Bulletin of the Mizunami Fossil Museum, no. 45 (March 15, 2019), p. 7–13, 3 figs., 1 table.

Oligocene pagurized gastropods from the River Bend Formation, North Carolina, USA

Rodney M. Feldmann[1], Carrie E. Schweitzer[2], and George E. Phillips[3]

[1]Department of Geology, Kent State University, Kent, Ohio 44242 USA <rfeldman@kent.edu>
[2]Department of Geology, Kent State University at Stark, 6000 Frank Ave. NW, North Canton, Ohio 44720 USA <cschweit@kent.edu>
[3]Conservation and Biodiversity Section, Mississippi Museum of Natural Science, 2148 Riverside Drive, Jackson, Mississippi 39202 USA <george.phillips@mmns.state.ms.us>

Abstract

Fourteen specimens of pagurized gastropods are completely enveloped by anascan cheilostome bryozoan colonies, and most of them bear serpulid worm tubes referred to *Hydroides* sp. These specimens from the Oligocene River Bend Formation in North Carolina constitute the first such occurrence on the Atlantic coastal region of North America.

Key words: Decapoda, Paguroidea, biotic associations, *Cymatium*, North Carolina

Introduction

The River Bend Formation is an Oligocene, sandy, carbonate unit exposed in quarries in east-central North Carolina. The formation has yielded an abundance of fossil material, but to date no decapod crustaceans have been reported. Discovery of small gastropods invested by bryozoans and serpulid worms provide evidence that the shells were the domiciles of hermit crabs. The purpose of this note is to document that occurrence and to provide generic identifications of some of the gastropods and the serpulid worms. Oligocene decapods are known from Mississippi and Alabama (in progress) and Florida (Rumsey *et al*., 2016). This new discovery also is notable in being the first record of decapod presence from the Oligocene of the East Coast of North America.

Occurrence

The material discussed herein was collected from the River Bend Formation exposed in Belgrade Quarry #2, Jones County, North Carolina (Fig. 1). Although collected from spoils, the sandy limestone lithology and associated macrofauna is most consistent with that described from the lower beds of the upper River Bend Formation (most likely bed "C") at Belgrade Quarry #1, Onslow County (Ward and Carter, 1992; Ward, 2002). At the Jones County quarry, which is immediately adjacent to the Onslow County quarry, this "very arenaceous bivalve biocalcirudite" (Ward, 2002) contains conspicuous numbers of the scallop *Rebeccapecten trentensis* (Harris, 1919), the jingle shell *Anomia ruffini* Conrad, 1843, the cyclostome bryozoan *Meandropora* cf. *M. cerebriformis* (de Blainville, 1843), and the small regular echinoid *Psammechinus carolinensis* Kier, 1997. (based on MMNS samples collected by D. Clements). The age of the unit, based largely on molluscan biostratigraphy, is middle to late Oligocene, and thus either latest Rupelian or Chattian (Rossbach and Carter, 1991; Ward and Carter, 1992).

Methods

The specimens were photographed using a Nikon D3100 camera with an AF-S Micro Nikkor 60 mm lens. The images were toned for contrast and brightness using Adobe Photoshop CC2018. Close-up images were taken using a Leica Z6 Macroscope with a Planapo 0.5 mm lens and a Spotflex digital camera. Scanning electron microscopic images were taken with a Hitachi TM3030 Tabletop Microscope. The specimens, MMNS IP-6932 and 6933, collected by Mr. Don Clements, and MMNS IP-9929 - 9940, collected by Adam Osborn, are deposited in the Invertebrate Paleontology collection, Mississippi Museum of Natural Science, Jackson, Mississippi.

