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Notes on Early Cretaceous echinoids of Jamaica and central Hispaniola (Dominican Republic), Greater Antilles

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Abstract

Early Cretaceous echinoids from the Greater Antilles have not been adequately investigated or described. In great part, this is because they are rare, except locally, and are commonly poorly preserved. Two sites are now identified that have yielded these rare fossils. The Lower Cretaceous Hatillo Formation in the Dominican Republic (central Hispaniola) is on the property of the Pueblo Viejo gold mine. Although these rocks are well-lithified, fossils can be seen on the weathered surfaces of the exposed limestone. These fossils include robust echinoid radioles (= spines) that are globular to elongate and are elliptical in section. More commonly, tests are recognised only in section and of uncertain orientation; at least some of these are regular echinoids, bearing auricles, but it is likely that more than one species is represented. Similar radioles have also been found in Jamaica, in the Benbow Inlier, from limestones of the Devils Racecourse Group; there are no associated tests. The preservation of these spines is undoubtedly a function of their mineralogy and the fact that there are few delicate structures to be destroyed. The radioles are referred to the hemicidarid taxon *Pseudocidaris* sp. cf. *P. clunifera* (L. Agassiz); *Pseudocidaris clunifera* has been recorded previously from Lower Cretaceous (Valanginian–Albian) formations of central Mexico.

Key words: *Pseudocidaris*, Hatillo Formation, Jubilee Formation, Benbow Formation, systematics, taphonomy

1. Introduction

The first records of macrofossils from the Antilles and contiguous regions were published almost 200 years ago (De la Beche, 1827) and new discoveries continue to be made; some recent and unrelated examples include Mitchell and Skelton (2013), Van den Hoek Ostende et al. (2018) and Szawaryn and Kupryjanowicz (2019), among others. Among the commonest of fossil marine invertebrates are the echinoids; other groups of echinoderms are present, but are most commonly preserved as disarticulated ossicles (see, for example, Dixon et al., 1994; Blake et al., 2015). In contrast, echinoids are locally common as complete and

partial tests, radioles (= spines) and fragments. They are best known from Cenozoic strata, particularly those of Eocene and Neogene age (Donovan, 2001, 2003).

Echinoids are also well known from the Upper Cretaceous of the Greater Antilles (Fig. 1), although they are rarely plentiful and are only moderately diverse (Sánchez Roig, 1949; Kier, 1984; Donovan, 1993). Those from the Lower Cretaceous are even less well known. Mihaljević et al. (2010, fig. 10) suggested that there were *circa* five genera in Jamaica >120 million years ago (Aptian), presumably awaiting detailed description.

The specimens described herein were collected by the authors in the early (Jamaica) and late 1990s (Dominican Republic, Hispaniola), Only one other occurrence in Hispaniola of a Cretaceous echinoid radiole has been recorded hitherto in a conference abstract (Draper et al., 1998). This was recovered from a carbonate lens in the deformed ?Aptian Maimon Formation. The delay in producing a report was due, in part, to our hope that superior material would have become available. This has not happened and one of the sites is now completely inaccessible due to industrial activity. We therefore present these notes as a record of occurrences and of where our specimens have been deposited, in the anticipation that future researchers will find them, not just of use and interest, but perhaps an inspiration to get into the field.

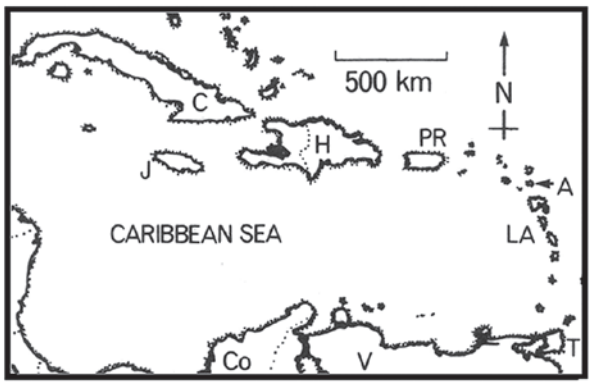


Fig. 1. Outline map of the Caribbean region showing the position of key territories (after Donovan et al., 2017, fig. 1 (*pars*)). Abbreviations (clockwise from Jamaica): J = Jamaica; C = Cuba; H = Hispaniola (Haiti + Dominican Republic); PR = Puerto Rico; A = Antigua (arrowed); LA = Lesser Antilles; T = Trinidad; V = Venezuela; Co = Colombia.

