18

Lower Mississippian Edwardsville Formation at Crawfordsville, Indiana, USA

WILLIAM I. AUSICH

A 'WARTY TOAD'

In 1842 Horace Hovey was collecting 'encrinites' along the banks of Sugar Creek, north of Crawfordsville, Indiana. He was collecting in response to an advertisement offering $5 per bushel for 'encrinites.' In addition to 'encrinites', this nine-year-old boy discovered a calcareous 'warty toad', the first crinoid calyx (a specimen of *Abatocrinus grandis*; see Fig. 154 for a complete crown) from the now-famous Crawfordsville crinoid beds.

Perhaps it is fitting that the first crinoid calyx discovered at Crawfordsville was found by someone who was fossil collecting for profit, because the magnificent Crawfordsville crinoids have been highly prized fossils ever since. Crawfordsville is one of the richest accumulations of exquisitely preserved crinoids in the world, and it has attracted numerous scientists, amateur collectors and professional collectors for the 150 years since the 'warty toad' was discovered. As in the latter half of the 19th century, today Crawfordsville crinoids are actively being studied by palaeontologists and sought by professional collectors.

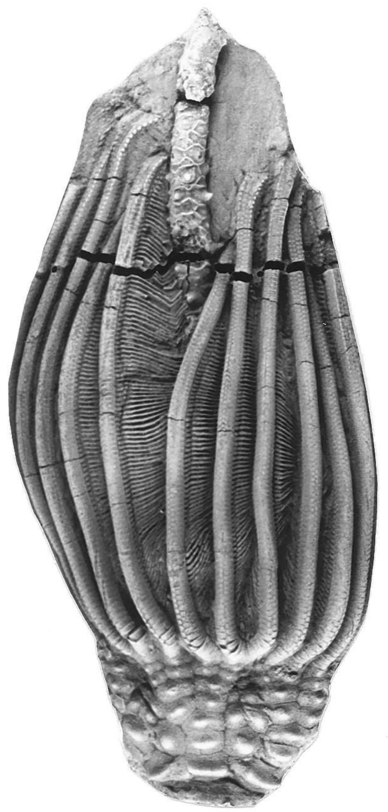

Fig. 154. *Abatocrinus grandis*. Edwardsville Formation, Crawfordsville, Indiana. Anal tube projecting above arms. This is the very first crinoid calyx found at Crawfordsville. (Reprinted by permission of the National Museum of Natural History, Washington D.C.) ×1.

DELTA SHED FROM THE EMERGING APPALACHIAN MOUNTAINS

Crinoids are known from a number of stratigraphic intervals in the greater Crawfordsville area, principally in

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

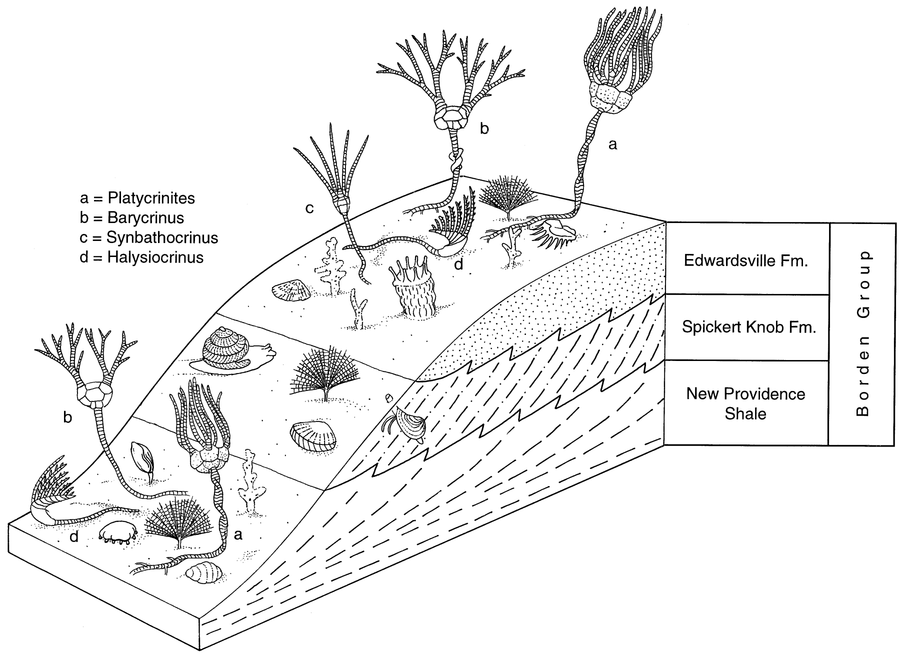

Fig. 155. Diagrammatic cross section through the Borden deltaic complex in southern Indiana and north-central Kentucky with characteristic communities, drawn very schematically on each part of the delta. (Modified from Ausich *et al.* 1979.)

