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Tertiary

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THE POOR RECORD OF INTACT TERTIARY CRINOIDS

As a result of the distribution of sea and land during the Tertiary, which was similar to that of today, most marine sediments were deposited in shallow water close to present coastlines. Therefore, there are only a few chances to collect from deposits in which crinoids might be well preserved. The predominance among echinoderms of echinoids, and the extreme rarity of well-preserved crinoids in such sediments, is therefore no surprise. The presence of isocrinids (*Metacrinus*) in shallow-water sediments of Palaeocene to Oligocene age in New Zealand and the Antarctic Peninsula, as described later in this section, reveal the shift of these stalked crinoids to a deeper environment during the later Palaeogene (Stilwell *et al.* 1994). It must be assumed that, starting from a low at the Cretaceous–Tertiary boundary, the number of crinoid species has steadily increased during the Tertiary to arrive at the present diversity (see Fig. 3). The poor fossil record of Tertiary crinoids is, therefore, most probably due to non-preservation rather than to a lack of species. In fact, a remarkable number of crinoid remains have been found in the Danian (lowermost Palaeocene), and these include species of *Cainocrinus*, *Calamocrinus*, *Isselicrinus*, *Nielsenicrinus* and *Bourgueticrinus* and also comatulids (Rasmussen 1972).

Tertiary crinoids are commonly known only as stem fragments and cups; these remains belong to bourgueticrinids (*Bourgueticrinus*, *Bathycrinus*, *Conocrinus*, *Democrinus*) and isocrinids (*Cainocrinus*, *Isselicrinus*, *Nielsenicrinus*). In addition, dorsal cups (centrodorsals with radials) of comatulids are found. Complete specimens are very rare. Well-known examples are crowns of *Isselicrinus subbasaltiformis* from the Lower Eocene of Denmark and England. In Denmark such crowns are known from the Rösnäs Formation, a red clay with pyritized fossils (Rasmussen 1972), and in southeastern England they occur in the contemporaneous London Clay, deposited in deeper waters on the continental shelf. These crinoids are associated with commonly occurring driftwood from tropical trees, such as palms. In contrast to the Lower Jurassic assemblages (Chapters 22 and 23), the wood appears to have been colonized only after reaching the bottom (Wignall & Simms 1990). Numerous remains of the comatulid *Amphorometra inornata*, found within 1 m of a fossil log in the London Clay, indicate that the animals were attached to the log with their strong, curved cirri while feeding (Paul 1992).

In the New World, the Keasey Formation (probably Lower Oligocene) of northwestern Oregon has furnished complete crowns of *Raymondicrinus oregonensis* (Moore & Vokes 1953). From the Miocene of Japan some rather well-preserved specimens of the recent species *Teliocrinus springeri* (now confined to the Indian Ocean) have been described by Oji (1990). These were found near the base of turbidite beds and appear to have lived in

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an offshore environment similar to that of extant isocrinids, their preservation resulting from rapid burial by turbidity flow (Fig. 230).

The Eocene, shallow-water La Meseta Formation of Seymour Island, Antarctic Peninsula, has furnished numerous well-preserved specimens of the isocrinid *Metacrinus fossils* and some specimens of the comatulid *Notocrinus rasmusseni* (Meyer & Oji 1993). More recently, Baumiller and Gazdzicki (1996) described a new isocrinid, *Eometacrinus australis* (Fig. 231), as well as the comatulid *Notocrinus seymourensis* and the cyrtocrinid *Cyathidium holopus* from the lower units of this formation. *Eometacrinus australis* is characterized by five primibrachials, with synarthrial articulation between IBr_{1+2} and a muscular $IIBr_{1+2}$ articulation. The extant genera *Metacrinus* and *Saracrinus* also have more than two primibrachials and a muscular articulation between $IIBr_{1+2}$, but IBr_{1+2} is syzygial. Surface water temperatures in this region during the Late Eocene were estimated to be 10–15°C and were thus well within the range of temperatures in the habitat of modern *Metacrinus* species in Japan. The separation of Australia from Antarctica at the end of the Eocene and the opening of the Drake Passage in the Oligocene, enabling the development of the cold circum–Antarctic current, resulted in a sharp decline of sea temperature that made life for *Metacrinus* and other isocrinids in these waters impossible.

Fig. 230. *Teliocrinus springeri*. Proximal stem with parts of cirri and proximal part of crown. Morozaki Group (Miocene), Utsumi, Japan (figured by Oji 1990). Note the relatively large basals and the cryptosyzygial articulation between IBr_1 and IBr_2. IBr_2 and $IIBr_2$ are axillary. (Courtesy T. Oji.) ×2.4.

