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Middle Jurassic of Southern England

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SHALLOW-WATER LIMESTONES

Throughout southern England the Middle Jurassic succession is dominated by shallow-water limestones, typically oolitic or bioclastic. These limestones are exposed along the coast and in a few crags inland, and they have been extensively quarried wherever they crop out. More massive beds have been the source of superb building stones, such as the famous Bath Freestone, whereas more thinly bedded units have been split for roofing slates, as in the case of the Stonesfield Slate of Oxfordshire.

Although commonly rich in marine invertebrates such as bivalves, brachiopods and gastropods, echinoderms are generally not as well preserved and, with the exception of the rich echinoid fauna, have largely been overlooked. Intact crinoids in the Middle Jurassic of southern England are rare, reflecting the predominantly high-energy environments in which the limestones were deposited. Any crinoids that lived in these environments disarticulated rapidly once they died, unless some exceptional event intervened.

Two of the most spectacular occurrences of intact Middle Jurassic crinoids in southern England present an interesting contrast in terms of the palaeoecology and taphonomy of the species involved and their history of discovery.

CRINOIDS FROM A CANAL

The earlier discovery, which is also the stratigraphically younger of the two, was made in the early part of the 19th century in a quarry alongside the Kennet and Avon Canal near Bradford-on-Avon, Wiltshire. The Forest Marble Formation, of Late Bathonian age (approximately 163 million years before present), is about 24 m thick in this area and is composed of mostly cross-bedded oolitic and bioclastic limestones. However, about 3 m above the base is a 3.5-m-thick band of clay with thin limestone partings, the Bradford Clay. This clay was exposed alongside the canal, and during excavation to puddle the canal, it was found that the lowest 10 cm, immediately above the underlying limestone, was packed with fossil debris. Among this fauna were numerous brachiopods, byssate bivalves, gastropods, regular echinoids and a host of other organisms encrusting or boring into the limestone beneath. However, without doubt the most spectacular and famous member of the Bradford Clay fauna was the millericrinid crinoid *Apiocrinites parkinsoni* (Fig. 204).

William Smith, the 'Father of Geology', was among the first to comment on the fauna of the Bradford Clay (Smith 1816, 1817) and even at that early stage realized that the fossils of this basal shelly layer of the clay had

