

## Trip A2

# Paleoecology and Taphonomy of Some Eurypterid-Bearing Horizons in the Finger Lakes Region of New York State

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## INTRODUCTION

The Upper Silurian Bertie Group in western and central New York State is famous for its eurypterid (Arthropoda: Chelicerata) *Lagerstätten*. From the earliest recognition of the genus *Eurypterus* by American zoologist James Ellsworth DeKay (1825), studies have concentrated on eurypterid growth and variation (see Andrews et al., 1974; Cuggy, 1994). More recent works have focused on ecdysis (Tetlie et al., 2008), and mating (Braddy, 2001; Vrazo and Braddy, 2011), as well as trace fossils and taphonomy (Vrazo et al., 2014, 2016, 2017, and Vrazo and Cieurca, 2018). Recurrent taphonomic patterns are recognized regardless of species with various hypotheses proposed to explain these occurrences. The purpose of this investigation is to provide an overview of the preservation patterns observed in the fossil record. The contortion of *Eurypterus remipes* and *Erieopterus microphthalmus* exuviae collected from different Finger Lake sites, as well as specimens held in the Samuel J. Cieurca Eurypterid Collection at Yale Peabody Museum of Natural History are interpreted to be the result of flexure of eurypterid exoskeletons by submarine paleocurrents. The present contribution and accompanying field guide review the facies and geological settings of the Bertie Group with an emphasis on eurypterid-bearing horizons in west central New York as well as a discussion of specific aspects of the preservation of these fossils.

## PALEOGEOGRAPHY AND PALEOENVIRONMENTAL SETTINGS

Silurian stratigraphy and paleoenvironmental conditions of western and central New York State have been studied extensively by Rickard (1969, 1975), Cieurca (1973), Belak (1980), Hamell and Cieurca (1986), Brett et al. (1990a, 1990b), Brett et al. (1994), and Cieurca (2013), among others. Siliciclastic muds and carbonates were deposited in the northern Appalachian Basin within a subtropical climatic belt approximately 20-25 degrees south latitude (Van der Voo, 1988; Witzke 1990). During the late Silurian Ludlow and Pridoli Epochs, about 408-419 mya, climatic conditions were very arid and circulation within the basin became restricted (Rickard,

1969) allowing micritic waterlimes, typically with laminated bedding, as well as mudstones and evaporites of the Salina and Bertie Groups to accumulate (Fig. 1). Intermittent subaerial exposure and evaporation resulted in hypersaline lagoonal to tidal flat environments indicated by desiccation cracks and salt hoppers. Ciorca and Hamell (1994) interpreted these facies to represent uppermost intertidal zones to lowermost sabkha. These strata often contain a low diversity of fossils, but microbialites (stromatolites and thrombolites) appear to be common (Ciorca, 2013). Eurypterids typically occur in these predominantly hypersaline peritidal, often ephemeral environments, in association with euryhaline taxa including gastropods, ostracods, leperditians, nautiloids, and rare lingulid brachiopods. Additionally, *Cooksonia*, one of the earliest known terrestrial vascular plants, sporadically grew on estuarine muds and other damp, low-lying habitats. Vrazo et al. (2014) have recognized that eurypterid-bearing horizons typically are subjacent to beds exhibiting evidence of subaerial exposure and have suggested that salt hoppers found in association with eurypterids formed as the result of post-burial processes. These stratigraphic and paleoecological conditions are also readily apparent at the study sites.