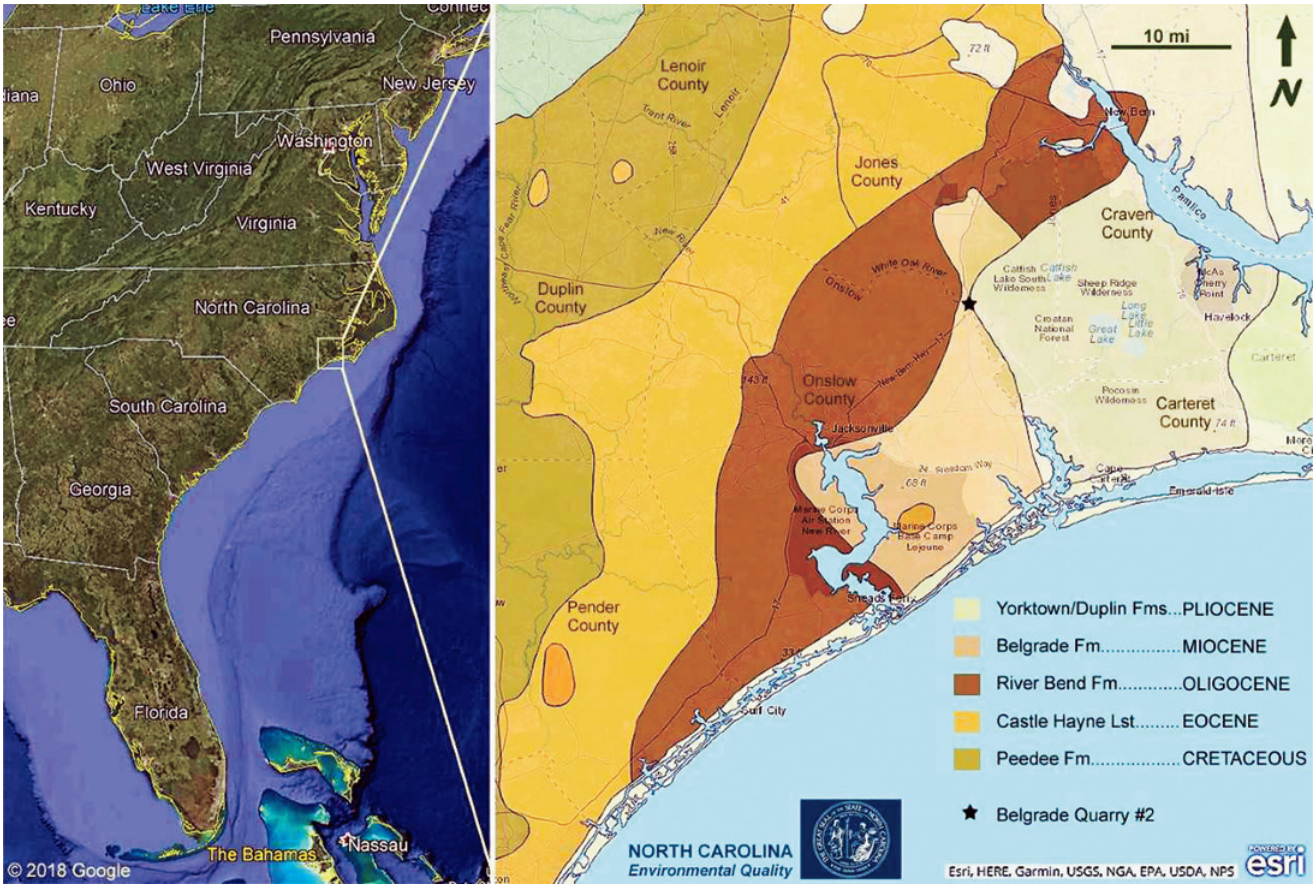


Fig. 1. Map of U.S. Atlantic Coastal Plain showing recovery locality of pagurized gastropod shells (black star). Note that the source unit, the River Bend Formation, does not crop out naturally in the immediate vicinity of Belgrade; however, it is frequently encountered in aggregate quarry excavations just outside its eastern contact with the immediately superjacent Belgrade Formation.

Table 1. List of specimens interpreted to be pagurized gastropods from the Oligocene River Bend Formation, North Carolina.

