

EURYPTERIDS IN GRAPTOLITE SHALES.

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The recent discovery of eurypterids in graptolite shales, such as the Deep Kill and Snake Hill shales, where they were hitherto unknown, and the discovery of other localities in the Normanskill shale have served to direct attention to the occurrences of eurypterids in New York in general and to the fact that enough species have been described to make the eurypterids an important biotic element of some of the graptolite faunas, especially when it is considered that the typical graptolite shales lack all other classes of organisms. In a recent paper, now in press as a memoir of the Geological Society, the writer has described the graptolites and their associated forms as largely derived from the plankton and pseudoplankton of Paleozoic Sargasso-seas. The eurypterids have there been mentioned but briefly as accidental stragglers that reached the toxic bottom waters where the graptolites came to rest. It appears now that there are altogether too frequent occurrences of the eurypterids in graptolite shales to treat the phenomenon as a negligible, minor incident.

We will therefore here first describe the new forms that have been recently found in graptolite shales of New York, then list the eurypterids so far known from our graptolite shales and finally analyze the facts that give promise of throwing light on the possible original habitat of the eurypterids that were deposited with the graptolites.

1. DESCRIPTIONS OF NEW EURYPTERIDS FROM THE GRAPTOLITE SHALES OF NEW YORK.

Eurypterus hudsonicus nov.

(Figure 1.)

Description. Carapace semioval to broadly subtriangular; widest in posterior fourth of length; length to width as 2:3 (13 mm. and 18 mm.). Lateral margins rounded in posterior portion, contracted toward the posterior margin and converging with nearly straight lines towards the slightly protracted anterior point, forming there a broad blunt angle. Posterior margin with broad depressed border (2.5 mm.); within anterior angle narrow depressed area, forming a snout-like pro-

trusion. Surface of carapace now flattened, originally probably evenly convex. Lateral eyes large (4.6 mm. long), narrowly kidney-shaped, prominent, situated halfway forward and about 1/7 the width from the lateral margin. Median eyes halfway between frontal margins of lateral eyes. No traces of sculpture observable.

Horizon and locality. Ordovician Snake Hill shale at excavation for state dam, in Hudson River, two miles below Mechanicville (R. Ruedemann, coll. 1899). The carapace lies close to a *Hughmilleria kilfoylei* in shale containing *Lasio-graptus eucharis*, *Lepidocoleus* and *Triarthrus becki*.

Remarks. *Eurypterus hudsonicus*, although represented by only a carapace, is well characterized by the broad sub-triangular outline of the carapace, the snout-like anterior protrusion and the large lateral eyes. It is in outline similar to *E. chadwicki* Clarke and Ruedemann from the Normanskill shale at Catskill, N. Y., and differs from the latter in the more posterior position of the lateral eyes and the development of the frontal protrusion.

Eusarcus triangulatus Clarke and Ruedemann.

(Figure 2.)