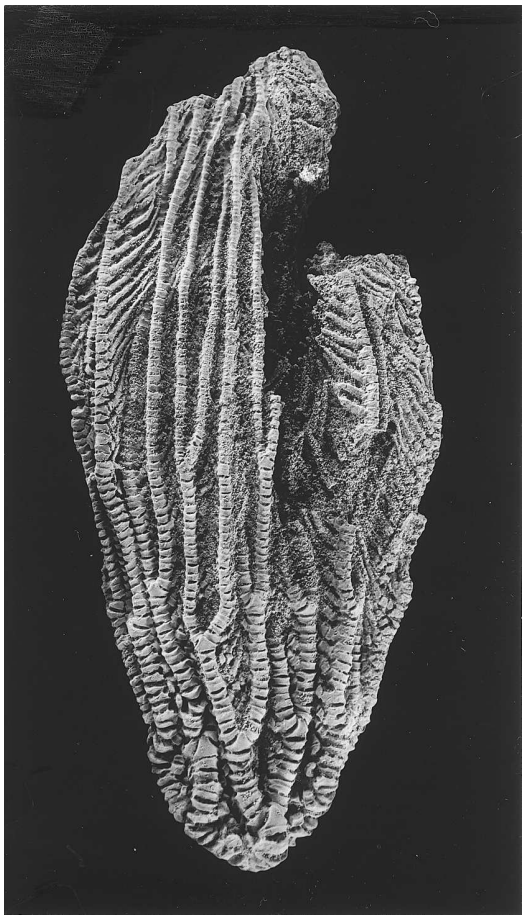

Fig. 231. Crown of *Eometacrinus australis*. Eocene La Meseta Formation, Seymour Island, Antarctic Peninsula. (Courtesy A. Gazdzicki; also figured by Baumiller & Gazdzicki 1996.) ×1.

THE OREGON SEA LILIES

For Tertiary sediments, the Oregon crinoids are quite exceptional and merit a brief description, which is based on the detailed work of Moore and Vokes (1953). The crinoids were discovered in a relatively unstratified to massive tuffaceous siltstone that is associated with some hard calcareous beds and a few layers of ashy tuff. The calcite of the ossicles was generally dissolved to some extent, and the fossils preserved partly as moulds. The difficulties of preparing and exposing the specimens from