Cat. No.	Gastropod	Serpulid	Notes
MMNS IP-6932	Indeterminate	*Hydroides*	Extended aperture
MMNS IP-6933	*Cymatium* sp.	*Hydroides*	Extended aperture
MMNS IP-9929	Indeterminate		
MMNS IP-9930	*Cymatium* sp.		
MMNS IP-9931	Indeterminate	*Hydroides*	
MMNS IP-9932	*Cymatium* sp.		
MMNS IP-9933	Indeterminate		
MMNS IP-9934	*Cymatium* sp.	*Hydroides*	
MMNS IP-9935	*Cymatium* sp.		Extended aperture
MMNS IP-9936	*Cymatium* sp.		Extended aperture
MMNS IP-9937	*Cymatium* sp.	*Hydroides*	
MMNS IP-9938	Indeterminate		Extended aperture
MMNS IP-9939	Indeterminate	*Hydroides*	
MMNS IP-9940	Indeterminate		

Results

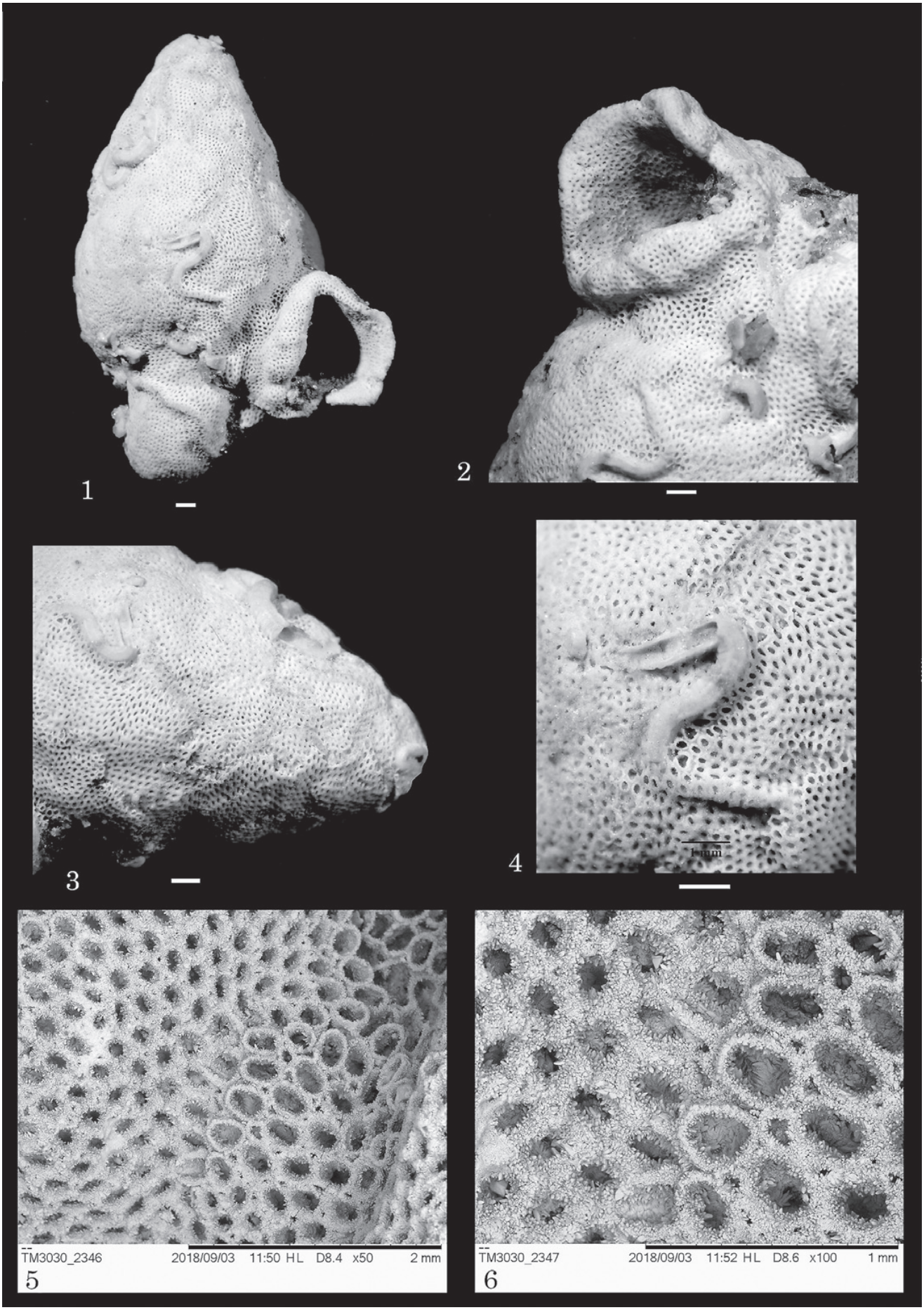
The specimens of pagurized gastropods were collected from the lower River Bend Formation, in the Belgrade Quarry #2, Jones County, North Carolina. The gastropods are completely encrusted by bryozoans and bear several serpulid worm tubes (Fig. 2, Table 1). Walker (1992) and Taylor (1994) provided extensive discussions of pagurized gastropods and concluded that complete coverage of the gastropod shell, epibiont growth within the aperture, extension of a helically coiled structure beyond the aperture, and a possible "pagurid facet" (Walker, 1992, p. 545) were strong evidence of paguroid occupation of the shell. These features, with the exception of the pagurid facet, are all present on the River Bend Formation specimens. Absence of the pagurid facet may be an indication that the crab carried the gastropod shell in an elevated position rather than dragging it along the bottom.