Montgomery County, Indiana. However, they are most abundant at two localities – Corey's Bluff north of Crawfordsville and along Indian Creek southwest of Crawfordsville. Strata at both of these localities are now considered to be within the Edwardsville Formation (Borden Group) (approximately 340 million years old), with the Indian Creek locality in the uppermost part of the formation (most previous literature placed the Indian Creek Beds within the Ramp Creek Formation). In central and southern Indiana, the Edwardsville Formation is Late Osagean in age (Visean). The Borden Group was deposited as a broad, low-relief delta that was one of the westward sediment pulses eroded from the newly formed Appalachian Mountains. The Borden delta is divisible into three basic parts – the subaqueous delta platform, delta slope and prodelta (Fig. 155). The Edwardsville Formation records the subaqueous delta platform in Indiana and yields numerous crinoid localities, including those in the Crawfordsville area.

CRINOID MINING

Crawfordsville crinoids were collected during six major periods. From 1832 to 1859 they were collected principally by residents interested in acquiring a teaching collection for the newly established Wabash College in Crawfordsville and developing natural history cabinets (see Van Sant & Lane 1964 for a history of Crawfordsville collection). In 1859 Lyon and Casseday described four new species from the cabinet of O. W. Corey, a Crawfordsville resident. The description of these crinoids, *Abatocrinus grandis Cyathocrinites multibrachiatus*, *Gilbertsocrinus tuberosus* and *Onychocrinus ramulosus*, ushered in the second period of collecting (1859–1875). The publication of information about these crinoids attracted collectors, palaeontologists and their agents to Crawfordsville to collect and quarry crinoids. In 1864 F. H. Bradley initiated systematic quarrying methods, used by many later; and various preparation techniques were developed. The period from 1875 to 1887 was dominated by land purchases for collecting and by more crinoid quarrying. During this period, D. A. Bassett developed preparation techniques that are widely considered the best (Van Sant & Lane 1964). Bassett prepared exquisite large slabs with fine detail of preparation and with many complete individuals – arms, calyx, column and holdfast. Large-scale quarrying continued from 1887 to 1906, and this collecting (Fig. 156) was funded by Frank Springer, who eventually amassed the largest collection of Crawfordsville crinoids (Van Sant & Lane 1964).

After 1906 little or no fossil collecting occurred in the Crawfordsville area until Gary Lane opened two small excavations (1964–1965) to study fossil distribution and the palaeoecology of these strata (Lane 1973). The final period of serious collection began in the early 1980s, providing magnificent crinoid specimens for amateurs and museums around the world (Figs. 157, 158).

THE CRAWFORDSVILLE FAUNA

More than 63 crinoid species assigned to 42 genera are known from Crawfordsville. (This takes into consideration the recent taxonomic revisions by T. W. Kammer and W. I. Ausich, in which numerous species were placed into synonymy). All major groups of Lower Mississippian crinoids are present, including the diplobathrid camerates, monobathrid camerates, disparids, primitive cladids, advanced cladids and flexibles.

A remarkable feature of these Late Osagean crinoids is their size. The crowns of many of these crinoids are quite large in comparison, especially, to those of younger faunas. Crowns greater than 10 cm are common for several species in this fauna, which adds further to their universal appeal. For example, crowns of the primitive cladid *Barycrinus rhombiferus* measure up to 15 cm or more, and the primitive cladid *Pellecrinus hexadactylus* may reach heights of more than 12 cm. Other especially large crinoids included the advanced cladids *Springericrinus magniventrus*; the monobathrid camerates *Abatocrinus grandis*, *Actinocrinites gibsoni*, *Agaricocrinus americanus* and *Paradichocrinus polydactylus*; and the flexibles *Onychocrinus exsculptus* (Fig. 56) and *O. ramulosus*.

Some of the most abundant and well-known Craw-

Fig. 156. Quarrying operations at the Sugar Creek, Crawfordsville, Indiana, site during the summer of 1906. Another photograph from the same time was published by Van Sant and Lane 1964. (Reprinted by permission of the National Museum of Natural History, Washington, D.C.)