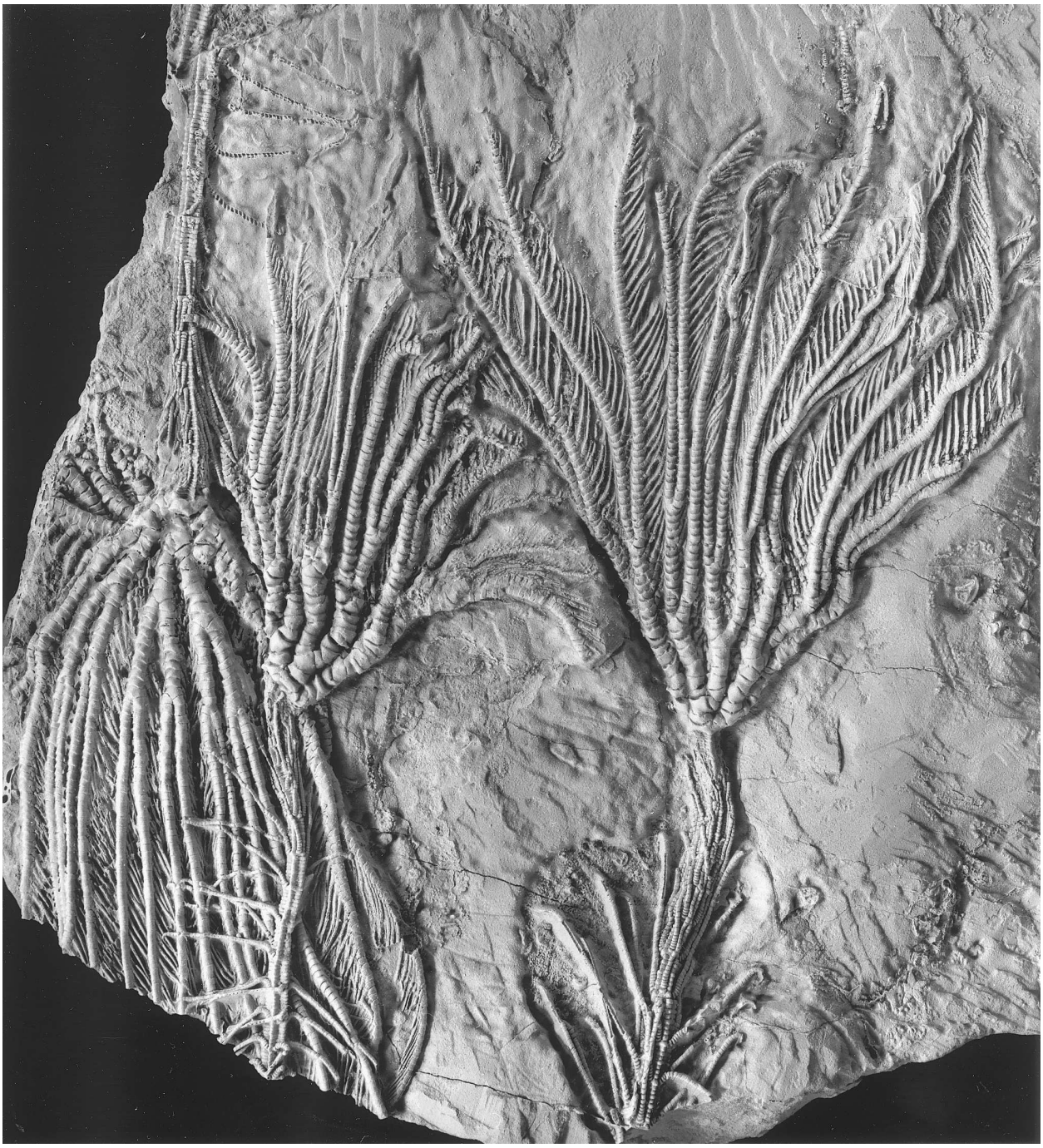

Fig. 232. *Raymondicrinus oregonensis*. Three crowns with attached proximal stems. Note three regenerated arms on specimen in the middle. Keasey Formation (probably Lower Oligocene), Mist, Columbia County, Oregon. (Hess Collection; photograph S. Dahint). ×0.85.

the hard matrix have been vividly described by the authors; and some good specimens were obtained by dissolving the calcite of the crinoids in acid, which resulted in sharp external moulds. Material recently collected at the Mist outcrop on the Nehalem River includes perfectly preserved specimens (Fig. 232). From the presence of ash pebbles and well-preserved land plants, it was concluded that the tuffaceous materials were produced by volcanic activity and thus derived from land not far away behind a shoreline. The associ-

ated invertebrate fauna consists mostly of molluscs that appear to have lived and to have been buried in relatively deep water. Associated with crinoids were a nearly complete ophiuroid with its spines, and also well-preserved leaves of an oak and a bayberry species, suggesting proximity of land.

The Oregon crinoid differs from most other isocrinids (including *Isocrinus*) in having a muscular articulation between $IIBr_1$ and $IIBr_2$, which led Klikushin (1982) to propose for this species the genus *Raymondicrinus*. Such an articulation occurs also in the Recent genera *Metacrinus* and *Saracrinus*, but in these the articulation between IBr_1 and IBr_2 is syzygial (synarthrial in the Oregon specimens), the basals are large and the primibrachials number more than two (there are generally seven primibrachials in *Metacrinus* and four in *Saracrinus*). Syzygies occur sporadically, the first one normally between $IIBr_3$ and $IIBr_4$. The rays of *Raymondicrinus oregonensis* bifurcate isotomously three times, making well-preserved crowns of this large crinoid objects of great beauty. The stem was rather long, and the nodals with their small cirrus sockets are hardly different from the six to seven internodals; the cirri have a terminal claw (Fig. 232). A second species, *Isocrinus nehalemensis*, was described by Moore and Vokes (1953) from the same area, but this may be just the juvenile form of *R. oregonensis*.

The lack of disarticulation of the crinoids, as well as the presence of a well-preserved ophiuroid on crinoid arm fragments and of weakly hinged bivalves with their valves still associated, suggests rapid burial in deep water below wave base, possibly as a result of volcanic activity on the nearby land. Thick sediment layers must have accumulated rather rapidly to prevent action by scavengers. The crinoids and the other members of the fauna appear to have lived in a zone marked by an upwelling of cool waters, such as occur along the present California coast. Therefore, their mode of life is comparable to that of existing stalked crinoids.

PLEISTOCENE CRINOIDS

A moderately rich crinoid locality in the Early Pleistocene of eastern Jamaica includes three isocrinids and a bourgueticrinid; they all belong to extant taxa and suggest a minimum depositional depth of about 180 m for these strata (Donovan 1994).