The gastropods are obscured by bryozoan colonies to the point that it is difficult to identify all of them with certainty. Rossbach and Carter (1991) described the molluscs from the lower River Bend Formation at the Martin Marietta New Bern Quarry in Craven County, North Carolina. They described 41 species of molluscs, of which *Cymatium planinodum* Rossbach and Carter, 1991, most closely resembles the form of some of some of the pagurized gastropods. *Cymatium planinodum* was estimated to be 36 mm in height and, based upon the illustration of the specimen (Rossbach and Carter, 1991, fig. 7.8), has an apical angle of about 42º. The pagurized specimens are estimated to be about 35 mm high with an apical angle of about 52º (Figs. 2.1, 3.1). A few nodes are evident on the pagurized specimen and they lie just above the sutures as they do in *Cymatium planinodum*. Thus, some of the specimens described herein, MMNS IP-6933, 9930, 9932, and 9934–9937, closely resemble *Cymatium planinodum*. Comparison with the illustrations of the other gastropods from the formation indicates that no other species exhibits a size or shape even closely approaching that of the pagurized gastropods. Taylor (1994, fig. 9A) illustrated an extant specimen of *Cymatium* from Hong Kong that was complete encrusted by bryozoans that he interpreted as pagurized; thus, reference to the Oligocene pagurized gastropods as *Cymatium* sp. is supported. The other specimens, MMNS IP-6932, 9929, 9931, 9933, and 9938–9940, exhibit all the characteristics necessary to conclude that they are pagurized gastropods, but their forms are so obscured by the bryozoans that identification of the gastropod is not possible.

The bryozoan colonies completely envelop the gastropods. They are multilaminar forms composed of ovoid zooecia, ca. 0.2 mm long, with tiny pores that may represent accessory zooecia in the coenosteum (Figs. 2.4–2.6). The bryozoans are recrystallized to the point that precise identification is not possible (Figs. 2.6, 3.4). Paul Taylor, The Natural History Museum, London (personal commun. to RMF, 8/2018) recognized them as membraniporimorph anascan cheilostomes. The colony extends as far into the apertural region as can be observed in MMNS IP-6933 and seems to have grown out from the actual gastropod aperture mimicking the gastropod growth form (Figs. 2.1, 2.2). This growth pattern has been frequently observed in fossil and extant bryozoans as overgrowths on gastropods (Taylor, 1994; Pérez *et al*., 2015). The extensional growth of bryozoans on MMNS IP-9936 (Fig. 3.1) is projected outward from the aperture and does not conform to the coiling pattern of the gastropod.

Serpulid worms are present on six of the specimens (Figs. 2.1–2.4, 3.3, 3.4). They seem to have grown at the same time that the bryozoan colony was active. Some of the serpulids lie directly on top of the bryozoans, whereas some are partially enveloped by the bryozoans so that the actively growing portion of the worm is exposed but the older part of the tube is covered by bryozoans (Fig. 2.4). A few worm tubes are evident as sinuous elevations completely covered by the bryozoans. The tubes attain a maximum diameter of about 0.7 mm and bear two keels on the wrinkled upper surface. One worm tube, on MMNS IP-9931, preserves the coiled apical region (Fig. 3.3).