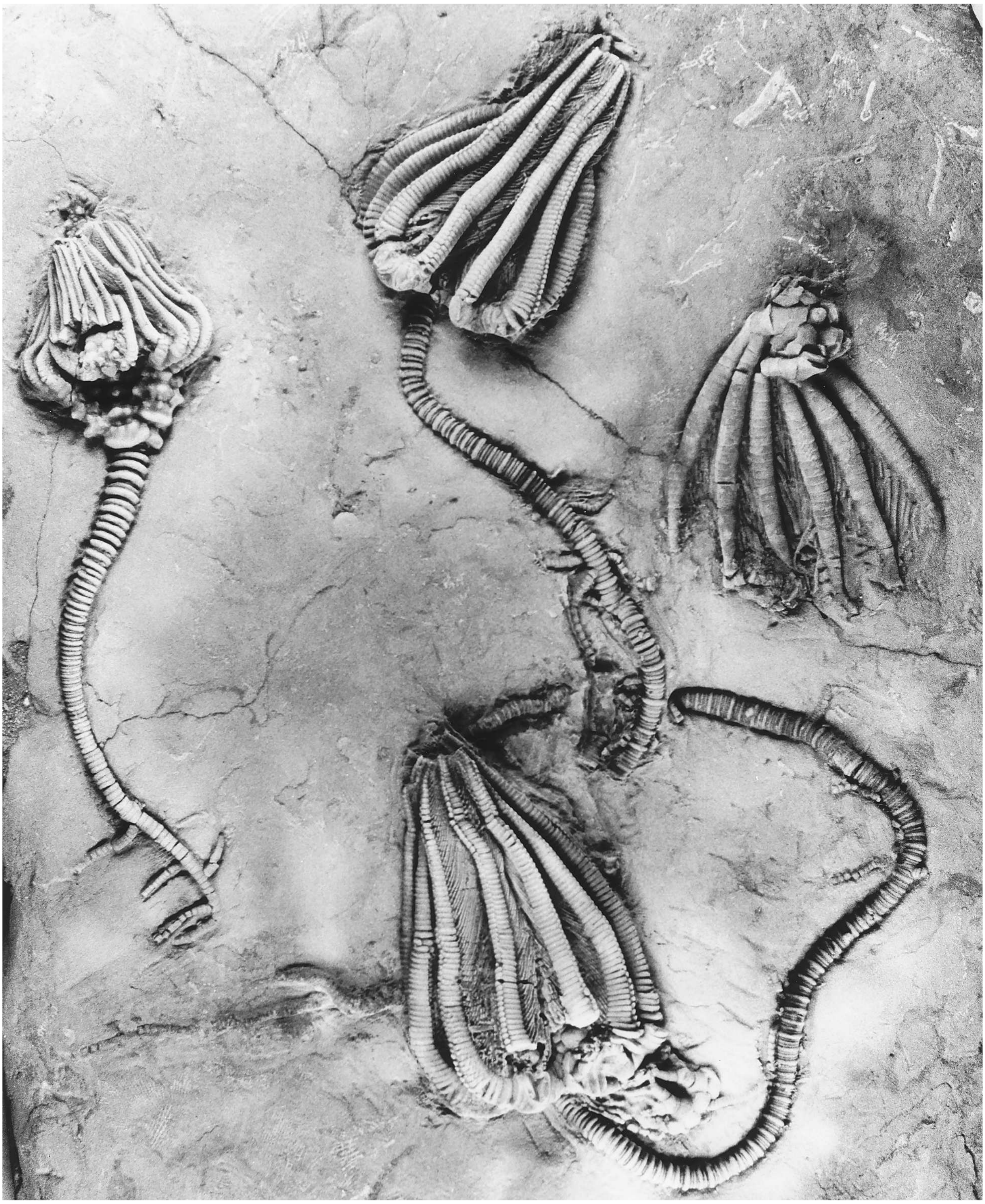

Fig. 157. Slab of complete crinoids from Indian Creek. From left to right these are *Actinocrinites gibsoni*, *Agaricocrinus splendens* (two specimens) and *Scytalocrinus decadactylus*. (Reprinted by permission of the National Museum of Natural History, Washington, D.C.) ×1.