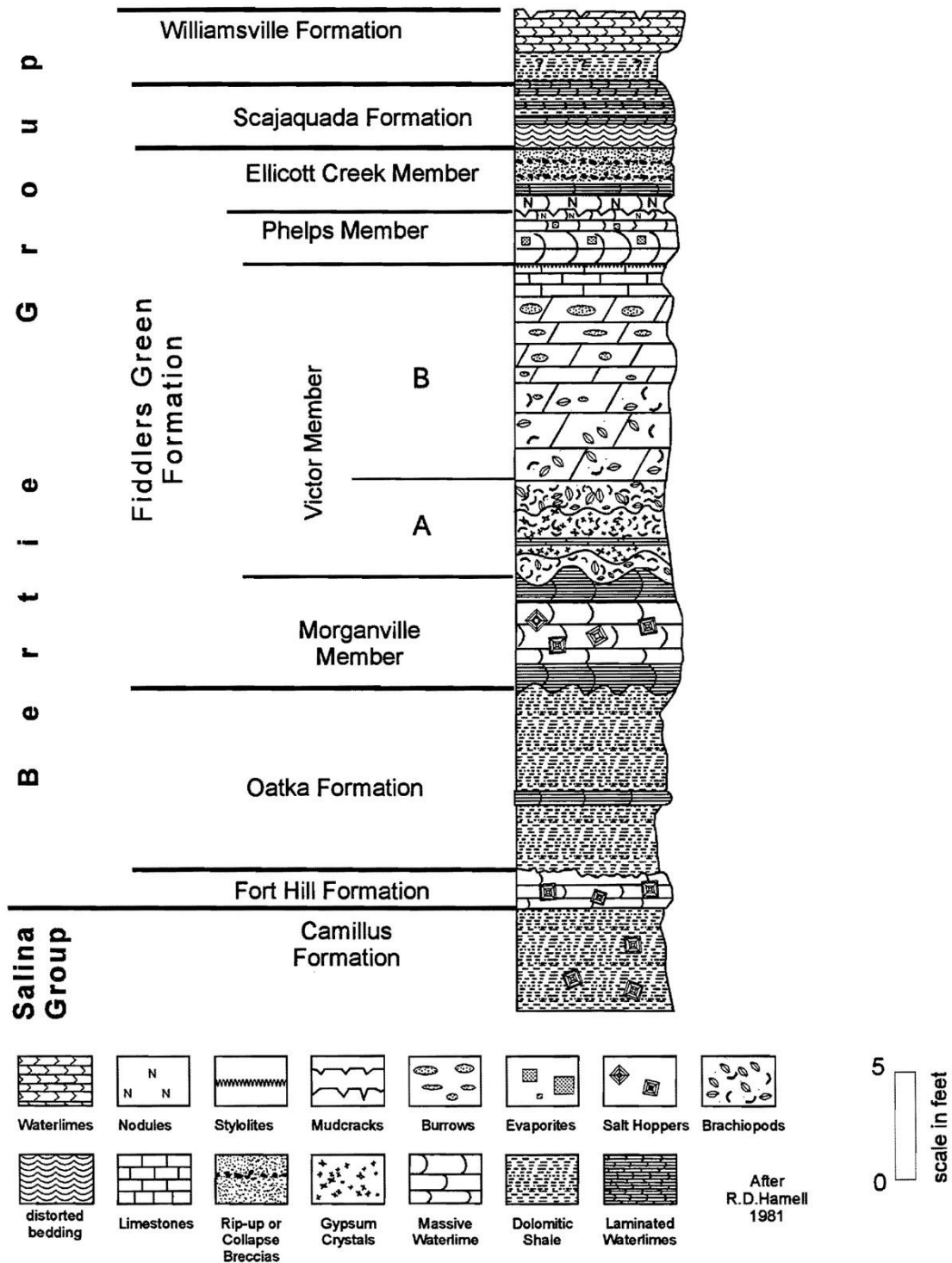


Figure 1. Stratigraphic column for Upper Salina and Bertie Groups in western and central New York State, from Hamell and Cieurca (1986). Vertical scale bar = 5 ft. (1.5 m).

## UPPER SILURIAN STRATIGRAPHY

The Bertie Group in western and central New York was originally named by Chapman (1864) for the strata consisting of massive dolostones and waterlimes of the Niagara peninsula of Ontario Canada. Subsequently, Fisher (1960) placed these units into the Oatka through Williamsville Formations of the Bertie Group. Ciarca (1994) further redefined the Bertie to include all of the eurypterid-bearing waterlimes overlying the Salina Group. These units included the Fort Hill Waterlime at the base through the Oatka, Fiddlers Green, Scajaquada, and Williamsville Formations as well as the overlying Akron Dolostone and Moran Corner Waterlime at the top. This sequence is erosionally overstepped by the sediments of either the Lower Devonian Manlius Formation or Middle Devonian Onondaga Limestone. The following is a brief description of the Bertie units. Additional information can be found in Ciarca (1994, 2010).

**Fort Hill Waterlime Formation-** This *Eurypterus* bearing unit is approximately 2 ft. (0.6 m) thick and is characterized by fine-grained stromatolitic, dolomitized mud with abundant salt hoppers, indicating a hypersaline nearshore environment.

**Oatka Formation** – This unit consists of about 8.5 ft. (2.6 m) of unfossiliferous, thinly bedded dolostones and dolomitic shales. Some bedding surfaces are covered by relict halite casts.