Serpulid worms in the fossil record are commonly referred to as *Serpula* Linnaeus, 1758, when they exhibit an irregular pattern on hard surfaces and do not exhibit a coiled initial growth form. *Serpula* spp. are reported as ranging from Silurian to Holocene (Robison, 1987), which suggests that this is a form genus. Tentatively, the specimens present on *Cymatium* sp. can be compared to *Hydroides elegans* Haswell, 1883, a very common extant fouling organism along the east coast of North America. *Hydroides elegans* is morphologically quite similar to the North Carolina fossil forms. Both produce a sinuous wrinkled tube with two keels extending along the upper surface. Based upon these characteristics, the specimens on *Cymatium* sp. can be assigned to *Hydroides* sp. One specimen, MMNS IP-6933, bears a worm tube that is broken in such a way as to expose the interior of the tube. Numerous tiny fecal pellets are preserved within the tube (Fig. 3.4). The pellets are elongate and tapered at both ends. The pattern of distribution of the pellets in a


1
2
3
4
1 mm
TM3030_2346 2018/09/03 11:50 HL D8.4 x50 2 mm
5
TM3030_2347 2018/09/03 11:52 HL D8.6 x100 1 mm
6

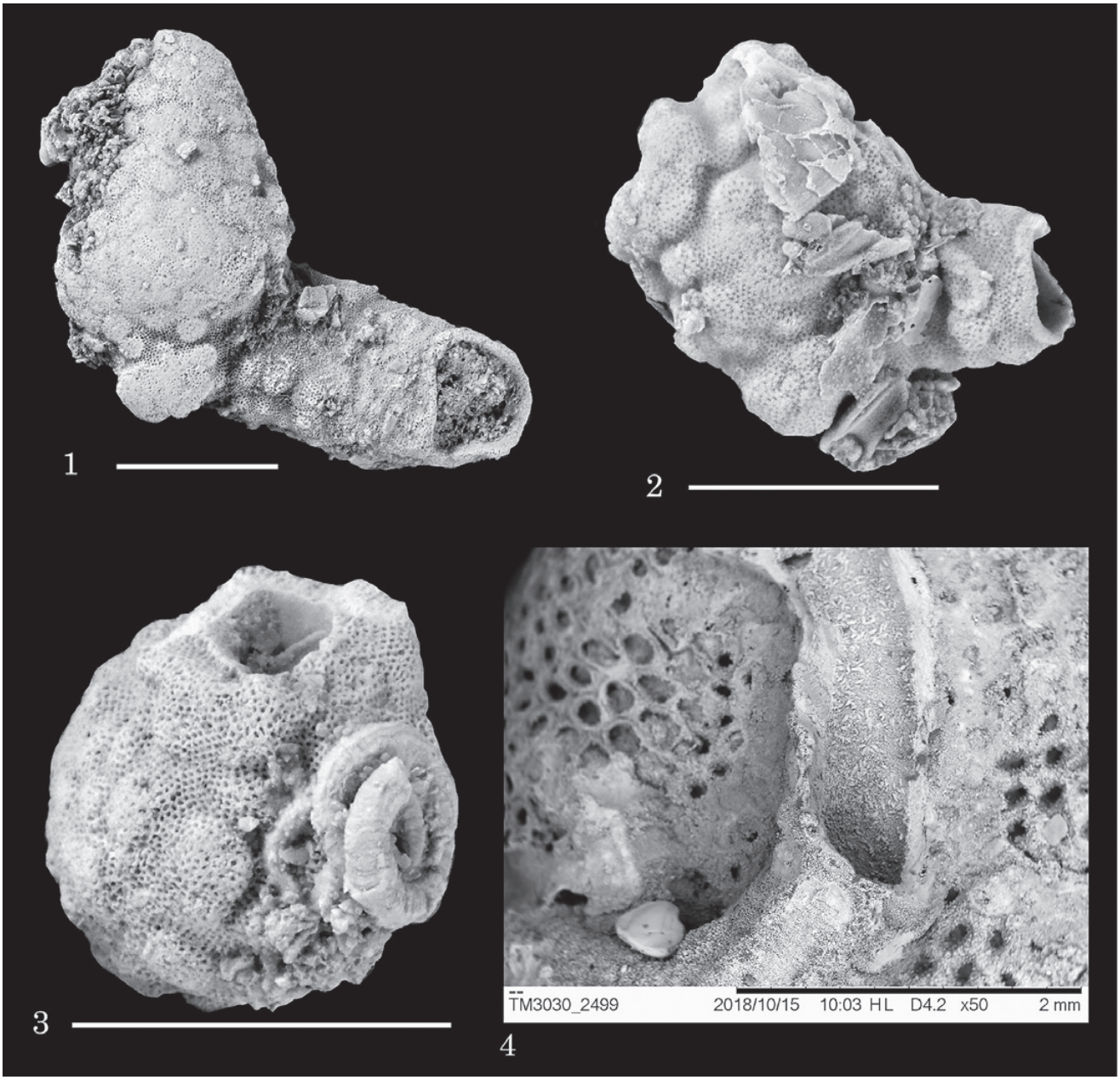


Fig. 3. *1*, *Cymatium* sp. showing a linear extension of bryozoan growth beyond the aperture, MMNS IP-9936. *2*, thick bryozoan colony obscuring the gastropod and extending beyond the aperture, MMNS IP-9938. *3*, nearly spherical bryozoan growth bearing the coiled, initial growth stages of *Hydroides* sp., MMNS IP-9931. The aperture of the gastropod is at the top of the illustration. *4*, Scanning electron microscope image of MMNS IP-6933 with a broken *Hydroides* tube exposing tiny fecal pellets. Scale bars for figures 1–3 = 1 cm. Scale bar for figure 4 = 2 mm.

Fig. 2. *Cymatium* sp. encrusted by an anascan cheilostome bryozoan colony and serpulid worm tubes, *Hydroides* sp., MMNS IP-6933. *1*, apertural view of entire specimen. *2*, enlargement of apertural region showing bryozoan growth within opening and bryozoan colony extension beyond gastropod aperture. *3*, apical region showing