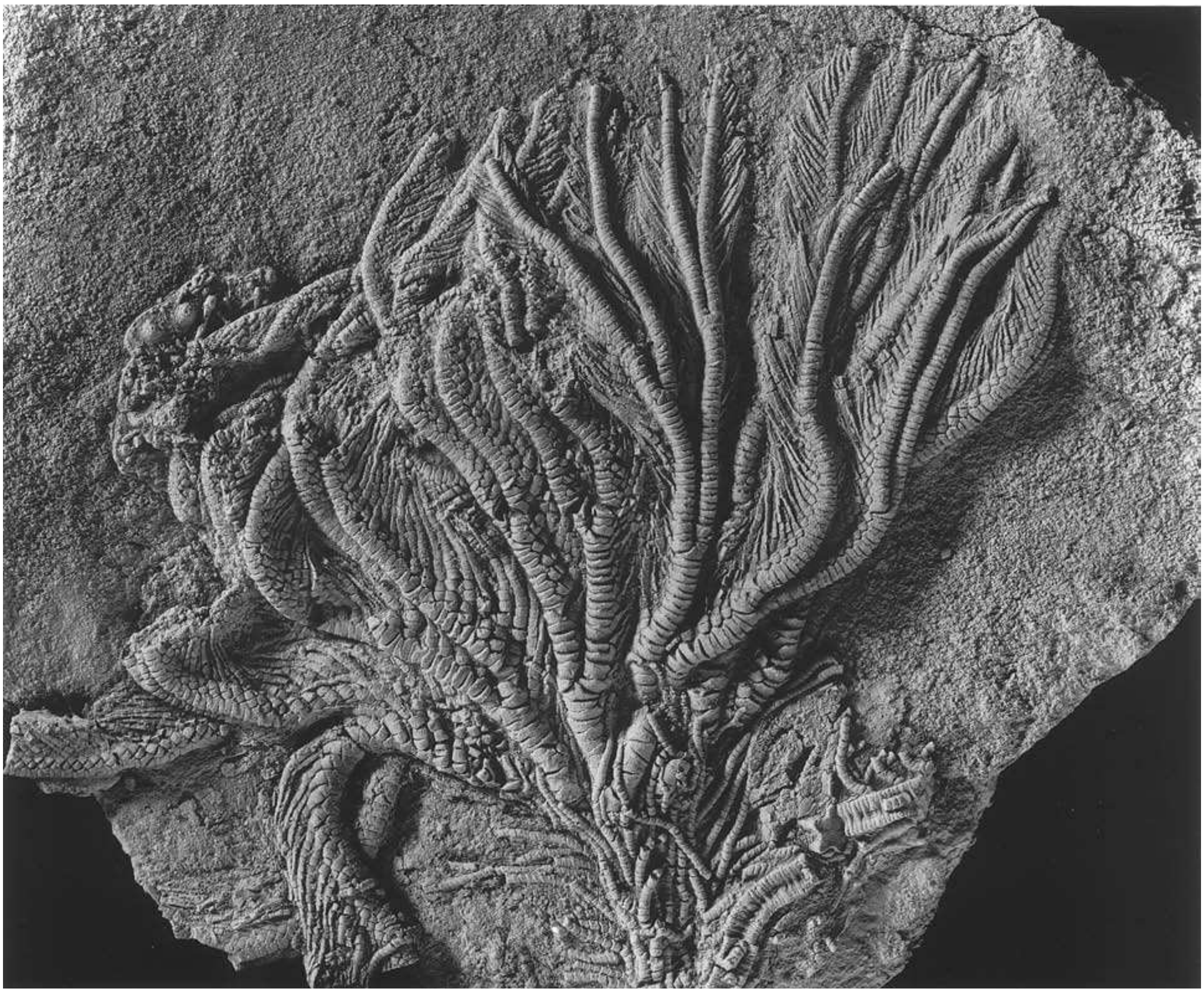


Fig. 214. *Isocrinus nicoleti*. Hauptrogenstein (Bajocian), Schinznach. This isolated individual with its broken stem lies on a lens of marl embedded in clay and was buried by a sand wave. (Hess Collection; photograph S. Dahint.) ×1.5.

cm) and a very short, tapering stem (length 5 cm or less). Only stellate to pentagonal nodals are apparent from the outside, rudimentary internodals being hidden, so that the stems are densely covered with whorls of very long cirri (up to 12 cm) with a rhomboidal cross section and a terminal claw. Such cirri would have served well in aggregations stretching out horizontally, thus forming mats.