2. Material and methods

All specimens from both islands were collected from float. The Early Cretaceous echinoid radioles of Jamaica were painted with red food colouring to give a uniform body tone and then coated with ammonium chloride for photography. They were photographed with a Pentax 35 mm single lens reflex camera during the late 20th century. The uncoated Early Cretaceous echinoids from the Dominican Republic have recently been photographed with a Canon G11 digital camera in natural light. Eighteen images of echinoids are provided; there are many more specimens, but they are all poorly preserved and not worthy of a photographic over-indulgence.

Descriptive terminology of the echinoid test used herein follows Melville and Durham (1966), Durham and Wagner (1966) and Smith (1984). The classification follows Kroh and Smith (2010) and Smith and Kroh (2011). The use of open nomenclature follows the protocol recommended by Bengtson (1988). Fossil specimens are deposited in the collections of Naturalis Biodiversity Center, Leiden, the Netherlands (prefix RGM).

3. Jamaica

3.1 Geological setting and locality

Similar radioles to those of the Dominican Republic have been found in Jamaica, in the limestone formations of the Devils Racecourse Group of the Benbow Inlier (Hauterivian–Barremian) (Burke et al., 1968; Robinson, 1994; Brown and Mitchell, 2010). These are the only surface outcrop of Lower Cretaceous rocks in Jamaica (Mitchell, 2021).

Hitherto, the only Early Cretaceous echinoderms recorded from Jamaica were disarticulated crinoid ossicles. These were first assigned to *Austinocrinus* n. sp. (Donovan et al., 1994), but were subsequently reclassified as *Apiocrinites* sp. (Donovan et al., 1996). These all came from the Benbow Formation (Barremian; Mitchell, 2021, fig. 4) of the Devils Racecourse Group. Donovan et al. (1994, p. 842) remarked that, "unreported cidaroid [*sic*] ossicles" occurred in the Lower Cretaceous of Jamaica. The locality details of this site are as follows (Donovan et al., 1996, p. 867): "All specimens are from between Boozy Ridge

and Copper, near Benbow, parish of St. Catherine, eastern Jamaica (approximate GR 498 748, Jamaica 1:50,000 topographic sheet 8 (metric edition), "Moneague"; see Donovan et al., 1994, fig. 2.2, 2.3) … Benbow Inlier."

Echinoid specimens came from at least two, likely three, localities. Unfortunately, SKD's notebooks are lost, so the following summaries are deciphered from labels on specimen bags. One group of specimens is from the 'Copper Limestone' at Copper (see, for example, Robinson, 1994, fig. 6.4; for a locality map, see Brown and Mitchell, 2010, fig. 2; Fig. 2a–d herein). Brown and Mitchell (2010, p. 30, table 1) showed this to be a junior synonym of part of what is now the Jubilee Formation (Hauterivian; Mitchell, 2021, fig. 4).

A second group of specimens are labelled, more cryptically, 'DR' (= Devils Racecourse). These are most likely to be from the Benbow Formation (Barremian; Mitchell, 2021, fig. 4; Fig. 2e–h herein). Further associated, but unlabelled specimens, are of similar lithology and are likely from the same formation. Two additional radioles, free from matrix, are labelled 'Angie [= Angella P. Graham] + Avery's [= Servel A. Miller] Benbow echinoid locality'. Again, this is assumed to be Benbow Formation; it may be their *Apiocrinites* sp. locality (see above).

3.2 Material

Preservation of specimens, all radioles, is, at best, poor. Nineteen clasts containing echinoid radioles (RGM.1342901–1342904 (Fig. 2a–d), RGM.1342905 [15 specimens]) are from the Jubilee Formation (Hauterivian). Sixteen clasts each bearing one or more echinoid radioles (RGM.1342906–1342909 (Fig. 2e–h), 1342910 [12 specimens]) are most likely from the Benbow Formation (Barremian). Two partial radioles, free from matrix, RGM.1342911, probably are from the Benbow Formation.

3.3 Echinoid radioles from the Jubilee Formation (Fig. 2a–d)

These are only shafts that mainly lack a cortex layer and commonly show just the calcite cleavage of the radiating layer. Radioles are swollen, globular and stubby, perhaps less than twice as long as wide. Two incomplete specimens (part of RGM.1342905), freed from matrix, show part of the external surface sculpted by low longitudinal ridges, perhaps in part formed from coalesced tubercles. One specimen (part of RGM.1342905) preserves two slender, elongate (secondary?) radioles.