multiple laminations of bryozoan colony. *4*, serpulid worm tube showing longitudinal ridges and wrinkled surface characteristic of *Hydroides* spp. and overgrowth of bryozoans on initial part of worm tube. *5*, SEM image of bryozoan colony showing small openings between major zoecia. *6*, SEM image showing recrystallized surface of colony. Scale bars for figures 1–4, 6 = 1 mm. Scale bar for figures 5 = 2 mm.

random fashion confirms that they were deposited within the burrow and were not a part of the burrow structure. The organism responsible for their deposit is not known.

Discussion

The River Bend Formation, although containing a rich and varied fauna of marine micro- and macrofossils (Rossbach and Carter, 1991), has not been reported to yield decapod crustaceans. Thus, the discovery of pagurized gastropods, seven of which are referable to *Cymatium* sp., constitutes the first possible notice of fossil decapods from the unit. Paguroid decapods, the hermit crabs, have a long geological history, ranging from the Jurassic to Holocene, and a cosmopolitan geographic distribution (Glaessner, 1969). Their fossil record consists in large part of isolated claws, but in some cases their presence is documented by gastropod shells that have served as a temporary domicile protecting the soft, uncalcified body of the animals. In rare cases, remains of the hermit crab are preserved within the gastropod shell (*e.g*. Hyden and Forest, 1980), and on even more rare occasions, hermit crabs have been documented occupying cast off shells of cephalopods (Fraaije, 2003). The history of more complex biotic associations, such as the hermit crab-gastropod-bryozoan-serpulid association documented here, has been summarized by Taylor (1994) and need not be repeated. Suffice it that this manner of association confirms the presence of a paguroid carrying a gastropod by its elevating the shell above the substrate and permitting the bryozoans to grow over the entire surface. Growth of bryozoans within the aperture, and extension of the colony beyond the gastropod aperture further confirms the association.