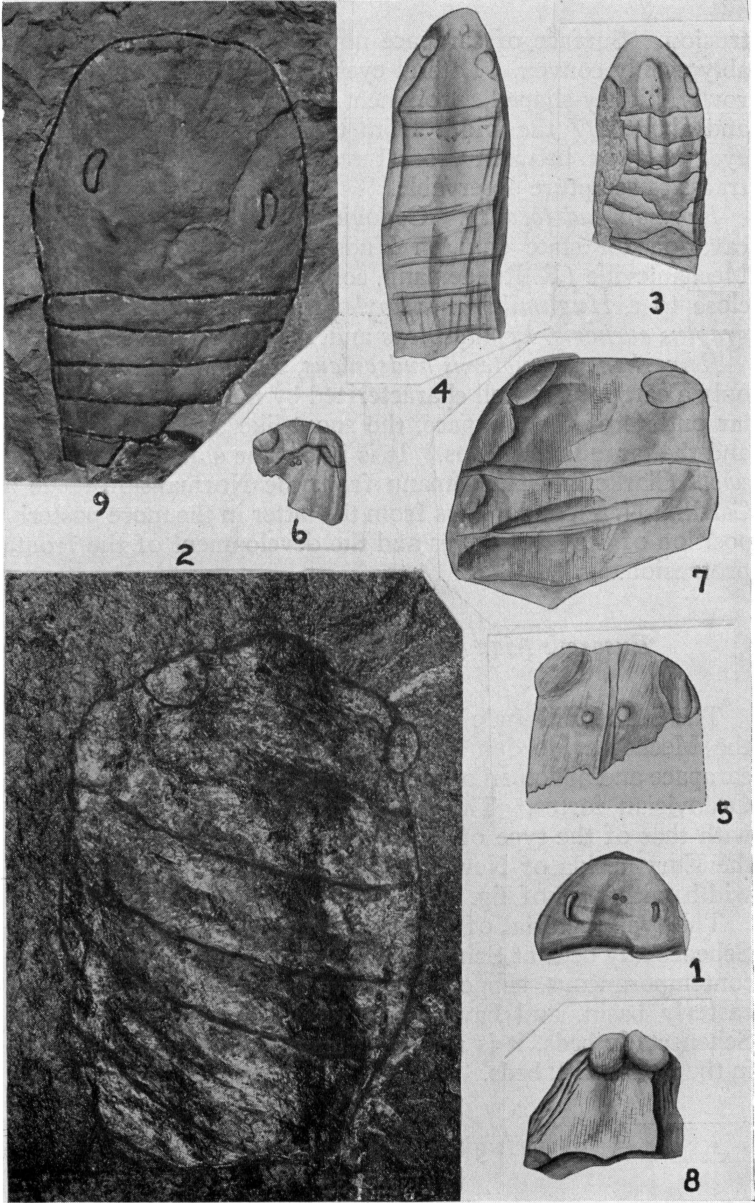
The Snake Hill shale brought out of the Hudson River when the Mechanicville dam was built, was found to contain the carapace and abdomen of an eurypterid larger than most of the Ordovician forms. The outline of the carapace fully agrees with that of the type of *Eusarcus triangulatus*, reproduced in the Euryptera of New York, pl. 84, fig. 7, and the relative width with that of fig. 9.

The type material of *Eusarcus triangulatus* came from the Schenectady beds at Schenectady. As the Snake Hill beds are contemporaneous, supposed to have been deposited in a more easterly basin, and have many fossils in common with the Schenectady beds, it is not surprising to find this species also in the Snake Hill beds.

Hughmilleria prisca nov.

(Figure 3.)

Description. Body small, lanceolate in general outline. Carapace short, semi-elliptic, length to width as 5:7, widest at base and converging with regularly convex margin to a some-



what narrowly truncated front. Surface of carapace smooth, evenly convex with a broad median elevation reaching $1/3$ of the length to the frontal margin. Lateral eyes marginal, located far back, directly behind transversal middle line; about one-third of length of carapace long. Median eyes situated between lateral eyes.

The six tergites are preserved, more or less shoved together and broken. They expanded but slightly in width to the middle of the body, altogether by about one-half the width of the carapace, and possessed considerable length (length to width as 1:3). The traces of the first two postabdominal segments are too poor to permit description. No traces of surface sculpture were observed.

Measurements. The carapace of the holotype is 10 mm. long and 14 mm. wide at the base; lateral eyes 3.5 mm. long. Tergites 4 cm. long and 12 cm. wide.

Horizon and locality. Ordovician Normanskill shale at Glenmont (West Shore railroad cut), N. Y. The specimen is lying on a slab with numerous rhabdosomes of *Diplograptus incisus*, *Corynoides gracilis* and *Climacograptus parvus* and a *Didymograptus sagittarius*.

Remarks. This interesting eurypterid is the first *Hughmilleria* from the Normanskill shale. It is quite similar to the *H. gracilis* nov. from the Snake Hill shale, but is relatively broader and the eyes are situated more posteriorly.

Fig. 1. *Eurypterus hudsonicus* Ruedemann. Holotype. Natural size. Ordovician Snake Hill shale at Mechanicville, N. Y.