3.4 Echinoid radioles from the Benbow Formation (Fig. 2e–h)

These are mainly shafts that largely lack a cortex layer (an exception is shown in Fig. 2f); where present, the cortex is moderately thick. These are similar to, but more varied than radioles from the Jubilee Formation, including more elongate and more slender forms (Fig. 2e, g, h). One small specimen (part of RGM.1342910) shows a constriction that is probably the collarette. Some radioles are long, slender and probably secondary (part of RGM.1342910). The longest of these is at least 4 mm wide and almost 50 mm in length, and may represent a second taxon. At least one slab preserves an elongate triangular structure with calcite cleavage, probably echinoderm, but otherwise indecipherable.

4. Hispaniola (Dominican Republic)

4.1 Geological setting and locality

The specimens described in the present paper are from the Lower Cretaceous Hatillo Formation (sometimes referred to as the Hatillo Limestone). The Hatillo Formation (first named and described by Bowin, 1966) is located in central Hispaniola, within an arc edifice of Early Cretaceous to Early Eocene age, which has been modified by Cenozoic left-lateral strike-slip tectonics (Lewis and Draper, 1990; Mann et al., 1991; Draper et al., 1994, 1996). It unconformably overlies the economically important, gold-bearing Aptian Los Ranchos Formation in the Pueblo Viejo Mining District. A relatively detailed description of the formation, including a map of its distribution, has recently been published by Nelson et al. (2020). Other fauna described from the Hatillo Formation includes rudists (Bonilla-Rodríguez et al., 2014) and ammonites (Myczynski and Iturralde-Vinent, 2005). Based on the latter, Myczynski and Iturralde-Vinent assigned a late early Albian age to this unit.