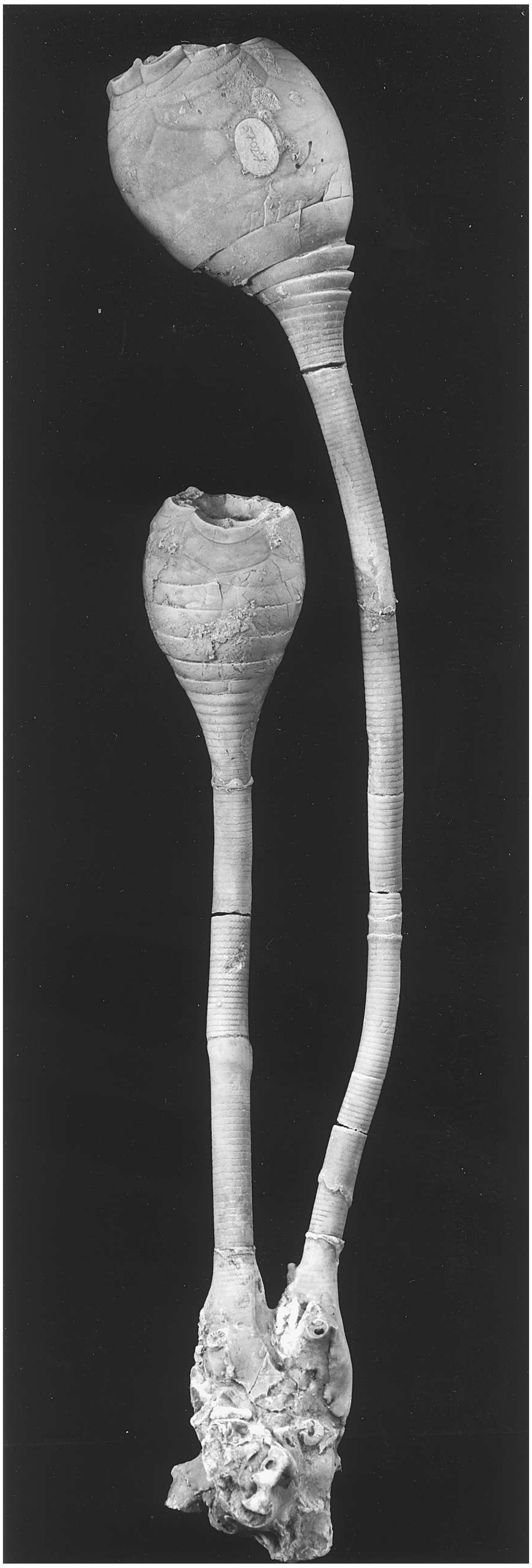

Fig. 204. *Apiocrinites parkinsoni.* Two specimens found isolated in the Bradford Clay, Forest Marble Formation (Late Bathonian), Bradford-on-Avon, Wiltshire. (The Natural History Museum, London; courtesy A. B. Smith.) ×0.8.

been associated with the top of the underlying limestone and had been buried by the clay. Where the clay had been stripped from the limestone beneath, the bare surface was commonly studded with the black holdfasts of *Apiocrinites* cemented firmly to it. Lying next to some of these holdfasts were intact specimens of the crinoid spread out flat on the limestone surface. Today, opportunities for collecting such specimens are rare, but many museum collections contain examples of the robust stems and the barrel-shaped cups of *Apiocrinites* from the original site. Far fewer complete specimens with the more delicate arms were collected, although fine examples can be found in the collections of the Bristol City Museum and the Natural History Museum in London.

THE BRADFORD HARDGROUND

The environment in which *Apiocrinites* and its associated fauna at Bradford-on-Avon lived is a classic example of a marine hardground (Palmer & Fürsich 1974). Early diagenetic lithification of carbonate sediments is commonplace in tropical marine environments today. Modern examples from the Persian Gulf bear a striking resemblance to the Bradford hardground. Lithification of the top few centimetres of the limestone occurred before deposition of the Bradford Clay, but appears to have been patchy. The hardground is highly irregular, with broad gullies separating and partly undercutting flat-topped hummocks. In places the limestone surface lacks the distinctive encrusting fauna, suggesting that it either remained unlithified in these areas or was lithified but covered by a layer of soft sediment preventing colonization, although evidence for periodic erosion of encrusting oysters does not support this latter scenario. The hardground is liberally encrusted and bored by a fauna of annelids, bivalves, bryozoans and other, more cryptic taxa such as acrothoracian barnacles, clionid sponges and phoronids. Palmer and Fürsich (1974) found a distinct polarization of the fauna between forms that occupied the top surface and those that occupied the undersurface of crevices and cavities within the hardground. The latter fauna was dominated by closely adpressed forms and contrasted strikingly with the fauna of the top surface, in which five distinct levels of ecological tiering could be recognized, from an endolithic layer through two distinct levels of encrusters to arborescent bryozoans and, finally, occupying the highest layer or tier, the crinoid *Apiocrinites* (Fig. 205). The crinoids themselves, particularly the robust holdfasts that survived long after the animal had died and the ossicles had been scattered by the currents, provided a substrate for yet more encrusters. Among these encrusters were the tiny holdfasts of juvenile *Apiocrinites*.