Fig. 2. *Eusarcus triangulatus* Clarke and Ruedemann. Plesiotype. Natural size. Ordovician Snake Hill shale at Mechanicville, N. Y. The outlines retouched. The specimen shows distinctly the margins of the tergites, which the photograph has lost.

Fig. 3. *Hughmilleria prisca* Ruedemann. Holotype. Natural size. Ordovician Normanskill shale at Glenmont, N. Y.

Fig. 4. *Hughmilleria kilfoylei* Ruedemann. Holotype. Natural size. Ordovician Snake Hill shale at Mechanicville, N. Y.

Figs. 5 and 6. *Pterygotus deepkillensis* Ruedemann. Holotype and paratype. x 2. Ordovician Deep Kill shale at Deep Kill, near Melrose, N. Y.

Figs. 7 and 8. *Pterygotus normanskillensis* Clarke and Ruedemann. Plesiotype. Natural size. Ordovician Normanskill shale at Kenwood, N. Y. The original of figure 8 compressed laterally.

Fig. 9. *Eurypterus* (*Stylonurus*?) *maccarthyi* Kjellesvig. Photograph of external mold of holotype. Natural size. Devonian Moscow shale. Ludlowville, N. Y. Originals of figures 1-8 are in the New York State Museum.

Hughmilleria kilfoylei nov.

(Figure 4.)

Description. Body slender. Carapace elongate, semi-elliptic, about as long as wide (probably somewhat laterally compressed, width 15 mm., length 13.5 mm.), widest at base, fairly regularly contracting forward to a more acutely rounded anterior portion. Surface apparently evenly rounded originally. Lateral eyes large (diameter 2.5 mm.), subcircular in outline, little projecting, situated upon or slightly forward of the middle line, marginal, little projecting. Median eyes not seen.

Abdomen of nearly uniform width, not expanding much if any beyond the basal width of the carapace, and of great length; the second and third tergites reaching a length of 9 mm. and a width of 16+ mm. The carapace and the first four tergites have a combined length of 46 mm. Traces of triangular scales are seen on the first tergite.

Horizon and locality. Snake Hill shale at excavation for state dam in Hudson River, two miles below Mechanicville (R. Ruedemann coll. 1899). The specimen lies close to the carapace of *Eurypterus hudsonicus* on slab containing *Lasio-graptus* (*Thysanograptus*) *eucharis*, *Lepidocoleus* and *Triarthrus becki*.

Remarks. *Hughmilleria gracilis* is comparable in outline to *H. magna*, one of the common forms of the Schenectady shale. As the Snake Hill and Schenectady shales are essentially equivalent formations, the identity of *H. kilfoylei* and *H. magna* is a possibility. Figures 11 and 13 (N. Y. State Mus. Mem. 14, pl. 85) are taken from specimens that present considerable similarity in outline and position of eyes to our form, especially Fig. 11. However, both the carapaces and the abdomen are distinctly broader than in *H. gracilis* and the eyes situated farther forward. In this connection is to be considered the fact that the holotype of *H. kilfoylei* shows distinct signs of having been compressed laterally and obliquely in the longitudinal wrinkles, especially on the right side. It is therefore possible that with more material this form may fall within the boundaries of *H. magna*.

Pterygotus deepkillensis nov.

(Figures 5 and 6.)

Description. Carapace small, subquadrangular in outline, a little longer than wide (l to w about as 11:10), lateral margins nearly straight, very slightly convex and convergent forward. Frontal margins convex, lateral eyes very large (4.5 mm. long), elliptic in outline, prominent, situated at the antero-lateral corners. Median eyes large, situated midway between the posterior margins of the lateral eyes. No sculpture markings were observed.

Horizon and locality. Deep Kill shale at Deep Kill, near Melrose, N. Y., associated with *Goniograptus thureaui* (R. Ruedemann coll. 1901).

Remarks. This species is represented by two specimens, both fragmentary, but the fact that this is the first eurypterid observed in the Deep Kill shale, warrants its description. The subquadratic shape of the carapace and the large prominent lateral eyes will serve as distinguishing characters.

Pterygotus normanskillensis Clarke and Ruedemann.

(Figures 7 and 8.)