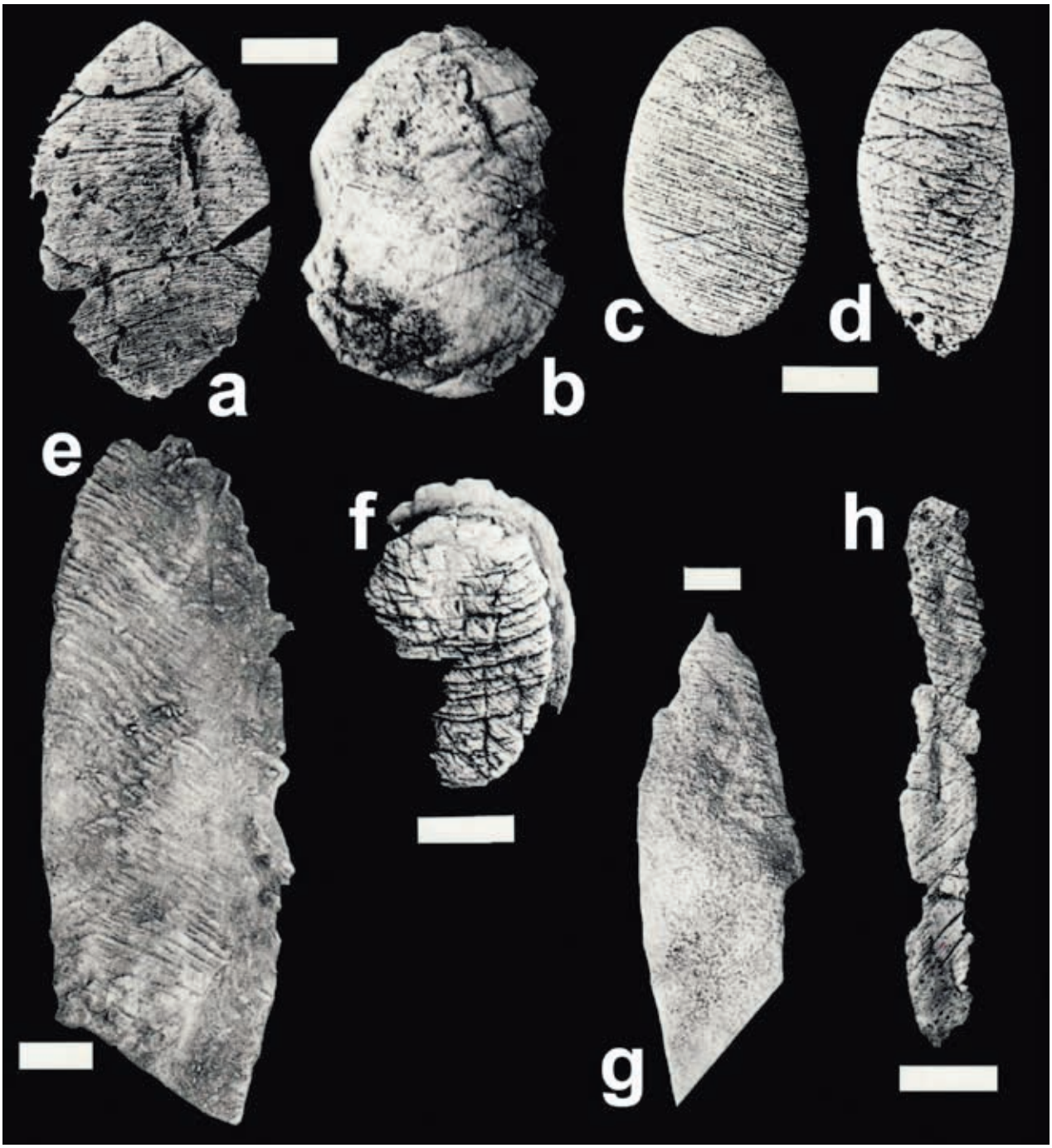


Fig. 2. Early Cretaceous echinoid radioles from Jamaica, *Pseudocidaris* sp. cf. *P. clunifera* (L. Agassiz, 1840). **a–d,** Jubilee Formation (Hauterivian), all incomplete sections through stubby radioles (RGM.1342901, RGM.1342902, RGM.1342903 and RGM.1342904, respectively). **e–h,** probably Benbow Formation (Barremian) (RGM.1342906, RGM.1342907, RGM.1342908 and RGM.1342909, respectively). Specimens coated with ammonium chloride prior to photography. All scale bars represent 5 mm.

The fossils described herein were collected from a small quarry on the property of the Pueblo Viejo mine in 1997, during a period when there was no production. The location of the quarry was at latitude 18.9275N and longitude 70.172222W (or in UTM: zone 19, ^{3}76564, ^{20}93215 WGS 84 datum, and on the Zambrana 6172-4 sheet of the 1:50,000 topographic maps). Unfortunately, this quarry no longer exists as it was removed when full-scale production of the mine resumed in recent years (Hugo Domínguez, pers. comm. to G.D., August 2020).

4.2 Material

Radioles include RGM.1342912 and 1342920; tests are commoner and include RGM.1342913 to 1342919. A large mixed collection of tens of specimens, broadly similar to those in Figure 3 and mainly tests, is lumped under a single number, RGM.1342921. Specimens RGM.1342912, 1342918 and 1342920 (Fig. 3a, g, i) have been stolen.

4.3 Echinoids (Fig. 3)

Radioles are swollen, globular and similar to those from Jamaica, described in detail above. Tests present an orientation problem. The oral surface may be readily apparent or not, either flat or depressed, with or without auricles (Fig. 2b–h), yet the large opening of the peristome is not seen and, despite the range of profiles, it is not apparent how many taxa are represented. Tests are consistently thin and external features, most notably tubercles, are not apparent.