Acknowledgments

The specimens forming the basis for this work were collected and donated by Donald N. Clements, Research Adjunct, North Carolina Museum of Natural Sciences, Raleigh, North Carolina, and Adam Osborn, Camden, South Carolina, whose individual stratigraphic observations were essential to the final interpretation. Paul Taylor, The Natural History Museum, London, United Kingdom, and Mark Wilson, Department of Geology, Wooster College, Wooster, Ohio, USA, examined photographs of the specimens and commented on the identification and preservation of the bryozoans. The final manuscript was reviewed by John W. M. Jagt, Natuurhistorisch Museum Maastricht. The Netherlands.

References

Blainville, H. M. D. De 1834. Manuel d'Actinologie ou de Zoophytologie. F.G. Levrault, Paris, Strasbourg, Volume 1: 644 p.

Conrad, T. A. 1843. Descriptions of nineteen species of Tertiary fossils of Virginia and North Carolina. Proceedings of the Academy of Natural Sciences of Philadelphia 1: 323–329.

Fraaije, R. H. B. 2003. The oldest *in situ* hermit crab from the Lower Cretaceous of Speeton, UK. Palaeontology 46: 53–57.

Glaessner, M. F. 1969. Decapoda. In: R. C. Moore (ed.), Treatise on Invertebrate Paleontology, Part R, Arthropoda 4(2). The Geological Society of America and University of Kansas: R400–R532. Lawrence KS.

Harris, G. D. 1919. A few mid-upper Eocene fossils from the Carolinas and Texas. In: K. Van Winkle and G. D. Harris (eds.), New or Otherwise Interesting Tertiary Molluscan Species from the East Coast of America. Bulletins of American Paleontology 8: 13–32.

Haswell, W. A. 1883. On some new Australian tubicolous annelids. Proceedings of the Linnean Society of New South Wales 7: 633–638.

Hyden, F. M. and J. Forest. 1980. An *in situ* hermit crab from the early Miocene of southern New Zealand. Palaeontology 23: 471–474.

Kier, P. M. 1997. Oligocene echinoids of North Carolina. Smithsonian Contributions to Paleobiology 83: 1–37.

Linnaeus, C. 1758. Systema Naturae per Regna Tria Naturae. Edito Decima, Reformata. Volume 1, Regnum Animale. Laurentii Salvii, Stockolm: 824 p.

Pérez, L. M., M. Griffin, G. Pastorino, J. López-Gappa, and M. O. Manceñido. 2015. Redescription and palaeoecological significance of the bryozoan *Hippoporidra patagonica* (Pallaroni, 1920) in the San Julián Formation (late Oligocene) of Santa Cruz province, Argentina. Alcheringa 39: 72. http://www.tandfonline.com/loi/talc20

Robison, R. A. 1987. Phylum Annelida. In: R. S. Boardman, A. H. Cheetham and A. J. Rowell (eds.), Fossil Invertebrates. Blackwell Scientific Publications: 194–204. Palo Alto, CA.

Rossbach, T. J., and J. G. Carter. 1991. Molluscan biostratigraphy of the lower River Bend Formation at the Martin Marietta Quarry, New Bern, North Carolina. Journal of Paleontology 65: 80–118.

Rumsey, B. T., A. A. Klompmaker and R. W. Portell. 2016. Paleobiogeography of the fossil box crab *Calappilia* (Brachyura: Calappidae) with a new species from the Eocene–Oligocene of Florida, USA. Journal of Crustacean Biology 36: 329–337.

Taylor P. D. 1994. Evolutionary palaeoecology of symbioses between bryozoans and hermit crabs. Historical Biology 9: 157–205.

Walker, S. E. 1992. Criteria for recognizing marine hermit crabs in the fossil record using gastropod shells. Journal of Paleontology 66: 535–557.

Ward, L. W. 2002. Eocene and Oligocene stratigraphy of southeastern North Carolina. Virginia Museum of Natural History Guidebook 4: 1–25.

Ward, L. W. and J. G. Carter. 1992. Cenozoic molluscan biostratigraphy of the North Carolina Coastal Plain: Introduction and geologic setting. In: J. M. Dennison and J. G. Stewart (eds.), Geologic field guides to North Carolina and vicinity. Geological Society of America: 115–130. Raleigh, North Carolina.

Manuscript accepted on October 28, 2018