The individuals of *Pentacrinites dargniesi* must have lived interlinked with their long cirri forming mats, which may have drifted through the seas. In spite of the presence of rare pieces of wood in the beds, life on driftwood can be ruled out. The heavily branched crown formed a dense filtration device. The crowns would have stuck out to collect food, and the whole system could not have been rolled over easily. In view of the short, stiff stem with its dense cover of long cirri, a filtration fan could not have been formed. This view is supported by the wide distribution of such mats over the Burgundy Platform of the French and Swiss Jura. At the Schinznach Quarry, crinoids settled directly on carbonate sand. They are preserved in life position, commonly with their tegmen uncovered, on the upper side of an oblique stratified bed of oolite. An overlying layer of clay may have been the reason for the death of this colony. However, such conditions are exceptional and at other localities colonies grew on muddy bottoms. In the Winkel Quarry (Dept. Haut-Rhin, France), the crinoid beds are preserved *in situ* at the foot of a tidal delta (Gonzalez 1993), in a situation comparable to the beds with *Chariocrinus andreae* in the Lower Oolitic Formation. As in the *C. andreae* beds, individuals are mostly of similar adult size, but one bed at Villey-Saint-Étienne (Meurthe-et-Moselle, France) is composed entirely of very small, juvenile individuals with crown heights of only 1.5–2 cm (Hess 1972a), confirming the same size per bed rule.

PARACOMATULA HELVETICA: AN AGGREGATION OF FREE-MOVING CRINOIDS

The bed with *Paracomatula* belongs to the Klingnau Formation, an alternation of mudstones (marls) and bioturbated bioclastic marly limestones. These were laid down in deeper water (20 m or more) under a low-energy regime. The lens of Hottwil had a width of about 8 m, wedging out on one side and passing into a marly limestone with some isolated ossicles on the other side. The bed, which lies on a layer of bluish clay, has a maximum thickness of 8–9 cm and includes the remains of four to five generations of the comatulid without intermediate layers of marl. However, clay particles are dispersed throughout the bed, which occasionally contains pieces of wood. Crinoids lie in all directions with no sign of preferred orientation, with a density of close to 300 individuals per square metre (Fig. 215). The specimens are all of similar size. They are preserved intact on the lower surface of the bed (which is covered by a layer of marl hiding the fossils) but are more or less disarticulated on the upper surface. Some *Isocrinus nicoleti* also occur both in the bed and on the lower surface, where complete individuals lie on their side with half-opened crowns. Additional fossils include the irregular echinoid *Holectypus depressus* with preserved lantern and spines, as well as a few small asteroids.

Paracomatula helvetica is a species with only 10 slender arms (length up to 16 cm) and thin, circular cirri (length 5 cm) with a terminal claw. The cirri are inserted on a small pentagonal centrodorsal composed of 5 closely jointed, low columnals. Arm articulations are synarthrial, syzygial and, most frequently, muscular.