5. Discussion

5.1. Identification

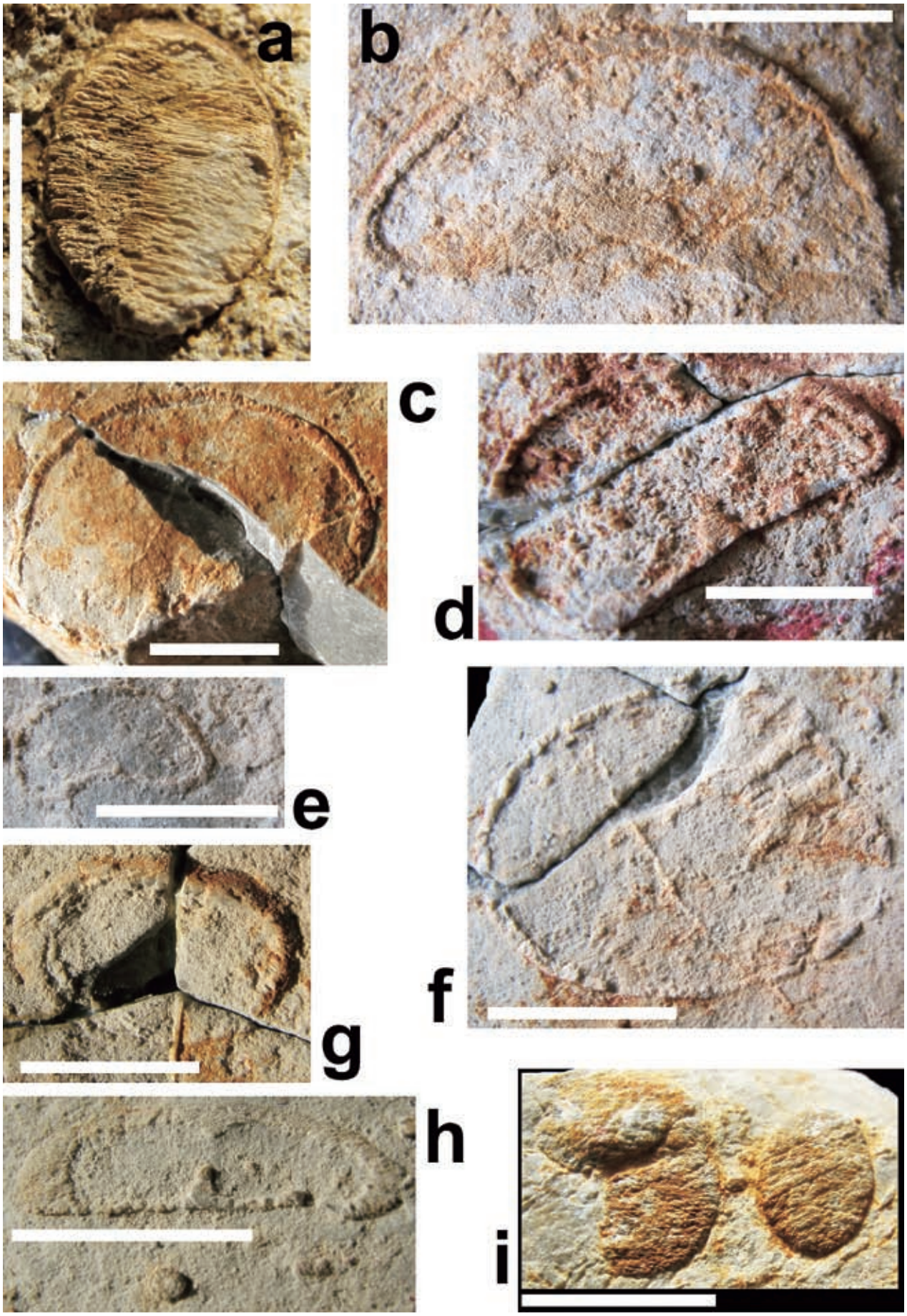
The distinctive bulbous form of many of the radioles provides the possibility of identification to the generic level. The similar radioles described above, found in both Jamaica and the Dominican Republic, are regarded herein as likely congeneric, at least. Various groups of regular echinoids had such swollen radioles, presumably as a structure to dissuade predation. The Antillean specimens are reminiscent of the hemicidarid genus *Pseudocidaris* Étallon, 1859, such as the approximately coeval *P. clunifera* (L. Agassiz, 1840) that is found in the Zapotitlán (Valanginian–Albian) and San Juan Raya (Aptian–Albian) formations of central Mexico (Buitrón, 1970). The generic diagnosis of Smith and Kroh (2011) stated, "Spines massive, clavate [= club-shaped], generally with a rather smooth shaft". Where the external sculpture of the Jamaican and Dominican Republic specimens can be seen, they are not smooth, but have a sculpture of low longitudinal ridges that appear to be formed by the coalescence of tubercles. Similar sculptures are found on the radioles of *P. clunifera* (see Buitrón, 1970, pl. 2, figs 7–11 [fig. 10 unnumbered; fig. 11 labelled fig. 10], pl. 3, figs 1–3, 5, 6, 8) and also spines assigned to *Pseudocidaris* sp. (Buitrón, 1970, pl. 3, figs 4, 7, 9) from the Zapotitlán Formation. In the present study, we make a preliminary identification of the radioles as *Pseudocidaris* sp. cf. *P. clunifera*.

Echinoid tests from the Dominican Republic are less easily determined. Tests in which auricles are identifiable are of lantern-bearing taxa and therefore regular (Fig. 3b, d, f, h). Tests (apparently) without auricles still may be regular, the cut effect not including identifiable structures, or are conceivably irregular. The presence of both flattened and depressed oral surfaces indicates that more than one taxon is present; the absence of identifiable large tubercles suggests none are cidaroids. But preservation is so poor that fine features such as ambulacral pores are not recognisable. In summary, more than one echinoid taxon is present and at least some are non-cidaroid, regular echinoids. It must be presumed that tests of *Pseudocidaris* sp. cf. *P. clunifera* are present, but not identified as such; these would be expected to bear some large interambulacral tubercles (Fell and Pawson, 1966, fig. 287.1a, 2, 3b; Buitrón, 1970, pl. 2, figs 1–6).