CATASTROPHIC BURIAL

The abundance and diversity of the encrusting and boring organisms of the Bradford hardground show that it remained exposed on the sea floor for a considerable time, perhaps several decades, yet the intact preservation of the crinoids beneath the Bradford Clay shows that burial was sudden and catastrophic. The underlying cause of this influx of mud is unknown. The limestone partings within the Bradford Clay indicate that it was deposited by several distinct influxes rather than a single event. This suggests a longer-term environmental change rather than an on–off event such as storm resuspension of sediment. In addition, the Bradford Clay is known to be laterally discontinuous, suggesting a relatively stable point source for the mud influxes. From the limited evidence available, it might be suggested that a medium-term relocation of a river mouth was the underlying cause of the mud influx responsible for the spectacular preservation of the *Apiocrinites* at Bradford-on-Avon.

A FORTUITOUS DISCOVERY

The second occurrence of intact Middle Jurassic crinoids considered here was discovered more than 150 years after that of the Bradford Clay *Apiocrinites* and in very different circumstances. The site was found by Paul Taylor, now a renowned authority on fossil bryozoa, while a student. In the summer of 1973 Paul was undertaking a geological mapping project in the Northleach area of the north Cotswolds. Although not an ideal area for mapping because of the limited exposures, Paul chose this area because of his interest in the Jurassic and also because of the opportunity for free accommodations offered by a relative. On one foray, coming across a low, partly vegetated bank, Paul broke off a small fragment of sandy-textured limestone to find it packed with echinoderm ossicles. A little excavation of the bank soon rewarded him with a small slab on which lay many intact crinoids with the arms splayed out. After this the site lay undisturbed until 1979, when, with a group of colleagues from Swansea University, Paul revisited the locality and excavated a substantial quantity of material. This formed the basis for a subsequent paper (Taylor 1983) in which the crinoids were described as a new species, *Ailsacrinus abbreviatus*, and its mode of life and taphonomy were interpreted. The great majority of this material is now housed in the Natural History Museum in London.

A CRINOID MONOCULTURE

Taylor's *Ailsacrinus* locality is a slightly lower stratigraphic level than that of the Bradford *Apiocrinites*. Paul identified the horizon within the Sharps Hill Formation, which lies close to the boundary between the Lower and Middle Bathonian. The *Ailsacrinus* Bed is approximately 25 cm of sandy and oolitic bioclastic limestone composed largely of shell debris with about 20% quartz sand. There is a gradational contact with the oolitic and bioclastic limestone below and a sharp contact with cross-bedded bioclastic limestone above. Several distinct bedding planes occur within the *Ailsacrinus* Bed where thin clay layers are present. The best-preserved crinoids are immediately above rather than below these clay layers and, hence, are on the undersurface of the bioclastic limestone units, the bulk of which contains only disarticulated crinoids. Although shell debris is abundant in the *Ailsacrinus* Bed, there are a few intact macrofossils other than the crinoids. Of the brachiopods, epifaunal bivalves and echinoids that have been found, all are abraded, suggesting that the *Ailsacrinus* Bed represents a virtual crinoid monoculture from which other macrofauna was excluded. The crinoids themselves occur crowded together on the bedding planes with population densities exceeding 200 per square metre in places (Fig. 206). More than half of them are preserved with the oral surface facing upward, suggesting life position, with most of the remainder lying on their side and only a few upside-down. Although the crinoids occur crowded together, their arms are not tangled but are spread out radially and are often flexed, sometimes ex-