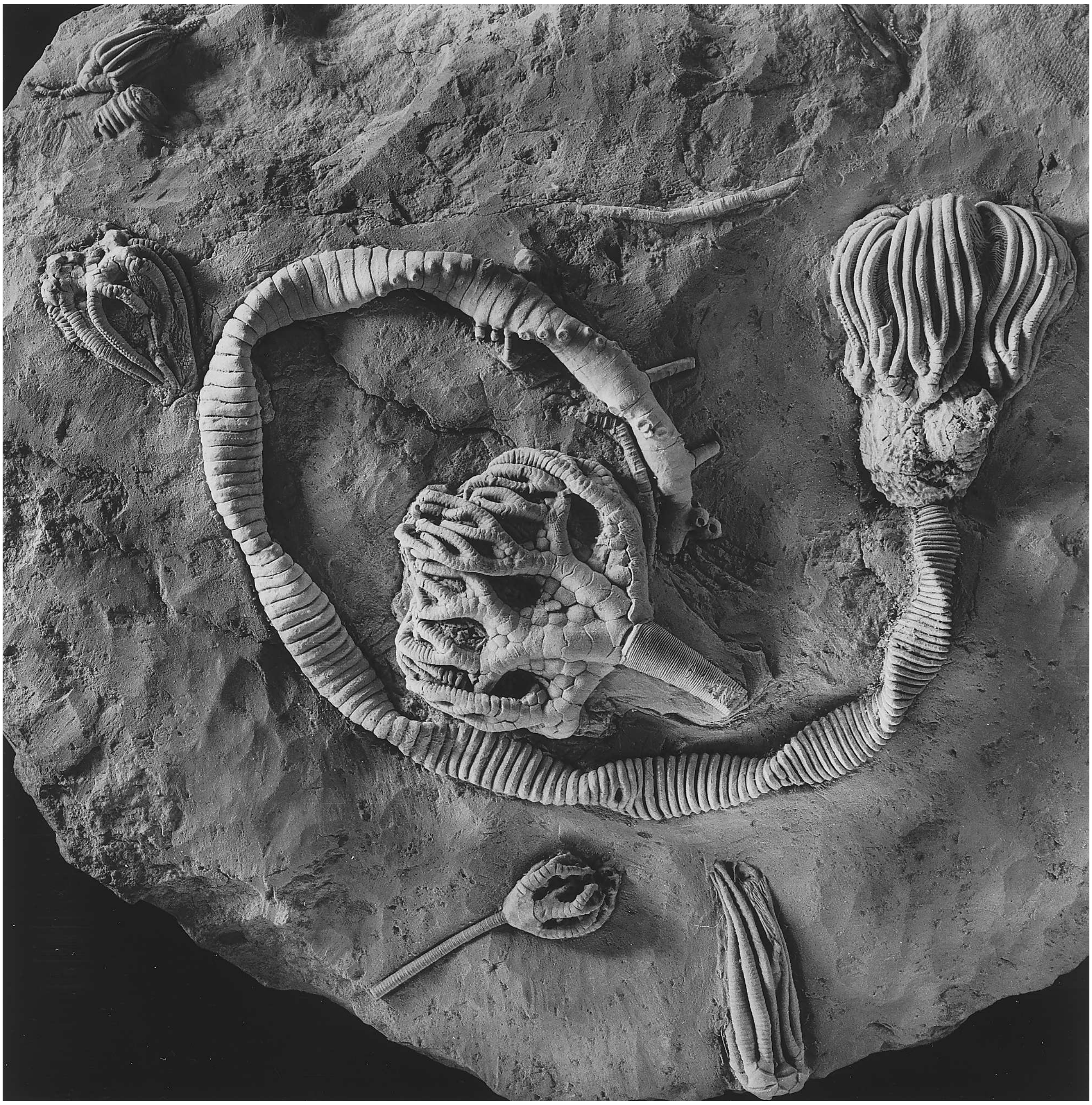

Fig. 158. Complete crinoids from Indian Creek, uppermost Edwardsville Formation. From left to right these are *Macrocrinus mundulus* (upper left corner), *Agaricocrinus splendens, Platycrinites saffordi* (the large complete specimen) carrying the gastropod *Platyceras, Taxocrinus ungula* (inside the stem of *P. saffordi*), probably a juvenile of *Taxocrinus ungula*, and *Scytalocrinus decadactylus*. (Siber Collection, Saurier Museum Aathal, Switzerland; photograph S. Dahint.) ×0.6.

fordsville crinoids are *Cyathocrinites multibrachiatus* (Fig. 47), *Dizygocrinus indianensis*, *Gilbertsocrinus tuberosus*, *Histocrinus coreyi*, *Onychocrinus exsculptus*, *Pachylocrinus aequalis*, *Platycrinites hemisphaericus*, *Scytalocrinus robustus* and *Taxocrinus colletti* (Table 4). Perhaps the most important aspect of this fauna is its high diversity of numerous well-preserved specimens, which allows for a full understanding of the morphology of a wide array of crinoids. This provides the baseline knowledge for understanding details as well as the range of structures of Lower Mississippian crinoids – for example, anal sacs, tegmens and stems.

Gilbertsocrinus tuberosus may, by default, be considered a typical Late Osagean diplobathrid camerate. As a

Table 4. *Taxonomic Distribution of the More Common Crawfordsville and Indian Creek Crinoids*

DIPLOBATHRID CAMERATES
Gilbertsocrinus tuberosus (C)
MONOBATHRID CAMERATES
Abatocrinus grandis (C)
Actinocrinites gibsoni (C) (IC)
Dizygocrinus indianensis (C) (IC)
Macrocrinus mundulus (C) (IC)
Platycrinites hemisphaericus (C)
Platycrinites saffordi (IC)
DISPARIDS
Halysiocrinus tunicatus (IC)
PRIMITIVE CLADIDS
Barycrinus rhombiferus (C) (IC)
Barycrinus stellatus (C) (IC)
Cyathocrinites iowensis (C) (IC)
Cyathocrinites multibrachiatus (C) (IC)
ADVANCED CLADIDS
Abrotocrinus coreyi (C) (IC)
Abrotocrinus unicus (C) (IC)
Histocrinus coreyi (C) (IC)
Hylodecrinus gibsoni (C)
Lanecrinus depressus (C) (IC)
Pachylocrinus aequalis (C)
Scytalocrinus robustus (C) (IC)
FLEXIBLES
Onychocrinus exsculptus (C)
Onychocrinus ramulosus (C)
Taxocrinus colletti (C) (IC)
Taxocrinus ungula (IC)