5.2. Taphonomy

In both the Dominican Republic and Jamaica, the echinoid-bearing units are hard, well-cemented limestone, a rock type that does not favour the easy collection of enclosed macrofossils (Fortey, 2000). Such rocks favour identification from thin sections of groups such as foraminifera, but such techniques are rarely applicable to echinoderms (but see Donovan, 2018). The Jamaican occurrences are entirely radioles; not just tests, but also test fragments were absent. It must be assumed as probable that tests completely collapsed *post-mortem* and were plates when winnowed away, so that radioles and other fragments were interred in distinct areas of the sea floor.

In contrast, in the Dominican Republic, complete tests were not uncommon and radioles less so. Yet again, there was no obvious accumulations of fragmented debris of echinoids. There is no confident evidence that any of the tests were of irregular echinoids. Auricles seem to be a common feature of these tests, depending on the line of section, and are a good indicator that an echinoid was regular. Thus, there is no strong evidence that many or even any of these tests were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irregular echinoids whose infaunal habit would have favoured preservation (Kier, 1977; Smith, 1984; Donovan, 1991). So, the only echinoid test site in the Lower Cretaceous of the Greater Antilles that yields common tests is dominated, apparently, by regular echinoids. This suggests some exceptional mode of preservation, such as rapid burial or early, perhaps pre-burial diagenesis.

5.3. Biostratigraphy

Until the discovery of the echinoids described herein (Draper et al., 1998), there was no biostratigraphical control of the Maimón Formation. In Mexico, *Pseudocidaris clunifera* (*sensu stricto*) is Early Cretaceous in age, having been recorded from the Zapotitlán (Valanginian–Albian) and San Juan Raya (Aptian–Albian) formations. *Pseudocidaris clunifera* does not, of course, have to range the full length of either of these formations (Shaw, 1964, 1971), which 'overlap' in the Aptian to Albian interval. In Jamaica, *Pseudocidaris* cf. *clunifera* is known from the Jubilee (Hauterivian) and Benbow formations (Barremian), that is, the two stages immediately preceding the Aptian. These data support a probable Early Cretaceous age for the Maimón Formation, perhaps no older than Hauterivian.

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7. References

Agassiz, L. 1840. Catalogus systematicus Ectyporum Echinodermatum fossilium Musei Neocomiensis, secundum ordinem zoologicum dispositus; adjectis synonymis recentioribus, nec non stratis et locis in quibus reperiuntur. Sequuntur characters diagnostici generum novorum vel minus cognitorum. Petitpierre. Neuchâtel. 32 p.

Bengtson, P. 1988. Open nomenclature. Palaeontology 31: 223–227.

Blake, D. B., S. K. Donovan, C. L. Mah, and H. L. Dixon. 2015. Asteroid (Echinodermata) skeletal elements from the Upper Oligocene of Jamaica and Antigua. Geological Magazine 152: 1043–1056. DOI: 10.1017/S0016756815000096

Bonilla-Rodríguez, A. J., L. A. González, J. D. Walker, and H. Santos. 2014. Strontium isotope ($^{87}Sr/^{86}Sr$) stratigraphy from the *Coalcomana-Caprinuloidea* rudist assemblage in the Greater Antilles (Puerto Rico, Dominican Republic and Jamaica). Cretaceous Research 50: 97–109. DOI: 10.1016/j.cretres.2014.04.008

Fig. 3. Early Cretaceous echinoids from the Dominican Republic. **a,** RGM.1342912, *Pseudocidaris* cf. *clunifera* (L. Agassiz, 1840), either an oblique section through a robust radiole or, less likely, a longitudinal section of a globular radiole. **b,** RGM.1342913, apical-oral section through a test with a depressed oral surface; the thickenings of the inside of the test are likely auricles. **c,** RGM.1342914, inflated, globular test. **d,** RGM.1342915, inflated test with flat oral surface. **e,** RGM.1342916, apical-oral section through a test with a depressed oral surface. **f,** RGM.1342917, likely oblique section through a test, making it appear unusually tall; flattened oral surface towards upper right with a pair of auricles. **g,** RGM.1342918, test partly weathered out to show external curvature. **h,** RGM.1342919, low test with broad, flat oral surface and a single auricle. **i,** RGM.1342920, *Pseudocidaris* cf. *clunifera* (L. Agassiz, 1840), probably an oblique section through a robust radiole (right) and a strange juxtaposition of two robust radioles. Specimens uncoated. All scale bars represent 10 mm.

Bowin, C. O. 1966. Geology of the central Dominican Republic – a case history of part of an island arc. Geological Society of America Memoir 98: 11–84.

