

Exceptionally preserved Early Cretaceous stalked crinoids from the Agrio Formation, Neuquén basin, west-central Argentina

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Abstract. Crinoid beds were studied from the Valanginian beds of the Agrio Formation, in the Cerro Mesa area, located 20 km northeast of the city of Zapala (Neuquén Basin, Argentina). Deposits represent a mixed clastic-carbonate succession broadly interpreted as storm-influenced shoreface to offshore settings. Crinoid paleocommunities developed in association with large migratory subaqueous dunes (sand waves) and were preserved in a number of stacked crinoid beds including a key surface with 20 specimens highly articulated. This is the first record of complete stalked crinoids from the Early Cretaceous of South America. Two distinct modes of occurrence have been recognized through a detailed taphonomic analysis. Well-preserved articulated specimens associated with rapid burial probably by avalanching processes and disarticulated specimens with more extensive periods of exposure before final burial. The specimens are provisionally assigned to the genus *Isocrinus* (Family Isocrinidae). However, some diagnostic characters remain unknown.

Keywords: Crinoidea, Valanginian, Agrio Formation, sand waves, large avalanche bedding

1 First record of stalked crinoids from the Lower Cretaceous of Argentina

Lower Cretaceous crinoids are generally known from the Northern Hemisphere, especially from Europe, North America and Japan. At the same time, they are scarcely recorded from the Southern Hemisphere and may well be considered a rarity. Records of complete specimens are only reported from Antarctica and Australia and as far as we know no records from South America have been published. Therefore, the first finding of crinoid beds, including complete specimens, from the Early Cretaceous Agrio Formation in the Neuquén Basin is remarkably important in terms of crinoid evolutionary history and paleobiogeography.

Early Cretaceous marine benthic assemblages of the Neuquén Basin are clearly dominated in abundance by bivalves, gastropods, corals, decapods and serpulids. However, crinoid-dominated paleocommunities are recorded for the first time suggesting that when paleoenvironmental conditions were favourable they

rapidly colonized the seafloor and developed crinoid meadows in close proximity to large subaqueous dunes.

In the present work we describe these crinoid beds, their facies relationships and taphonomy. We also propose a preliminary taxonomic identification.

2 Sedimentary context and age

The crinoid beds proceed from the Pilmatué Member of the Agrio Formation in the Cerro Mesa area, in the central region of the Neuquén Province. Cerro Mesa (38°44'41"S, 69°54'58"W), located some 20 km northeast of the city of Zapala, is a classical Lower Cretaceous locality of the basin where several regional geology and biostratigraphic works have been done in the last century (Fig. 1).

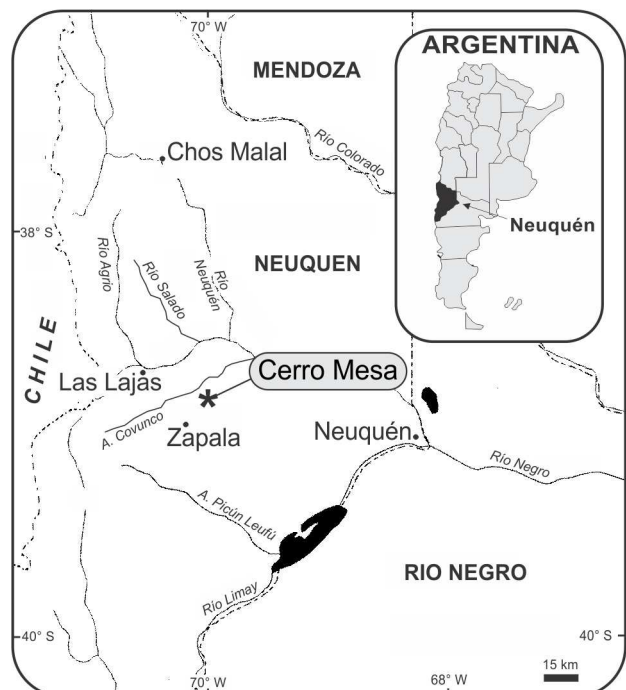


Figure 1. Location map of Cerro Mesa in central Neuquén Province.