Abbreviations: C, Crawfordsville; IC, Indian Creek.

diplobathrid camerate, it has infrabasals, basals and radials, fixed brachials in the calyx and biserial arms; but beyond these generalities, it is a most unusual crinoid. *Gilbertsocrinus tuberosus* is a medium to large crinoid with a broad, flat tegmen. Tubular, bifurcating extensions of the tegmen grew interradially from the tegmen margin (Fig. 159). The arms are narrow threads, rarely preserved, that hung beneath these tegmen extensions. The calyx is deep and wide, with the spinose basal plates the lowest calyx plates visible in side view. The infrabasal circlet is hidden in a basal concavity and is nearly covered by the proximal-most columnal. In addition to

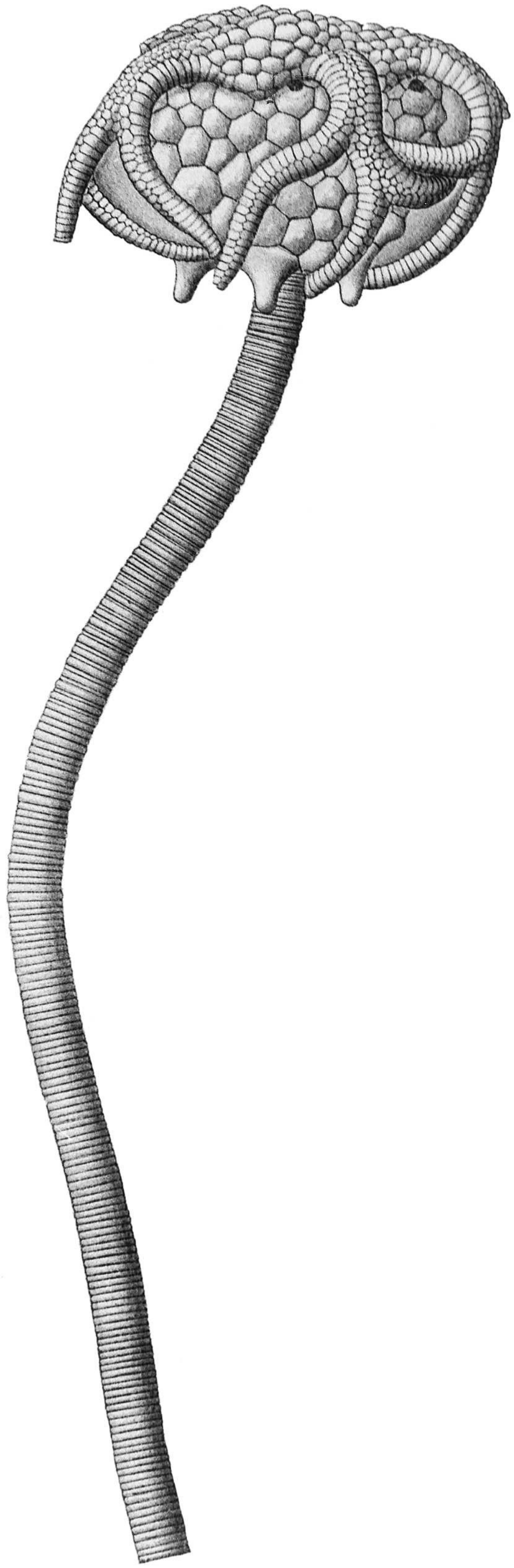

Fig. 159. *Gilbertsocrinus tuberosus*. Edwardsville Formation, Crawfordsville, Indiana. (From Wachsmuth & Springer 1897.) ×1.

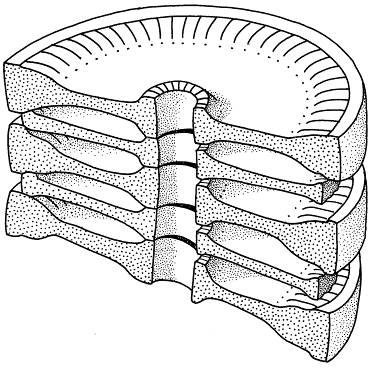

Fig. 160. Reconstruction of *Gilbertsocrinus tuberosus* stem showing the radical changes to the articulation on columnal facets. These changes greatly increased the potential flexibility of these stems. (Redrawn from Riddle *et al.* 1988.) ×8.