Brown, I., and S. F. Mitchell. 2010. Lithostratigraphy of the Cretaceous succession in the Benbow Inlier, Jamaica. Caribbean Journal of Earth Science 41: 25–37.

Buitrón, B. E. 1970. Equinoides del Cretácico Inferior de la region de San Juan Raya-Zapotitlán, Estado de Puebla. Paleontología Mexicana 30: 1–65.

Burke, K., A. G. Coates, and E. Robinson. 1968. Geology of the Benbow Inlier and surrounding areas, Jamaica. In J. B. Saunders, ed., Transactions of the Fourth Caribbean Geological Conference, Port of Spain, Trinidad, 28th March-12th April, 1965. Ministry of Petroleum and Mines. Port of Spain. p. 299–307.

De la Beche, H. T. 1827. Remarks on the geology of Jamaica. Transactions of the Geological Society of London (2)2: 143–194.

Dixon, H. L., S. K. Donovan, and C. J. Veltkamp. 1994. Crinoid and ophiuroid ossicles from the Oligocene of Jamaica. Caribbean Journal of Science 30: 143–145.

Donovan, S. K. 1991. The taphonomy of echinoderms: calcareous multi-element skeletons in the marine environment. In S. K. Donovan, ed., The Processes of Fossilization. Belhaven Press. London. pp. 241–269.

Donovan, S. K. 1993. Jamaican Cretaceous Echinoidea. In R. M. Wright, and E. Robinson, eds., Biostratigraphy of Jamaica. Geological Society of America Memoir 182: 93–103.

Donovan, S. K. 2001. Evolution of Caribbean echinoderms during the Cenozoic: moving towards a complete picture using all of the fossils. Palaeogeography, Palaeoclimatology, Palaeoecology 166: 177–192.
DOI: 10.1016/S0031-0182(00)00208-X

Donovan, S. K. 2003. Completeness of a fossil record: the Pleistocene echinoids of the Antilles. Lethaia 36: 1–7.
DOI: 10.1080/00241160310001227

Donovan, S. K. 2018. The internal morphology of primary spines of extant regular echinoids in the tropical western Atlantic: a SEM atlas. In C. A. Meyer, B. Thuy, C. Klug, D. Marty, and S. K. Donovan, eds., Hans Hess: A Lifelong Passion for Fossil Echinoderms. Swiss Journal of Palaeontology 137: 363–377.
DOI: 10.1007/s13358-018-0157-x

Donovan, S. K., D. A. T. Harper, R. W. Portell, and J. K. Toomey. 2017. Echinoids as hard substrates: Varied examples from the Oligocene of Antigua, Lesser Antilles. Proceedings of the Geologists' Association 128: 326–331.
DOI: 10.1016/j-pgeola.2017.04.003

Donovan, S. K., S. A. Miller, A. P. Graham, and H. L. Dixon. 1994. New fossil crinoids from Jamaica. Journal of Paleontology 68: 842–845.
DOI: 10.1017/S0022336000026287

Donovan, S. K., C. V. Milsom, and C. J. Veltkamp. 1996. Jamaican Cretaceous Crinoidea. Journal of Paleontology 70: 866–871.
DOI: 10.1017/S002233600002388X

Draper, G., S. K. Donovan, and J. F. Lewis. 1998. Cretaceous echinoid fossils from central Hispaniola and Jamaica. In W. Ali, A. Paul, and V. Young On, eds., Transactions of the 3rd Geological Conference of the Geological Society of Trinidad and Tobago and the 14th Caribbean Geological Conference (in two volumes) 1, p. 83.

Draper, G., G. Guitierrez, and J. F. Lewis. 1996. Thrust emplacement of the Hispaniola peridotite belt: orogenic expression of the mid Cretaceous Caribbean arc polarity reversal? Geology 24: 1143–1146.
DOI: 10.1130/0091-7613(1996)024<1143:TEOTHP>2.3.CO;2

Draper, G., P. Mann, and J. F. Lewis. 1994. Hispaniola. In S. K. Donovan, and T. A. Jackson, eds., Caribbean Geology: An Introduction. UWI Publishers' Association. Kingston. p. 129–150.

Durham, J. W., and C. D. Wagner. 1966. Glossary of morphological terms applied to echinoids, In R. C. Moore, ed., Treatise on Invertebrate Paleontology, Part U, Echinodermata 3(1). Geological Society of America and University of Kansas. New York and Lawrence. p. U251, U253–U256.

Étallon, M. 1859. Études paléontologiques sur le Haut Jura. Rayonnés du Corallien. Mémoires de la Société d'Émulation de Doubs (3)6: 53–260.