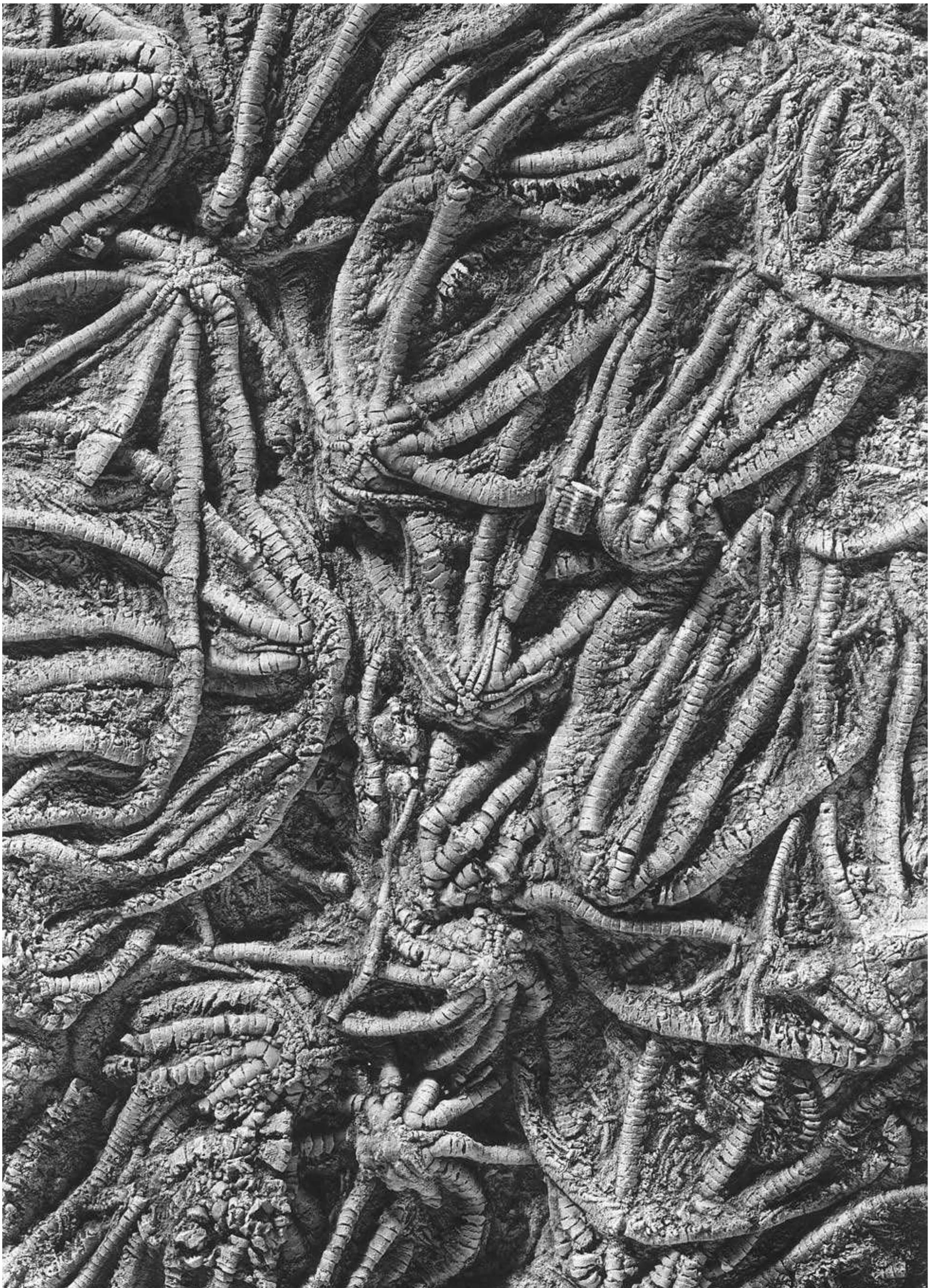
On the lower surface of the bed, the fossils are mostly lying on their side. The crowns are somewhat opened, as one would expect during life, and the cirri extend upward. Rare individuals are preserved with the aboral side down and extended arms. On the upper surface of the bed, some individuals are preserved in oral view, but most are disarticulated. Almost all individuals are adults. We think it unlikely that the assemblage was brought together by currents. It appears to be the only preserved dense assemblage of a comatulid in geological history. This must have been a local colony where several generations lived in a spot richly supplied with plankton; this place may have been close to an eddy, as indicated by pieces of wood contained in the bed. Disarticulated fossils on the upper surface suggest that burial of these individuals occurred some time after death. The few specimens of *Isocrinus nicoleti*, with stems exceeding 20 cm in length, were able to collect food (presumably smaller-sized plankton) at a higher level by raising their crowns above the comatulid colony. There is hardly any doubt that this colony was embedded where it lived. The presence of large amounts of phytoplankton in the bed (C. A. Meyer 1988) suggests that the animals may have died from toxins (caused by a red tide, as in the case of *Chariocrinus andreae*) or lack of oxygen.