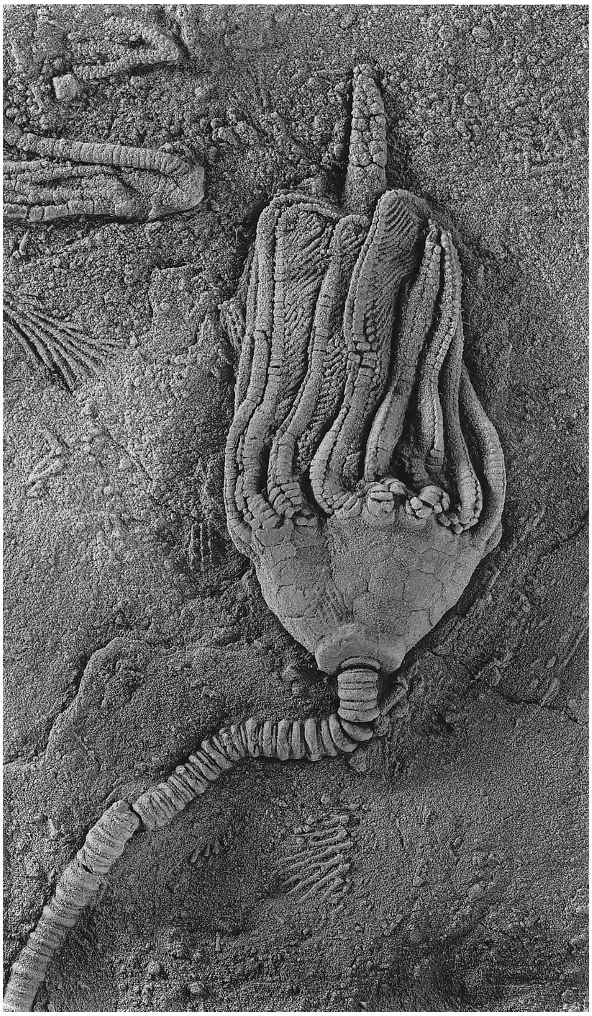

Fig. 161. *Macrocrinus mundulus*. Edwardsville Formation, Crawfordsville, Indiana. (Hess Collection; photograph S. Dahint.) ×1.8.

the peculiar tegmen and arms, the stem is unusual in its high degree of flexibility, which is commonly preserved looped back over itself. This high degree of flexibility is the result of highly modified columnal facets. The crenularium for intercolumnal articulation is on a small raised area immediately surrounding the lumen called the perilumen (Riddle *et al.* 1988), rather than being broad and extending to the periphery of the facet (Fig. 160). With this arrangement, the mechanics of the articulation is altered and greatly increases the column flexibility (Baumiller & Ausich 1996). Stems may be as long as 65 cm, and the holdfast is a relatively small bulbous feature that was apparently anchored into the sediment (Lane 1963b).

Macrocrinus mundulus is a typical medium to small monobathrid camerate crinoid (Fig. 161). It has a truncate, conical calyx, with basal plates visible in side view and articulating with the stem. Fixed brachials and interradial plates are present, and the second primibrachial is axillary. At the top of the calyx, 16–20 free arms emerge that are biserially pinnulate and unbranched. The tegmen is high, conical and dominated by a long, conical, centrally located anal tube with a terminal anal opening. The arms and the anal tube are approximately the same length. The stem of *M. mundulus* may be as much as 20 cm long. The distal half of the stem tapers, and radicular cirri for the holdfast are along the distal quarter of the column.

Platycrinites hemisphaericus is probably the most common camerate at Crawfordsville (Fig. 158 shows *Platycrinites saffordi*, the species occurring at Indian Creek). It is the monobathrid camerate crinoid that mimics an inadunate. The calyx is basically the aboral cup, and the arms are basically free above the radials. Both radial and basal plates are large, and distinctive, coarse nodes form the plate sculpturing. Free arms divide as many as four times in each ray and are biserially pinnulate. Columnals of *Platycrinites* are highly modified into an elliptical shape with a fulcral ridge nearly paralleling the long axis (a synarthrial articulation) (Fig. 162). The articular

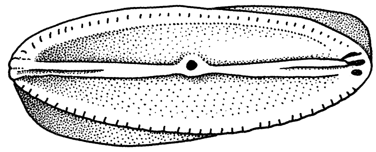

Fig. 162. Articular facet of *Platycrinites* columnal showing articular ridge along its maximum width. (Redrawn from Ubaghs 1978.) Approx. ×8.

ridges on opposite facets of an individual columnal are slightly offset from one another, which results in a helically twisted stem (Riddle 1989). As in *Gilbertsocrinus tuberosus*, modifications of the *Platycrinites* column altered the mechanics of the articulation and increased the flexibility of the stem (Baumiller & Ausich 1996). This helically twisted stem reached lengths of up to 30 cm. The distal holdfast had modified columnals with radicular cirri growing from the narrow ends of the columnal. This produced the appearance of a sparse bottle brush, and the distal stem probably lay along the sea floor as a runner-type holdfast similar to that of living isocrinids.