Collecting of graptolites by Prof. O. H. Reinholt of Hartwick College, Oneonta, N. Y., at the Normanskill type locality led to the discovery of some eurypterid remains that are worth recording. We are figuring two carapaces that apparently belong to *Pterygotus normanskillensis*, Clarke and Ruedemann, as described from the Normanskill shale at Catskill. The variable compression of the leathery tests has led to manifold appearances.

Fig. 7 is a larger specimen than the holotype. The carapace measures 32 mm. in width and 16 mm. in length. It is quite probable that this head has suffered compression in an anterior direction. Two sternites are preserved, which are also shorter than would seem natural. Each is 7 mm. long.

Fig. 8 is distinctly compressed laterally. It is here reproduced on account of the large size of the lateral eyes, which being placed far forward are pushed together with the right one partly over the left.

Both specimens show distinctly the fine interesting cleavage lines in the thick carbonaceous test, which led to the description of "Rhombodictyon" a supposed sponge, by Whitfield.

II. LIST OF EURYPTERIDS FROM THE NEW YORK GRAPTOLITE SHALES.

- Deep Kill shale: *Pterygotus deepkillensis* Ruedemann.
 Normanskill shale:
 a. Catskill: *Eurypterus chadwicki* Clarke & Ruedemann.
Eusarcus linguatus C. & R.
Dolichopterus breviceps C. & R.
Stylonurus modestus C. & R.
Pterygotus? (*Eusarcus*) *nasutus* C. & R.
P. normanskillensis C. & R.
 b. Kenwood: *Hughmilleria prisca* Rued.
Pterygotus normanskillensis C. & R.
 Snake Hill shale: *Eurypterus hudsonicus* Rued.
Hughmilleria kilfoylei Rued.
Eusarcus triangulatus C. & R.
 Schenectady beds: *Eurypterus?* (*Dolichopterus?*) *stellatus* C. & R.
E. pristinus C. & R.
E. megalops C. & R.
E.? sp.
Dolichopterus frankfortensis C. & R.
D. latifrons C. & R.
Eusarcus longiceps C. & R.
E. triangulatus C. & R.
Stylonurus? *limbatus* C. & R.
Hughmilleria magna C. & R.
Pterygotus prolificus C. & R.
P. nasutus C. & R.
 Utica shale: *Echinognathus clevelandi* Walcott
Eurypterus rusti Rued.
Eusarcus breviceps Rued.
Dolichopterus insolitus Rued.
Stylonurus sp.
Hughmilleria uticana Rued.
Pterygotus walcotti Rued.

III. MODE OF OCCURRENCE OF THE EURYPTERIDS.

There are altogether 29 different forms of eurypterids recognized in the graptolite shales. While those of the Deep Kill and Snake Hill shale have only been found as single specimens, the faunas of the Normanskill shale at Catskill and of the Schenectady beds at Schenectady consisted of numerous fragments, in some places crowding the surface of the slabs as much as the graptolites. We have a slab from Catskill on exhibition in the Museum, that bears in an area of 6×5 inches 2 species of graptolites and 3 species of eurypterids (8 heads and numerous body fragments), thereby demonstrating a strange commingling of the two very different classes of organisms.

The following general observations can be made as to the distribution of the eurypterids in the graptolite shales.

1. The eurypterids found in the pure graptolite shales (Deep Kill, Normanskill), where obviously no bottom fauna could exist in the foul bottom waters, are always very fragmentary. No complete specimens retaining the appendages have been found. The remains consist of carapaces and separate body segments as is readily seen in the illustrations of the Normanskill fauna on pp. 423-417 of the Eurypterids of New York. Only of *Stylonurus modestus* were obtained a few specimens with both carapace and body segments still in contact and one specimen showed part of a walking leg.

2. The eurypterids in the graptolite shale are rarely found in the midst of black mud shale deposits. The few specimens obtained in the Deep Kill shale are in black graptolite-bearing shale, those of the Normanskill shale collected in the Broom street quarry at Catskill, N. Y., rest on a thin black shale layer, with graptolites, that covers a sandy bed, and the Normanskill eurypterids at Kenwood, near Albany, were found on the surface of a grit bed at the boundary between the grit and the black shale.