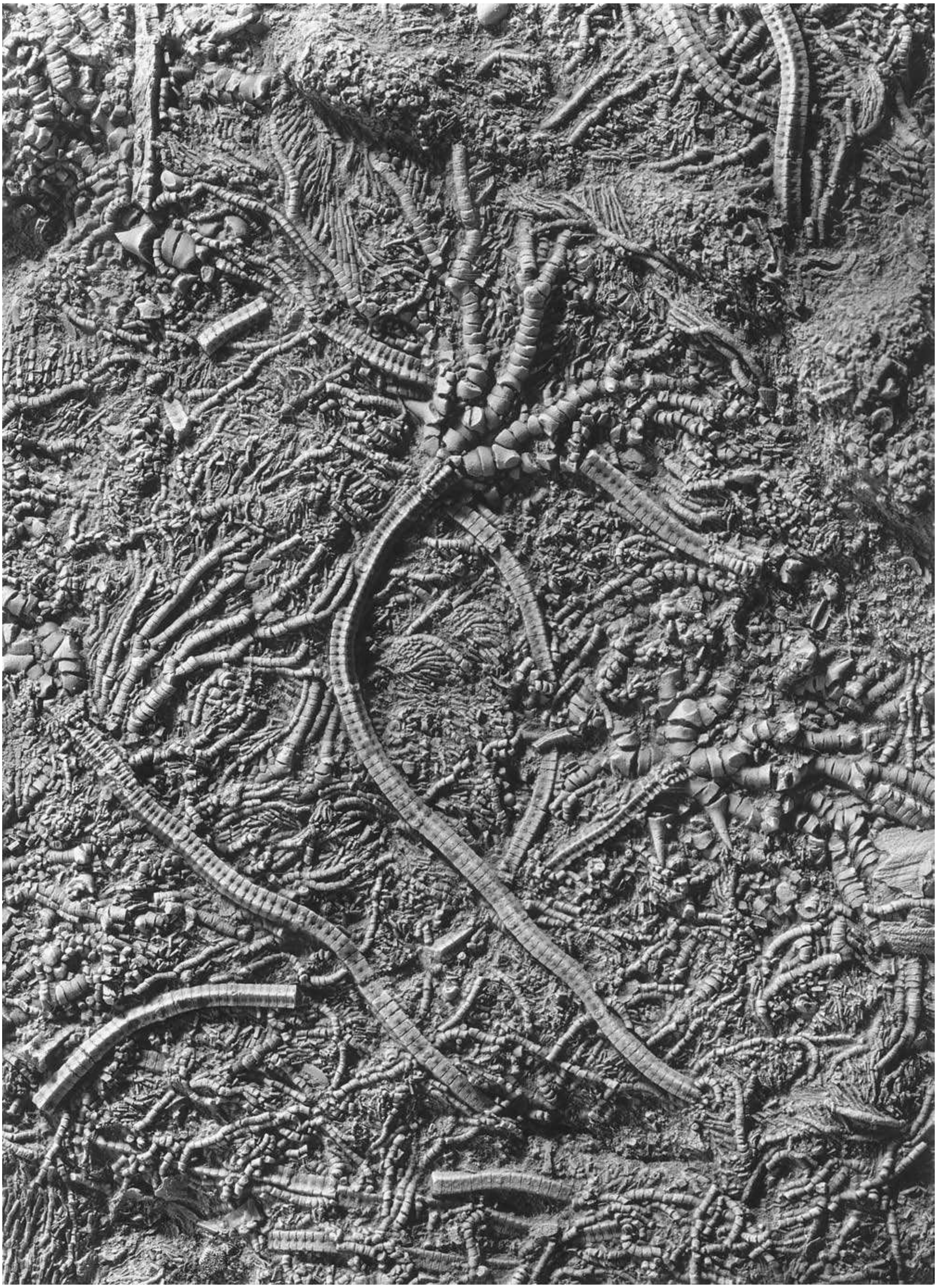
With its exceptionally long arms, *Paracomatula helvetica* resembles the similarly gregarious *Ailsacrinus abbreviatus* from the Bathonian of southern England (see Chapter 24) and is also reminiscent of *Uintacrinus socialis* from the Niobrara Chalk (see Chapter 27). The development of long arms may have been a necessity for stemless crinoids living on muddy bottoms where currents were weak.