A typical cladid is *Scytalocrinus robustus* (see Figs. 157 and 158 for a species of *Scytalocrinus* from Indian Creek). Only part of the infrabasals are visible in side view, and both the basals and radials are large plates. The arms are free above the radial plates, and only one large, axillary primibrachial is present. The arms divide only this one time, and they are pinnulate with broadly rounded, cuneate, uniserial brachials. The stem length of *Scytalocrinus robustus* can reach up to 40 cm.

Many disparid crinoids seem unusual, but this is especially true of the catillocrinids. The catillocrinid at Crawfordsville is *Eucatillocrinus bradleyi* (Fig. 163). This crinoid has multiple fine, non-branching arms articulated to the radial plates. Centrally a very long, thick anal sac is present; and when the arms were in a closed posture, the arms fit into grooves along the proximal anal sac. Plating of the aboral cup is unusual because radials vary in size. Three radials are very narrow and have only one arm (one radial also supports the anal sac). However, two radials are very large, and each gives rise to approximately 20 arms. The proximal stem is differentiated from the middle column and called the proxistele. The proxistele is composed of extremely thin and wide columnals, and more typical columnals are present in the middle column, or mesistele. Intuitively, the very thin columnals of the proxistele would seem to be an adaptation for increased flexibility, but the opposite is true. Proxisteles constructed similarly to those of *E. bradleyi* were interpreted to be extra rigid portions of the stem, based upon preserved postures (Baumiller & Ausich 1996). The total stem length of *E. Bradleyi* is as much as 35 cm.

Finally, flexibles are represented by *Forbesiocrinus wortheni* (Fig. 27) and *Taxocrinus ungula* (Fig. 158), typical flexibles. Flexibles generally have poorly sutured calyx plates. The subclass name, Flexibilia, refers to the general flexible appearance of the crown due to typical

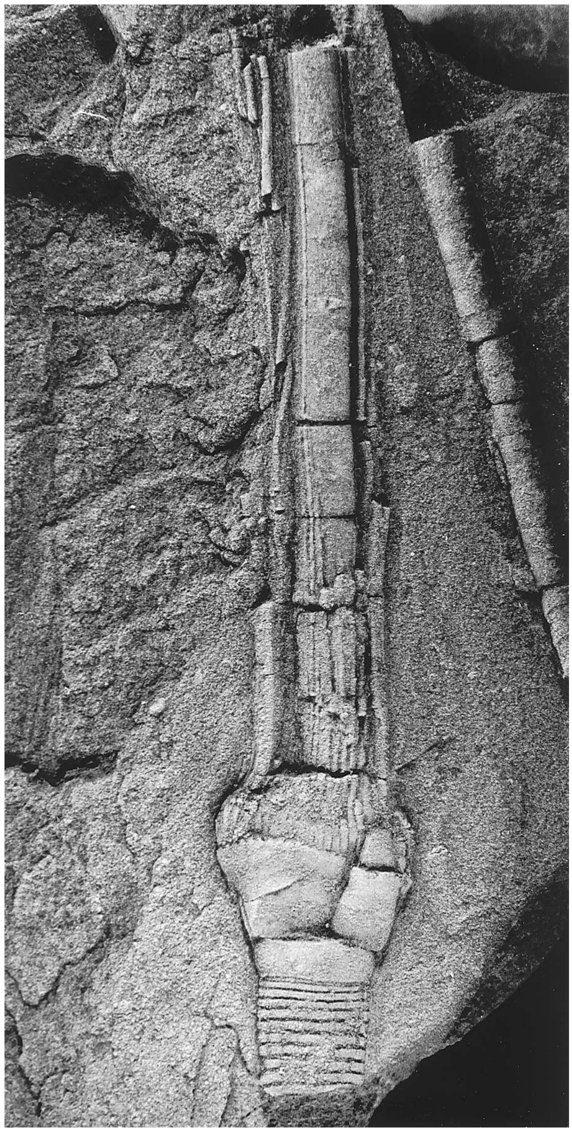

Fig. 163. *Eucatillocrinus bradleyi*. Edwardsville Formation, Crawfordsville, Indiana. Note massive anal sac and very fine arms, which are mainly broken away. (Reprinted by permission of the Field Museum of Natural History, Chicago.) ×3.

crushing during compaction. *Forbesiocrinus wortheni* is a large crinoid; the calyx may reach up to 10 cm in height. Characteristic of flexibles, three infrabasal plates are present. In *F. wortheni*, the infrabasal plates are rather short, and radial and basal plates are large. Several primibrachials are present before the first bifurcation, above which the arms branch several times. The distal arms curve or coil in toward the centre of the crown, which is a typical arm posture among the Flexibilia. As in *Eucatillocrinus bradleyi*, the proximal stem is differentiated into a proxistele with extremely thin and wide columnals. The calyx, arm and stem construction of *Taxocrinus ungula* from Indian Creek is similar to that of *F. wortheni*. However, *T. ungula* can be differentiated by its distinct column of anal plates in the posterior, higher basal circlet and arms that are more rounded and distinct from one another.