3. In the Schenectady beds the writer discovered in the blue-stone quarries at the outskirts of Schenectady a rich eurypterid fauna that afforded 11 species. The Schenectady beds consist there of barren impure sandstone beds with thin black shale intercalations. The latter contained the mixed fauna of eurypterids, graptolites, brachiopods, mollusks and trilobites listed in 1912 by the writer (1912, pp. 48-49), altogether 38 forms being cited and one, quite common seaweed, *Sphenothallus latifolius* (Hall). The best fairly complete eurypterids were found in the black shale, fragments were also frequently observed on the surface of the sandstone.

4. The Utica shale contains the six species of eurypterids described by the writer (1926) in black shale together with the fairly large mixed Utica fauna, composed of graptolites and a somewhat impoverished aggregation of brachiopods, cephalopods and trilobites. The eurypterids are fairly well preserved, retaining the carapaces and all, or the larger part of the bodies. In one case (see Ruedemann, 1926, plates 27, 28) two specimens, representing two different genera were rolled together into a ball, that was labelled as a seaweed (*Discophycus typicale* Walcott).

5. The black Snake Hill shale has furnished three specimens belonging to different genera, one a carapace and body, the other a carapace lying close together on a small slab, 2×3 inches in size, in association with graptolites, *Lepidocoleus*, etc., and a large carapace and abdomen of the Schenectady species *Eusarcus triangulatus* C. and R.

IV. MEANING OF THE DIFFERENT MODES OF OCCURRENCE.

It is natural to ask oneself how these very different organisms, the graptolites and eurypterids, happen to come together in the graptolite shales, like immigrants from different countries in a common "melting pot." The graptolites found in these shales are known to have had their habitat in the open ocean, and to have been drifting either as plankton or as epiplankton, attached to the seaweeds of the Paleozoic Sargasso-sea. The eurypterids on the other hand were distinctly bottom-dwellers and mostly mud-grovelers, such as many trilobites were. Their well-developed walking legs and their flattened bodies testify to a walking and swimming life near the bottom.

Grabau and O'Connell (1913) solved the problem easily and ingeniously by placing the eurypterids in the rivers, whence they drifted into the deltas, while the graptolites were thrown and stranded upon the same deltas by storms. The writer has often wished that this view would solve the problem. However, there are constantly arising difficulties that caution against a too ready acceptance of Grabau's and O'Connell's hypothesis. They placed their main argument for the river habitat of the eurypterids on the occurrences in the Bertie waterlime. The latter has been shown by the writer (1925, p. 9) to be marine and a deposit in lagoons behind coral reefs, with a fairly large truly marine fauna (some forty species). The often large eurypterids occur there in such perfection, together with very young growth-stages, that they could not have been transported far.

The same is true of the Pittsford shale fauna with its beautifully preserved specimens, found in black shale together with lingulas and other brachiopods. On some slabs the eurypterids occur in great profusion and perfection, as on a slab with *Hughmilleria socialis* in the State Museum.

These Silurian faunas show no graptolite association, or only sessile *Dendroidea* (the Bertie waterlime contains three

species of *Dendroidea* and a minute planktonic graptolite, *Climacograptus ultimus*; the Pittsford shale not any graptolites). Yet planktonic graptolites (*Monograptus*, *Retiolites*) entered the Silurian sea of Western New York in multitudes at the time when the Williamson shale was deposited, and the presence of the small *Climacograptus ultimus* in a single layer shows also a temporary connection of the lagoon with the open sea.

