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Two halves make a Holotype: two hundred years between discoveries

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ABSTRACT.—The holotype specimen of *Atlantochelys mortoni*, a large sea turtle of Cretaceous age, consisted of only the proximal half of a humerus. Remarkably, the distal half of the same bone has now been recovered, 163 years after the holotype was first described. Besides clarification of the type locality, the size of the complete humerus suggests that this is among the largest turtles known. Circumstances of the discovery suggest that multiple periods of deposition and erosion took place at the discovery site.

Amusing stories abound of fossil specimens that are found and reunited with previously known material from the same individual (Caldwell and Bell, 2005; Gill, 1973). Such specimens may have been collected over a period of time, or separated during field recovery, or curated incorrectly. Presumably a less common situation is the taphonomic circumstance of prehistoric separation into portions that are buried or re-buried apart from each other and the fact that they represent the same individual defies detection at least for a time (Brochu *et al*., 2012). We report here a particularly remarkable case of a notable type specimen, the proximal half of a single bone, which was published more than 160 years before the distal portion was recovered by field collecting. Collection of the two portions may have been separated by as much as 200 years. This astounding situation did not occur as the result of any human misinterpretation nor blunder; the matching portions simply appear to have been separated by erosional processes sometime in the past, and collected at different times. The implications for field paleontology and curatorial practice are considerable.

The sites collectively known as the Monmouth Brooks have been among the most productive sources for fossils in the State of New Jersey. However, interpretations of the ages of the fossils from these sites are hindered by vagueness of depositional history, such as erosion from original emplacement, followed by re-deposition, processes that may have occurred more than once (Parris, 1983). Within the Atlantic Coastal Plain area of the Monmouth Brooks, so-called lag deposition, secondary concentration of durable specimens, and false associations are all seen as possibilities. Most specimens are found in modern point bar sediments of the streambed, having been eroded from Cretaceous, Paleogene, Neogene, and Holocene deposits. Most can be readily attributed to an appropriate age, but detailed interpretations of the specimens always proceed with caution.

The type specimen of *Atlantochelys mortoni* Agassiz 1849, at the Academy of Natural Sciences in Philadelphia (ANSP 9234) is essentially the only known specimen ever referred to the genus (Agassiz, 1849; Leidy, 1865; Hay, 1908). It is the proximal end of a right humerus of a very large sea turtle (Family Cheloniidae), generally resembling that of a Loggerhead Turtle, *Caretta caretta* (Zug *et al*., 1996), but probably of an individual that is larger than any living turtle, even the largest individuals of the Leatherbacks (Family Dermochelyidae). It has been compared to the largest known fossil turtles of the Family Protostegidae (Kaddumi, 2006). Its overall form is similar to thalassic type humeri as described by Weiland (1900) for typical sea turtles, and was so well known to him that he used it as an example of that form, "entire development is in an ecto-enteral plane," and, "the chief variation is seen in the distal retreat of the radial process." The diaphysis of the specimen is proportionately and distinctively narrow, unlike any other known species (Hay, 1908), so that it may be considered a diagnosable genus and species, despite being described from only a portion of a single bone. The type specimen also possesses numerous subparallel grooves, oriented perpendicular to the long axis of the humerus, that are assumed to be traces of shark scavenging.

During 2012, Mr. Gregory Harpel, an avocational paleontologist, recovered the distal portion of a right humerus of a fossil turtle in active point bar deposits of a brook locality in Monmouth County, New Jersey. The site has since been fully determined by maps and geographical positioning and recorded for future reference. Mr. Harpel brought the specimen to the New Jersey State Museum, generously donating it as soon as it was identified (NJSM GP23363). The immediate reaction from paleontologists at the time was to check it against the type of *Atlantochelys mortoni*, the expectation being that it would likely give details of the entire humerus of the genus. Remarkably, the new specimen actually fits precisely onto the type of *Atlantochelys mortoni*. The break between the specimens occurred at mid-shaft and the broken surfaces fit like puzzle pieces. The size and shape of the shaft, even the surface weathering, are identical such that there can be no doubt that these are two pieces of the same bone (Figure 1). The entire specimen, with a total length of 527 mm and maximum widths at the proximal and distal epiphyses measuring 178 and 194 mm, respectively, confirms that it is one of the largest turtles recorded for any geological period (Fig. 1), probably approaching a snout to tail tip length of three meters, according to published formulae for estimation of overall size from humeri (Zug *et al*., 1996; Kaddumi, 2006). The diaphysis, which is generally cylindrical in cross section, measures only 66 mm in diameter; proportionally smaller relative to the total length of any of the fossil turtles we examined (Table 1). We can now give a revised diagnosis of the genus: Large cheloniid with a thalassic humerus (Wieland, 1900) resembling that of *Caretta* and *Desmatochelys*, but having a distinctively slender diaphysis. The type specimen also exhibits an open, ectepicondylar grove rather than a canal, although it is possible that a canal existed originally but has been physically altered by taphonomic processes (Fig. 1).