### **Fiddlers Green Formation**

**Morganville Member** – This member is the lowermost waterlime of the Fiddlers Green. The unit consists of 4-10 ft. (1.2-3.0 m) of massive bedded, laminated waterlime or fine-grained dolostone with conchoidal fractures and rare eurypterids.

**Victor Member** – The Victor Member comprises approximately 15 ft. (4.5 m) of massive dolostone beds, which are further subdivided into A, B, and C submembers (Hamell, 1961) containing a fauna of abundant brachiopods, ostracods as well as *Eurypterus* sp. Ciarca and Hamell (1994) have interpreted this facies to constitute a deep water, more offshore, hypersaline subtidal environment. Small thrombolitic buildups are common. The uppermost C submember grades upward into the overlying Phelps Member waterlime.

**Phelps Member** – The Phelps Member is approximately 3 ft. (1 m) to 5 ft. (1.5 m) thick and can be subdivided into a cyclic sequence of eurypterid-bearing, tabular, laminated waterlimes interbedded with layers altogether lacking fossils. Typically, microbialites of irregular shapes and sizes are associated with the eurypterid fauna and Ciarca (2013) has suggested that they resemble rip-up clasts.

The strata records minor sea level transgressions that periodically flooded restricted lagoons freshening the otherwise hypersaline sea water allowing eurypterids and other euryhaline fauna to migrate shoreward alternating with retreating seas increasing salinity to the point that organisms could not readily live in these environments. Continued shallowing resulted in subaerial exposure and conditions favorable to the formation of mudcracks and salt and/or gypsum crystals. When seas subsequently flooded these surfaces again, sediments became jumbled. Older layers containing buried eurypterid remains, along with the microbialites were diagenetically altered. Early stage evaporite precipitates within the sediments were subsequently dissolved forming salt hopper or gypsum molds. These early diagenetic salts may have aided in preservation of associated buried eurypterids. Vrazo et al. (2014, 2016, 2017) observed similar facies in the Upper Silurian Tonoloway Formation of Pennsylvania and proposed a model, which suggests that these transgressive-regressive cycles supported eurypterid habitats as well as the formation of eurypterid *Lagerstätten*.

**Ellicott Creek Breccia Member** – The uppermost unit of the Fiddlers Green Formation consists of about 3 ft. (1 m) of brecciated waterlime, which possibly formed as a result of a Late Silurian earthquake shocks (Cieurca, 2010). This unit is unique in that only two different *Eurypterus* species have been observed and are concentrated in channels formed between adjacent stromatolites. Salt hoppers are widespread throughout the unit.

**Scajaquada Formation** – This unit consists of approximately 3 ft. (1 m) of thinly bedded, medium dark gray argillaceous dolostones and dolomitic shales. The unit grades eastward into the Forge Hollow Formation in central and eastern New York where it is about 40-50 ft. (12-15 m) thick (Cieurca, 2010). The interval is nearly barren with rare eurypterids confined to a basal waterlime. Chert nodules are scattered within some intervals, and may have replaced earlier evaporite salts. Gypsum nodules may have been replaced by chalcedony that recrystallized to chert; small cubic salt crystals molds, up to 1 cm, occur on slabs of slightly shiny, pale reddish gray dolostone near Phelps, New York. Minor deformed beds occur within the member and may have formed as a result of Silurian earthquakes or tsunamis (Cieurca, 2010).

**Williamsville Formation** – The Williamsville consists of about 3 ft (1 m) thick light gray, slightly argillaceous waterlime. Together with the Phelps Member in western and central New York, the Williamsville has yielded hundreds of eurypterids especially from the region around Buffalo, New York and the Niagara Peninsula. This unit contains several extremely hard, thinly laminated intervals with a diverse fauna including nautiloids, gastropods, horseshoe crabs, and many species of eurypterids, as well as moderately common *Inocaulis* algae and rare *Cooksonia*.

**Akron Formation** – This massive vuggy and slightly cherty dolostone, up to 5 m thick, contains a poorly preserved marine fauna including stromatoporoid sponges, small rugose corals, brachiopods as well as

gastropods. This unit is erosionally overstepped by Early and Middle Devonian sediments. Cuirca (2010) reports an absence of eurypterids.

**Moran Corner Formation** - A waterlime of very localized extent that probably was a very thin unit with only this small erosional remnant remaining. Rare eurypterids and the typical associated hypersaline faunas occur within this interval. It ends the depositional cycles of the Upper Silurian.