The third case of a large Silurian eurypterid fauna lacking association with graptolites is that of the Shawangunk grit fauna discovered by the writer at Otisville, N. Y. As in the Schenectady beds we have here a thick formation composed of alternating sandstone and shale; in the Shawangunk grit thin layers of black shale filled with mostly fragmentary eurypterids, but lacking all other fossils. The grit has furnished a few specimens of eurypterids and some fish remains. A single *Lingula* on black shale is in the State Museum. The Shawangunk grit is currently considered by stratigraphers as a delta deposit. Assuming that this view is correct, the Shawangunk grit beds would, on account of their very regular alternation of grit and shale, less probably represent the topset beds than the bottomset or foreset beds. If they represent the marine end of the delta, marine fossils except the eurypterids should be found, especially also graptolites. Their lack would seem to support Grabau's view that the eurypterids represent the river fauna and were brought down by the river into the delta. Against this view stands the fact of the occurrence of numerous small growth-stages of all genera, down to 1 mm. in size (see Memoir 14) which prove that the eurypterids must have been living and breeding in that neighborhood. It is therefore our conviction that like their recent relative, the *Limulus*, they came from the deeper sea to the shore and deposited their eggs in the sand of the littoral zone. The graptolites did not reach the interior of this early Silurian epicontinental sea at all because no ocean currents entered it.

The Bertie waterlime, Pittsford shale and Shawangunk grit occurrences of eurypterids, the most important and perfect faunas of our Silurian, leave no doubt that eurypterids and graptolites were not associated in the same habitat. The same conclusion is suggested by the faunas of the Normanskill and Schenectady beds, for in the Normanskill shale they occur only in a single layer on top of or close above a sandstone bed and in the Schenectady beds they are found both in the shale and the

sandstone. The other finds, those in the Deep Kill and Snake Hill shales, are only occurrences of one or two specimens and serve but to support the view of their accidental commingling with the graptolites. It is here also significant that the foreign graptolite shales have never afforded any eurypterids and that normally eurypterids and graptolites are not associated. This relegates them from the marine plankton.

As the Ordovician and Silurian eurypterids, with which alone we are here concerned, were undoubtedly marine in habitat, there remains the nektonic life near the bottom and the vagrant benthonic life on the bottom of the sea. The extreme rarity of the eurypterids in the black shales of the pure graptolite shales (Deep Kill shale and Normanskill shale) and their more frequent occurrence near the sandstone beds, as well as in the mixed graptolite faunas (Utica shale) suggest that they lived in the littoral, or higher neritic zone, perhaps like *Limulus* wandering up and down seasonally, and that thereby they were liable to be carried into the quiet dead and toxic bottoms where the graptolites were deposited, by the same agencies, extreme storms or tidal currents, that brought the sand into these deeper levels and that wrecked the graptolite colonies that gradually settled with the seaweeds, the black shale forming mainly from the wreckage after the storms subsided.

Many of the eurypterid remains were undoubtedly the leathery integuments shed after moulting. Clearly moulted tests, split open at the front were observed by the writer (see Clarke and Ruedemann, pl. 6, fig. 1) in the Bertie waterlime, and the dismembered fragments have all the appearance of residues from moulting. Likewise the rolled up group of specimens observed in the Utica shale suggests transportation of light moulted skins rather than the heavier carcasses on the muddy bottom where only the weakest of currents, if any, prevailed. It is then very probable that these light exoskeletons were more easily transported than the shells of the associated benthonic life and thus appeared alone when the storms and currents that moved the sand subsided and black mud deposition began again. This happened hundreds of times in repetition in the Shawangunk sea and similarly in the Schenectady sea. We consider it even very probable that many of these light skin-fragments floated in the water and did not come to rest at the bottom until complete quietude was restored. To reach the deep toxic waters where the Deep Kill graptolites were deposited they had to float out much farther than in the case

of the Normanskill shale and, especially, the Schenectady shale, hence their much less common occurrence.

To summarize our observations on the eurypterids in the graptolite-shales of New York, they clearly indicate that the eurypterids and graptolites did not have a common habitat and became associated only post mortem, in a common burying ground. The graptolites were denizens of the open oceans, partly as free plankton and partly as epiplankton (pseudo-plankton of authors). Whether the eurypterids already in Ordovician and Silurian time lived in fresh water, as many believe and as they did in Carboniferous time—or inhabited the lagoons and embayments and other protected parts of the littoral region, perhaps also its deeper reaches, is not readily determined by their occurrences in the graptolite shales; but other evidence constrains the writer to believe in their marine habitat and origin notwithstanding the claims of some students of the group.

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