The modern label on the type of *Atlantochelys mortoni* lists the provenance as Burlington County, New Jersey. The original description by Agassiz (1849) mentions that the specimen was found in the collections of the Academy of Natural Sciences, and only provides Cretaceous of New Jersey as its provenance. It was Leidy (1865) who first gave the Burlington County provenance. In our experience, this probably signifies only that it came from New Jersey and was attributed to Burlington County simply because that seemed likely, it being a New Jersey county near Philadelphia and well known for Cretaceous fossils. The holotype certainly must have come from the same Monmouth County brook locality that yielded the distal end of the bone.

We have fully checked numerous possible records of the type specimen, but no additional definitive information has been added. Morton (1834) mentions large Cretaceous turtle material in the Academy's collection, suggesting that ANSP 9234 may have been at the Academy for some time prior to Agassiz's notice. It is also possible that the type specimen had originally been in the paleontogical collections of the American Philosophical Society, which were transferred to the Academy of Natural Sciences in the late 1840s. Although not described by Agassiz until 1849, it seems possible that the proximal end of the bone was collected as much as two centuries before discovery of the distal end.

Implications for interpretation of the taphonomy of the Monmouth Brooks fossils are debatable, but the simplest interpretation is that the entire unbroken bone was originally embedded in sediment during the Cretaceous Period, eroded from its original interment and fractured during the Pleistocene or (perhaps more likely) the Holocene, then the two portions, displaced from each other, were again embedded in alluvium, preserving the surfaces at the breakage. Published studies of the Monmouth Brooks deposits have previously indicated this possibility, there being several radiocarbon determinations of Pleistocene bones that indicate an age of approximately

12,000 years B.P. for the animal bones, despite the age of less than 3,000 years B.P. for the sediments from which they are derived (Parris, 1983; Stanford, 1992, and Radiocarbon Determinations GX-18789, GX-25818, and UGAMS-13936). Historical mapping (Lewis and Kummel, 1915) supplemented by current fieldwork, confirms that Cretaceous, Pleistocene, and Holocene bedded sediments are all proximal to the discovery of NJSM GP23363. However, the immediate area of the discovery has only Cretaceous sediments overlain by Quaternary alluvium.

Subsequent field inspections of the discovery site determined that the stratigraphy is typical of the Monmouth Brooks, with Cenozoic bedded deposition overlying formations of Cretaceous age. The Cenozoic deposition was traditionally attributed to the Cape May Formation (Lewis and Kummel, 1915), but current practice subdivides it into various units of Pleistocene and Holocene age (Stanford, 1992). We identified the underlying unit as the Mount Laurel Formation (Cretaceous, Campanian) and its biostratigraphic correlation is to the *Exogyra costata* Zone. We collected specimens at the discovery site including the name giver *Exogyra costata* (NJSM GP23435), and its common associated taxa *Exogyra cancellata* (NJSM GP23434) and *Belemnitella americana* (NJSM GP23436), and also a palatine fang of the characteristic fish *Enchodus ferox* (NJSM GP23437), all considered to be guide fossils. Original emplacement of the type specimen of *Atlantochelys mortoni* in the Mount Laurel Formation seems probable, and its age is thus now known with precision. Samples of the formation from the site have been examined for microfossils, but as yet no age-diagnostic microtaxa have been recovered.