COMPLETE CRINOIDS: THE SEED FOR THE IDEA OF TIERING

The number and diversity of crinoids from Crawfordsville are nearly unbelievable, but even more amazing is the fact that complete crowns with attached stems are so abundant. With careful quarrying and care of preparation, like that of Bassett, numerous complete individual crinoids – with a crown and stem complete to the holdfast – have also been collected (Fig. 164). Of the approximately 63 species of crinoids recognized from Crawfordsville, nearly half (29) are known from complete or nearly complete specimens, and a few species are represented by multiple complete individuals. Such wonderfully preserved fossils provide data that are rarely available, and such a *Lagerstätte* commonly leads to more general interpretations about the behaviour, ecology or physiology of fossil organisms.

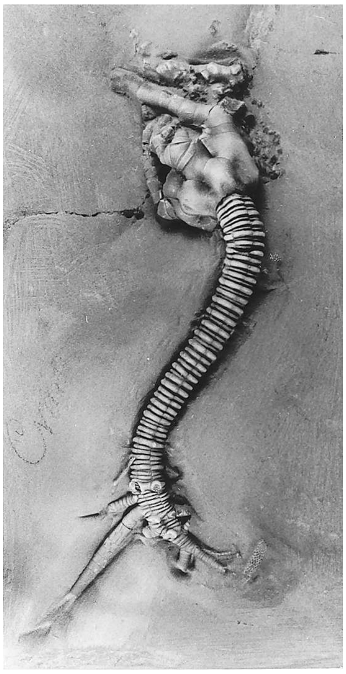

Fig. 164. *Barycrinus stellatus*. Edwardsville Formation, Crawfordsville, Indiana. Example of a complete specimen. (Reprinted by permission of the National Museum of Natural History, Washington, D.C.) ×1.

In this case, the exceptional Crawfordsville crinoids led Lane (1963b) to recognize the ecological significance of differing stem lengths among crinoids. In 1980, Ausich developed a more comprehensive model for ecological niche separation among crinoids, again by careful consideration of Crawfordsville crinoids. In a sea floor setting, suspended food particles move horizontally across the substratum (from a crinoid individual's perspective). This resource can be partitioned among different crinoid species in two ways: (1) different species can be elevated to different levels (tiers) above the sea floor, thereby filtering food from different parcels of water, and (2) even within a single tier crinoids can filter food particles of different sizes. In a community of crinoids with a range in stem length and a range in filtration fan densities and ambulacral groove widths, a series of non-overlapping or only slightly overlapping niches can be established, thereby making it possible to separate different species ecologically (Ausich 1980).

Furthermore, understanding niche differentiation among crinoids led to the development of the general tiering model (Ausich & Bottjer 1982; Bottjer & Ausich 1986). Tiering is a general ecological structural ordering defined as 'vertical subdivision of space by the organisms in a community' (Bottjer & Ausich 1986). Entire epifaunal suspension-feeding communities are tiered, as are infaunal suspension-feeding communities and infaunal deposit-feeding communities.

Tiering is now widely recognized to have been an important aspect of the structure of many benthic marine communities throughout geological history. Tiering was especially important for the numerous crinoid communities discussed in this book (e.g., Figs. 80, 107, 155). It is important to remember, however, that this concept is rooted in the detailed collection and preparation of crinoids by D. A. Bassett during the late 19th century.

OTHER LATE OSAGEAN CRINOID FAUNAS

Late Osagean crinoids are present throughout the eastern United States. Crawfordsville and Indian Creek contain subaqueous delta platform faunas, and faunas from the delta platform are present elsewhere, such as Monroe County, Indiana. Delta slope facies supported few crinoids, but at the toe of the delta in the prodelta facies, crinoids also flourished locally (Ausich *et al.* 1979; Kammer 1984). Prodelta faunas occur in the New Providence Shale in southern Indiana and Kentucky. Farther south, where the toe of slope along this basin margin received less sediment, carbonate build-ups developed in the Fort Payne Formation of Kentucky and Tennessee. These deeper-water carbonate build-ups associated facies also supported significant crinoid faunas. West of the Illinois Basin, the extensive Burlington–Keokuk carbonate ramp developed (see Chapter 17). The latest phase of this ramp was the Keokuk Limestone, composed principally of crinoids. Crinoids continued to flourish on this western margin until the close of the Osagean, even after Borden siliciclastics (the Warsaw Formation) encroached onto this platform. Both the Keokuk Limestone and the lower part of the Warsaw Formation are Late Osagean in age and approximately coeval with the Edwardsville Formation, New Providence Shale and Fort Payne Formation, completing a regional perspective of facies and crinoid assemblages around this epicontinental basin.

IMPORTANT COLLECTIONS IN THE UNITED STATES

Field Museum of Natural History, Chicago, Illinois
National Museum of Natural History, Smithsonian Institution, Washington, D.C.