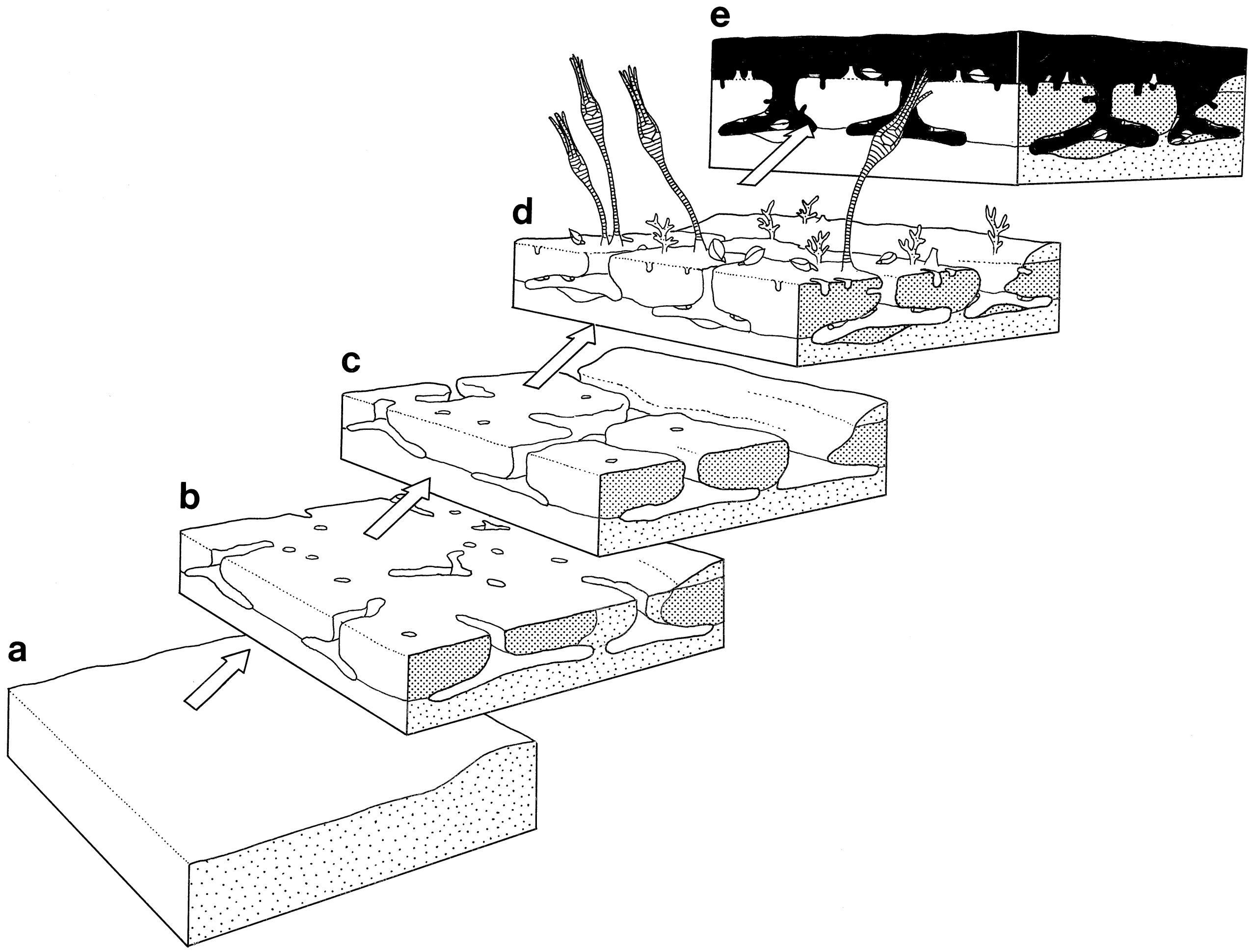

Fig. 205. History of the Bradford hardground. (a) Deposition of lime sand. (b) Burrowing by crustaceans and selective cementation. (c) Continued lithification and erosion of the uncemented material. (d) Colonization by boring, encrusting and other sessile animals occupying different tiers; periods of shell accumulation on the hardground alternated with periods of bioerosion, which removed some encrusters; floors of the crevices started to lithify. (e) Shell material derived from the hardground accumulated within crevices; clay deposition (black) buried the hardground and its fauna. (After Palmer & Fürsich 1974.)

tending for several centimetres through the overlying sediment. In some specimens traces of red and purple colours are preserved, as has been described for another Jurassic millericrinid (Fig. 62).