HISPIDOCRINUS LEUTHARDTI: SMALL AND SPINY SEA LILIES

A lens with *Hispidocrinus leuthardti* has been found embedded in clay. It was overlain by Bathonian marly limestones (Varians Member) with a rich fauna of

Fig. 215. (*On facing page*) *Paracomatula helvetica*. Klingnau Formation (Bajocian), Hottwil. Lower surface of the lens with complete specimens. Near the centre is a stem fragment of *Isocrinus nicoleti*. (Hess Collection; photograph S. Dahint.) ×1.2.





brachiopods, bivalves and irregular echinoids. The size of this lens, which was completely removed at the turn of the century, is estimated to be about 3 m^2, based on the material preserved in the Basel Natural History Museum. The bed has a maximum thickness of 12 cm and thins at the edges to a few millimetres. Approximately half of the bed is composed of crinoid ossicles. Both the lower and the upper surfaces of the lens are quite irregular. Finger-like patterns of infilled burrows, packed with small crinoid ossicles, occur on the lower surface. The size and shape of the burrows suggest the work of a callianassid crustacean.

This crinoid is smaller than *Chariocrinus andreae*, with a maximum stem length estimated to be 12 cm (the stems are usually broken) and a crown height reaching 5.5 cm. Otherwise it is similar, with a tapering stem ending in a whorl of cirri. Morphological characters are similar to those of *Chariocrinus andreae*. However, the axillaries bear large conical spines – hence the assignment by Simms (1989) to *Hispidocrinus*. Small individuals occur at the upper surface and close to the fringes of the bed; they seem to be juvenile because the axillary spines are very poorly developed. Even well-preserved specimens, which lie on their side, may be partly disarticulated. These individuals occur on the lower surface and also within the lens but are confined to the central part (Fig. 216). The edges and the upper surface are largely composed of disarticulated remains. No signs of preferred orientation by currents can be detected.

In contrast to the other beds, the *Hispidocrinus leuthardti* colony contains a considerable number of other fossils, namely well-preserved ophiuroids, bivalves ('*Avicula*'), brachiopods ('*Rhynchonella varians*'), serpulid worms and remains of two crustaceans (presumably responsible for the traces mentioned earlier). In such an environment, axillary spines may have been advantageous for defence. The similar *Chariocrinus andreae*, very rarely associated with other fossils, did not develop any spines.

It can be assumed that this occurrence was similar to that of *Paracomatula helvetica*, a strictly local colony where several generations were living in a spot well supplied with plankton. Again, there is no doubt that the colony was entombed where it lived. The relatively high percentage of disarticulated fossils in parts of the lens suggests that the colony was not rapidly buried.

IMPORTANT COLLECTION IN SWITZERLAND

Natural History Museum, Basel. This museum contains the majority of bedded crinoids found in Switzerland (collected by Leuthardt, Hess and others); some of them are shown in an exhibition gallery.

Fig. 216. (*On facing page*) *Hispidocrinus leuthardti*. Varians Beds (Bathonian), Liestal. Lower bedding plane of the lens with complete specimens and burrows. Note whorls of cirri at the end of some of the stems. (Natural History Museum, Basel; photograph S. Dahint.) ×2.2.