The Agrio Formation is an important Valanginian-Barremian unit developed over much of the basin that

reaches 1600 m of maximum thickness. In particular, the Pilmatué Member represents a mixed clastic carbonate succession, comprising shales, sandstones, and limestones. The member was broadly interpreted as a storm-influenced shoreface to offshore depositional system (Spalletti *et al.*, 2011). The unit has abundant macrofossil content including bivalves, gastropods, nautiloids, ammonoids, corals, crustaceans, echinoderms, bryozoans, and serpulids, diverse trace fossils, and scarce vertebrate remains. Echinoderm records were, until the present study, restricted to regular and irregular echinoids and isolated crinoid ossicles. Indeed, Leanza (1981) is the first mention of crinoid ossicles from the Agrio Formation at Cerro Mesa.

The studied crinoid beds were recorded at three different sites in the surrounding area of Cerro Mesa encompassing less than 1 km². The sites were easily correlated in the field by means of biostratigraphy and facies relationships. Crinoid beds were accurately dated as late Valanginian by the presence of trigoniod bivalves belonging to the *Steinmanella pehuenmapuensis* Zone that partially overlaps the *Pseudofavrella angulatiformis* ammonoid zone (see Lazo *et al.*, 2009).

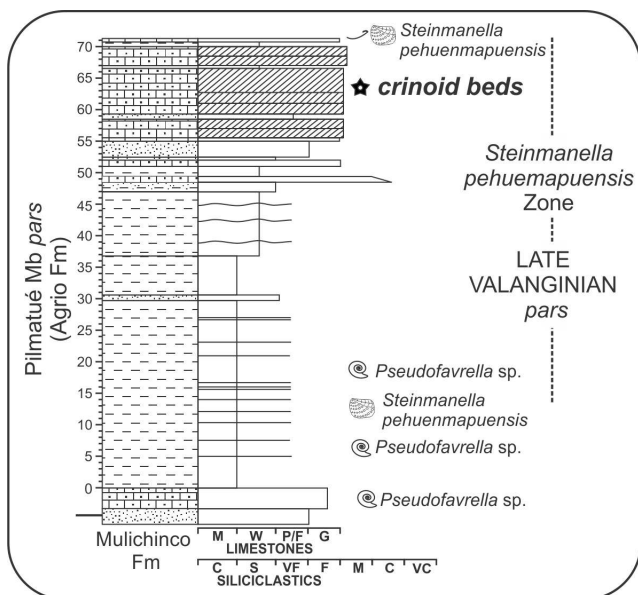


Figure 2. Sedimentary log of the basal Agrio Formation at Cerro Mesa showing the stratigraphic position of the studied crinoid beds along with trigoniod and ammonoid levels used as biostratigraphic markers.

The crinoid beds occurred about 60 m above the base of the Pilmatué Member, within a 30 m thick succession consisting of cross-bedded sandstones and mixed sediments with variable proportion of bioclasts, ooids and terrigenous sands (Fig.2). Cross-bedded sets are up to 5 m thick and the crinoid beds are invariably associated with reactivation surfaces separating consecutive sets (Fig. 3). The scale and architecture of these cross-bedded strata suggest that they represent the migration of large subaqueous dunes (or *sand waves*) in tide-influenced subtidal settings.

In the best exposed site, the crinoid beds occurred in a 40 cm thick lenticular interval which is associated with a reactivation surface that separates two large-scale cross-bedded sets (up to 5 m thick). The interval is lens shaped with an approximate lateral extension of 10 m and is characterized by alternating sandstones and crinoid beds. On one hand, the sandstone beds show cross lamination and contain disperse isolated crinoid ossicles and short fragments of stems and arms. On the other hand, crinoid beds are lens shaped and have between 2.5 and 6.2 m of maximum lateral extension and vary between 1 cm thick pavements and 15 cm thick beds. They have sharp lower contacts and sharp to transitional upper contacts and show an internal lamination parallel to the lower portions of the large-scale cross sets. They are densely packed with more than 70 percent-volume of crinoids. They are exclusively composed of crinoids with variable degrees of articulation, from ossicles to complete specimens.