AILSACRINUS: A FREE-LIVING MILLERICRINID

Ailsacrinus, like *Apiocrinites*, is a representative of the order Millericrinida, yet the two taxa are, in many respects, very different morphologically. The most profound difference lies in the stem. Whereas *Apiocrinites* is cemented to the substrate by a holdfast at the base of the stem, the *Ailsacrinus* stem is greatly reduced, in some instances to a single ossicle, with a rounded distal end. At least in adult life, *Ailsacrinus* lacked any fixed attachment to a hard substrate. Whereas *Apiocrinites* was at the mercy of any adverse changes in its local environment, powerless to move away from its chosen spot, *Ailsacrinus* had a more flexible mode of life somewhat akin to that of the enormously successful comatulids that dominate most crinoid faunas today. Should things take a turn for the worst, *Ailsacrinus* could, in theory, pack its bags and move on. *Ailsacrinus abbreviatus* is

Fig. 206. Lower surface of bedding plane with *Ailsacrinus abbreviatus*. Sharps Hill Formation (Bathonian), Eastington, Gloucestershire. Most of the arms are broken at autotomy sites (syzygies); note rudimentary stems consisting of only one columnal (lacking in the specimen at the bottom). (Hess Collection; photograph S. Dahint.) ×1.

strikingly similar in appearance and population density to the Middle Jurassic comatulid *Paracomatula helvetica* (see following chapter), except that *Ailsacrinus* lacks cirri. Because comatulids can anchor temporarily to objects on and above the sea floor with cirri, they were able to occupy a much wider range of habitats than the less versatile *Ailsacrinus*. *Ailsacrinus* appears to have been a rather short-lived, although locally successful, experiment in millericrinid design, with only two species, *Ailsacrinus abbreviatus* and *Ailsacrinus prattii*, currently known.

DEATH AND RECOLONIZATION

As in the case of the Bradford Clay *Apiocrinites*, the intact preservation of *Ailsacrinus abbreviatus* points to rapid and catastrophic burial of a living assemblage of crinoids. However, unlike the Bradford Clay example, in which the fauna was completely wiped out, it is evident that in the case of the *Ailsacrinus* Bed there were repeated episodes of burial, each of which was followed by a period in which the crinoid population became re-established. The oral-up position of more than half of the crinoids and the lack of tangling of the arms indicate that they were buried *in situ* rather than swept into the area. The position of the clay layers *beneath* the well-preserved crinoids indicates that the crinoids were not killed by an influx of mud as in the Bradford Clay example. Instead, it seems that clay deposition was the normal background sedimentation for this environment and that the crinoids were instead buried by the oolitic bioclastic limestones that make up the bulk of each unit. Following each influx of sediment that buried the crinoids, slow mud deposition resumed. The thin mud layer that formed on the sea floor may have been stabilized by an algal film, which also may have inhibited scavenging and burrowing, thereby enhancing the preservation potential of the intact crinoids.

The underlying cause of each influx of coarse bioclastic sediment that buried the crinoids remains unclear. Storm resuspension appears unlikely because of the sorting and subparallel orientation of the grains in the bioclastic units. Symmetric wave ripples occur near the top of the *Ailsacrinus* Bed and indicate shallow water in which wave action may have moved material across the sea floor, periodically smothering any crinoids in its path. The fact that the area was repeatedly recolonized by an identical crinoid fauna suggests that the burial of crinoids at this particular site was a very localized phenomenon and that recruitment of the area from neighbouring populations occurred almost immediately following these burial events. However, the abrupt change to a cross-bedded shelly limestone suggests a broader environmental change, perhaps by the migration of a submarine dune field (sand waves; see following chapter), causing the final disappearance of *Ailsacrinus* from this area.

IMPORTANT COLLECTION IN THE UNITED KINGDOM

The Natural History Museum, London