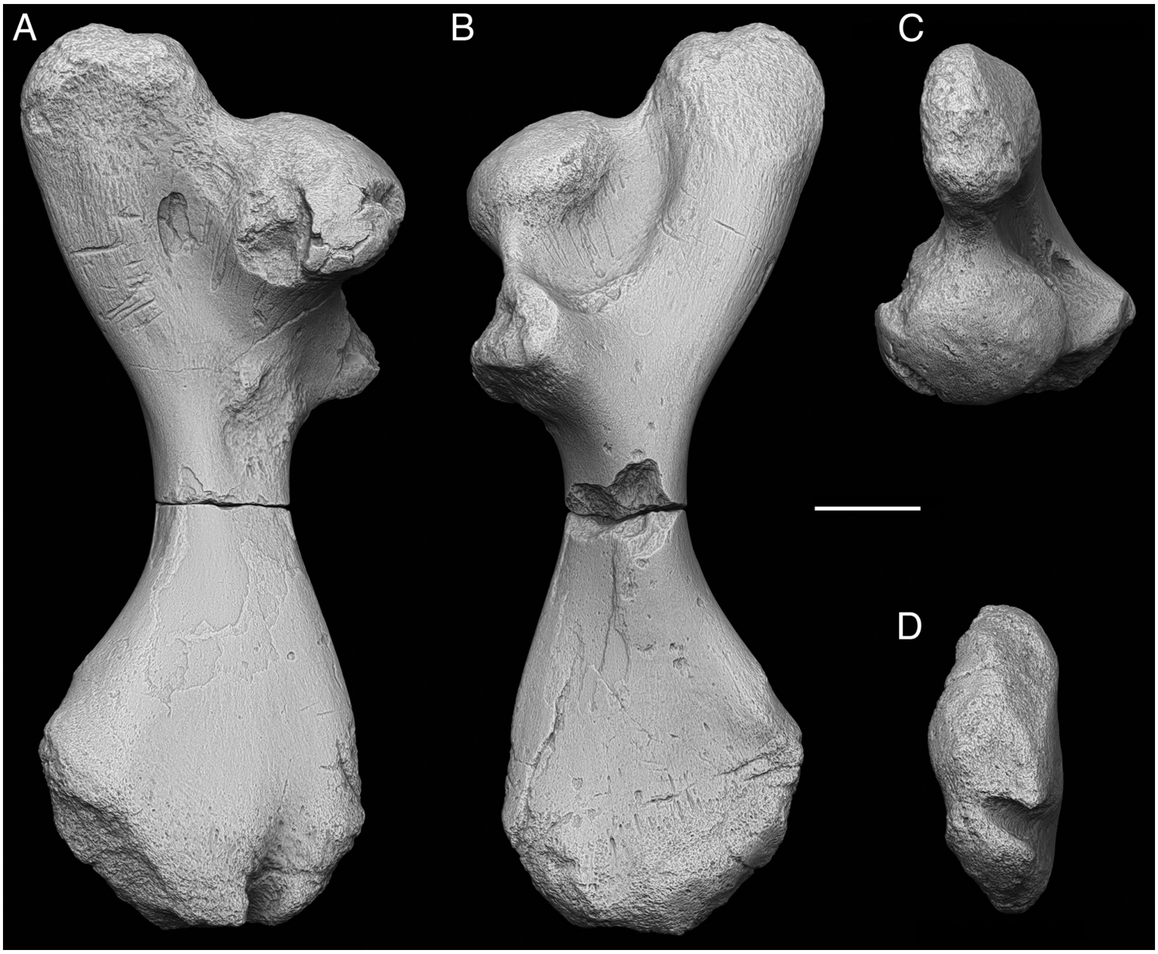

Fig. 1. Holotype of *Atlantochelys mortoni* rendered with 3D scanning. Right humerus, A. dorsal view, B. ventral view, C. proximal view, and D. distal view. Proximal portion (ANSP 9234); Distal portion (NJSM GP23363). Scale bar equals 5cm.

Table 1. Measurements of the total length and the width of diaphysis in dorsal aspect of select contemporaneous Late Cretaceous sea turtles.

	Length	Width of Diaphysis	Ratio	Specimen Number	Reference
Archelon ischyros	650	90	0.138	YPM 3000	Weiland, 1896
Atlantochelys mortoni	527	66	0.125	ANSP 9234 & NJSM GP23363	This paper
Protostega potens	412	126	0.306	AMNH 180	Zangerl, 1953
P. dixie	384	123	0.320	CNHM P 27314	Zangerl, 1953
P. dixie	290	90	0.310	CNHM P27452	Zangerl, 1953

The obvious cautionary note for curators is that there is a possibility that separate specimens from this sort of locality may actually be parts of the same bones and/or the same individual animals. It would be prudent to note that possibility in the case of sites with such complex erosional and depositional history. We have already noted the presence in NJSM collections of several additional fossil specimens from the Monmouth Brooks that are from very large turtles. The terse comment of Wieland (1900) remains valid, "A complete skeleton of *Atlantochelys* should be diligently sought for." Now that an accurate and precise type locality has been determined, other pertinent specimens from there may indeed be considered, notably a large mandible (NJSM GP23438). As the area is well known and popular among fossil collectors, it is possible that significant specimens may be in private collections.

A broader implication, vastly more important for the sake of antiquities conservation, is that portions of specimens that are the same bones or possible skeletal associations may be recovered at much different times, in spite of the frequent contention that surface collected specimens are quickly destroyed if not recovered. There already are known cases in which specimens that are exposed at the surface have remained in good condition for decades, but this discovery suggests that associated specimen portions may be found at intervals of centuries.

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AUTHOR CONTRIBUTIONS

D. C. P. and J. P. S. initiated the study, performed fieldwork, and compiled pertinent literary citations. E. B. D., E. S. G., and J. P. S. made laboratory comparisons. E. B. D., E. S. G., and R. A. P. reviewed historical records and completed curation. E. B. D and J. C. P. produced illustrative materials.

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Geochron Laboratories Radiocarbon Date GX-25818 (Borodin Mastodon, NJSM GP18773) 12,510 +/- 180 C-14 years BP

University of Georgia Radiocarbon Date UGAMS-13936 (Big Brook Elk-Moose, NJSM GP12109) 12370+/-25 C-14 years BP