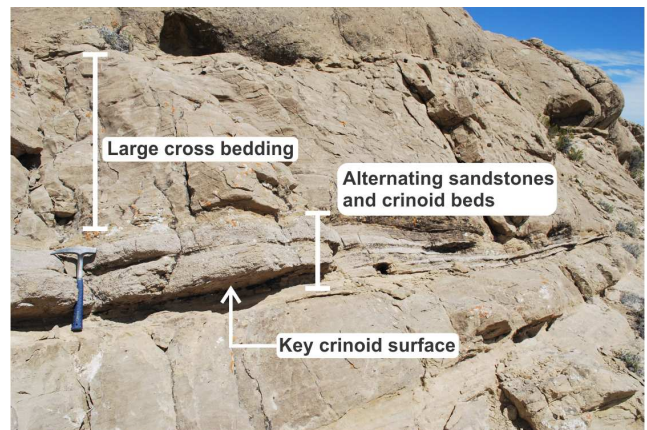


Figure 3. General view of the best exposed site showing the studied interval, including the crinoid beds. Pilmatué Member, Agrio Formation, Cerro Mesa, Late Valanginian.

3 Morphological and taxonomic remarks

Stem: heteromorphic stems, long and slender. Nodals and internodals petaloid in transverse section. The articulation between internodals is symplexy. Canal narrow and rounded. Internodals 6-7 in number. Nodal plates twice as high as internodal plates.

Nodals: with 5 circular cirrus sockets, occupying the entire height of nodal. Proximal cirral plates ovate in transverse section and distal cirral plates subcircular in transverse section. Synarthry articulation facets. Up to 28 cirral plates in cirri.

Calyx: cryptodicyclic, composed by five radial plates and five basal plates not forming a contiguous cirlet. Calyx width approximately 5 mm.

Arms: more slender toward distal ends, but almost uniform in diameter within each brachitaxis. Isotomous

arm branching. At least 6 bifurcations in line per ray. One series of pinnules. Pinnulars reduced towards distal ends. Maximum crown height approximately 80 mm (Fig. 4).

Taxonomic identity: the studied specimens resemble the genus *Isocrinus* Von Meyer (Family Isocrinidae, Suborder Isocrinina, Order Isocrinida) as described by Hess and Messing (2011, p. 50) especially in terms of small basal plates not forming a contiguous cirlet, low columnals and large cirrus sockets as high as nodals. However we could not identify articular facets of primibrachials and secundibrachials that are diagnostic features at family and subfamily levels and thus our material is provisionally assigned to *Isocrinus* Von Meyer. The genus has been previously recorded from Upper Triassic?-Lower Jurassic to Lower Cretaceous in Europe, Russia, Crimea, Caucasus, and Japan.



Figure 4. Detailed view of the key crinoid surface showing two articulated crowns with pinnules, fragments of stems and cirri. Note isotomous branching. Pilmatué Member, Agrio Formation, Cerro Mesa, Late Valanginian.

4 Taphonomic remarks

The best preserved specimens were recorded from the base of a key crinoid bed that was easily available for study in the outcrops at one of the studied sites. Some of these specimens (N=11) are almost completely articulated including stem with cirri, calyx and arms with pinnules but lacking the basal portion of the stem and its attachment to the substrate. Other specimens (N=6) are represented by articulated arms with attached pinnules and finally there are isolated stem fragments with cirri (N=3). In cross-section the crinoids are concordant, while in plan view most of the crowns show unimodal orientation, parallel to avalanching processes. There are variable degrees of recrystallization and external dissolution of ossicles, but there are undetectable degrees of fragmentation, abrasion,

and roundness. Bioerosion and encrustation were neither recognized. Apart from the key crinoid surface the rest of the beds are composed of moderately to highly disarticulated crinoid remains with dense ossicle-packing. Articulated fragments of stems, cirri, arms and pinnules appear concordant in cross section.

The exceptional preservation of complete articulated crinoids indicates that these specimens were suddenly buried, probably during life, and no subsequent reworking or bioturbation took place. These specimens are associated with a rapid sedimentation event into an environment that favoured final preservation. Avalanching was the most likely burial mechanism of stalked crinoids that probably inhabited the dune toe and/or through on the leeward side of the bedforms. In contrast, the rest of the crinoid beds preserving mainly disarticulated specimens suggest that these suffered *in situ* winnowing and significant exposure time prior to final burial in the dune through.

The crinoid beds may be classified as primarily sedimentologic in origin but there is a significant biologic overprint as the crinoid remains are envisaged as autochthonous, time-averaged relics of crinoid meadows developed in the leeward side of the dunes during pauses in avalanching progress.

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