Fell, H. B., and D. L. Pawson. 1966. Echinacea. In R. C. Moore, ed., Treatise on Invertebrate Paleontology, Part U, Echinodermata 3 (2). Geological Society of America and University of Kansas. New York and Lawrence. p. U367–U440.

Fortey, R. A. 2000. Trilobite! Eyewitness to Evolution. Knopf. New York.

Kier, P. M. 1977. The poor fossil record of the regular echinoid. Palaeobiology 3: 168–174. DOI: 10.1017/S0094837300005248

Kier, P. M. 1984. Fossil spatangoid echinoids of Cuba. Smithsonian Contributions to Paleobiology 55: 1–336.

Kroh, A., and A. B. Smith. 2010. The phylogeny and classification of post-Palaeozoic echinoids. Journal of Systematic Palaeontology 8: 147–212. DOI: 10.1080/14772011003603556

Lewis, J. F., and G. Draper. 1990. The geology and tectonic evolution of the northern Caribbean margin. In G. Dengo, and J. E. Case, eds., The Geology of North America. Volume H. The Caribbean Region. Geological Society of America, Boulder. Colorado. p. 77–140.

Mann, P., G. Draper, and J. F. Lewis. [eds.] 1991. Geologic and tectonic studies of the North American Caribbean plate boundary in Hispaniola. Geological Society of America, Special Paper 262: 1–401.

Melville, R. V., and J. W. Durham. 1966. Skeletal morphology. In R. C. Moore, ed., Treatise on Invertebrate Paleontology, Part U, Echinodermata 3(1). Geological Society of America and University of Kansas. New York and Lawrence. p. U220–U251.

Mihaljević, M., C. Klug, O. Aguilera, T. Lüthi, and M. R. Sánchez-Villagra. 2010. Palaeodiversity of Caribbean echinoids including new material from the Venezuelan Neogene. Palaeontologia Electronica 13 (3; 20A): 1–36.

Mitchell, S. F. 2021. Cretaceous geology and the tectonic assembly of Jamaica. In I. Davison, J. N. F. Hull, and J. Pindell, eds., The Basins, Orogens and Evolution of the southern Gulf of Mexico and the northern Caribbean. Geological Society, London, Special Publications 504: 507–547.

Mitchell, S. F., and P. W. Skelton. 2013. A new rudist bivalve, *Polytorreites* gen. nov., from the Campanian of Puerto Rico demonstrating iterative evolution of American multiple-ray Hippuritidae. Caribbean Journal of Earth Science 45: 119–123.

Myczynski, R., and M. Iturralde-Vinent. 2005. The late Lower Albian invertebrate fauna of the Río Hatillo Formation, Dominican Republic. Caribbean Journal of Earth Science 41: 782–796.

Nelson, C., J. Polanco, A. Macassi, H. Dominguez, J. Proenza, L. Torró, D. Rhys, and M. Iturralde-Vinent. 2020. The Hatillo Limestone, Pueblo Viejo district, Dominican Republic: marginal reef or impermeable cap? Boletín de la Sociedad Geológica Mexicana 73: 1–17. DOI: 10.18268/bsgm2020v72n3a011119

Robinson, E. 1994. Jamaica. In S. K. Donovan, and T. A. Jackson, eds., Caribbean Geology: An Introduction. UWI Publishers' Association. Kingston. p. 111–127.

Sánchez Roig, M. 1949. Los equinodermos fósiles de Cuba. Paleontologia Cubana 1: 1–302.

Shaw, A. B. 1964. Time in Stratigraphy. McGraw-Hill, New York.

Shaw, A. B. 1971. The butterfingered handmaiden. Journal of Palaeontology 45: 1–5.

Smith, A. B. 1984. Echinoid Palaeobiology. George Allen and Unwin. London.

Smith, A. B., and A. Kroh. [eds.] 2011. The Echinoid Directory. World Wide Web electronic publication. http://www.nhm.ac.uk/research-curation/projects/echinoid-directory [accessed 6 August 2020].

Szawaryn, K., and J. Kupryjanowicz. 2019. The first fossil Discolomatidae (Coleoptera) from Hispaniola. PalZ 93: 593–598. DOI: 10.1007/s12542-019-00467-w

Van den Hoek Ostende, L.W., D. Van Oijen, and S. K. Donovan. 2018. A new bat record for the late Pleistocene of Jamaica: *Pteronotus trevorjacksoni* from the Red Hills Road Cave. Caribbean Journal of Earth Science 50: 31–35. DOI: 10.18475/cjos.v47i3.a16