## LOWER DEVONIAN STRATIGRAPHY

**Chrysler and Manlius Formations** – Lack of diagnostic zonal fossils in the basal beds, comprising the Helderberg Group in New York, has led to much confusion in the placement of the Silurian-Devonian boundary. The Manlius Formation, in Onondaga County in the vicinity of Syracuse, NY has been placed in both periods (see Berdan, 1964). Cuirca (1994) arbitrarily placed the boundary based on the occurrence, or lack of, different species of eurypterids within the uppermost beds of the Chrysler Formation. Specifically *Erieopterus microphthalmus* replaced the *Eurypterus sp.*, which may reflect a transition in depositional environments. Most recently the S-D boundary has been placed within the Green Vedder Member, which was formerly considered as part of the Thacher Member, of the Manlius Formation (Wilson et al., 2011). These units overlie the Late Silurian Chrysler limestone and are subjacent to the Early Lochovian (Early Devonian) Olney Member, Manlius Formation.

## FIELD LOCALITIES

**Locations:** The Fiddlers Green Formation extends from southern Ontario, Canada across the Finger Lakes to Herkimer, New York. The Fiddlers Green comprises dolomitic and chemically precipitated limestones of the Morganville Member at the base overlain by the Victor, Phelps and Ellicott Creek Breccia Members, respectively. Field collecting was conducted at four sites in the Finger Lakes region; however, the Ellicott Creek Breccia was not examined in this study.

At Phelps, the New York State Thruway (Interstate-90) passes through a roadcut (Fig. 2) characterized by gently sloping to near vertical sides exposing waterlimes of the Phelps Member and dolostones of the Victor Member. The New York State Thruway permitted access to this highly restricted outcrop to aid in this study of the lithology and paleoecology of these units. Here, the NYS Thruway only permitted surface collecting of rock samples which were further split in the laboratory in order not to miss critical information. This site represents the type locality for the Phelps Member of the Fiddlers Green Formation (Cuirca, 1973), which contains a eurypterid fauna with some fossils displaying highly contorted body postures.

The Phelps and Victor Members were further examined at an outcrop along McBurney Road in close proximity to the roadcut along the Thruway at Phelps. Eurypterids as well as other fossils were strikingly absent in the Phelps Member at this locality. In addition, the Morganville, Victor and Phelps Members were also collected at Cayuga Junction, along the east side of Cayuga Lake.



Figure 2. Type section of Phelps Member, Phelps, New York.

Field sampling was conducted at Split Rock Quarry, southwest of Syracuse, from the Lower Devonian Olney Member. *Erieopterus microphthalmus* was concentrated in localized very thin calcareous bands in association with more normal marine fauna (Cieurca, 1978) including abundant brachiopods and bivalves.

Sampling eurypterids and associated fauna from four different localities ensured that contortion patterns were not limited to one eurypterid horizon but instead occurred throughout the fossil record. Confirming these observations further were data supplemented by specimens held in the Samuel J. Cieurca Eurypterid Collection at the Yale Peabody Museum of Natural History. Taken all together, eurypterid habitation, population and preservation was defined.

## RESULTS AND OBSERVATIONS

Field collecting for three years at Phelps yielded many eurypterid fossils including common *Eurypterus remipes* exuviae; however, complete *Eurypterus remipes* were scarce. Moreover, very rare *Dolichopterus macrocheirus* and pterygotid remains were found associated with the *E. remipes*, but these fossils were limited only to widely scattered parts.

The smallest *Eurypterus* specimen was just over 15 mm from prosoma to telson, while the largest specimen measured 13 cm. Due to the scarcity of complete exoskeletons, a more useful parameter may be the size of the prosoma. However, this in itself has certain limitations because the head is only one part of the eurypterid body. Tollerton (1989) noted the prosoma unquestionably could become deformed and distorted before and after burial and these affected samples were not measured. Based on 61 complete, or nearly complete, carapaces, height by width measurements ranged from 4 mm x 5 mm to 60 mm x 75 mm respectively, so clearly there were both immature and some large adults living in this environment. A size-frequency distribution graph (Fig. 3) gave a mode of 17 mm with most specimens falling within approximately 15 to 25 mm. The Phelps population was found to be similar to the distribution reported by Vrazo et al. (2014) for the Upper Silurian Tonoloway Formation in the central Appalachian Basin of Pennsylvania.

At Cayuga Junction, *Eurypterus remipes* occurred less frequently than at Phelps. Fossils were well preserved but due to a small sample size, even after combining them with fossils held at the Peabody Museum, only 15 carapaces were measured in all. With a ratio of 1:4 respectively, (Cayuga Junction to Phelps), it is difficult to determine a representative size-frequency distribution (Fig. 3).

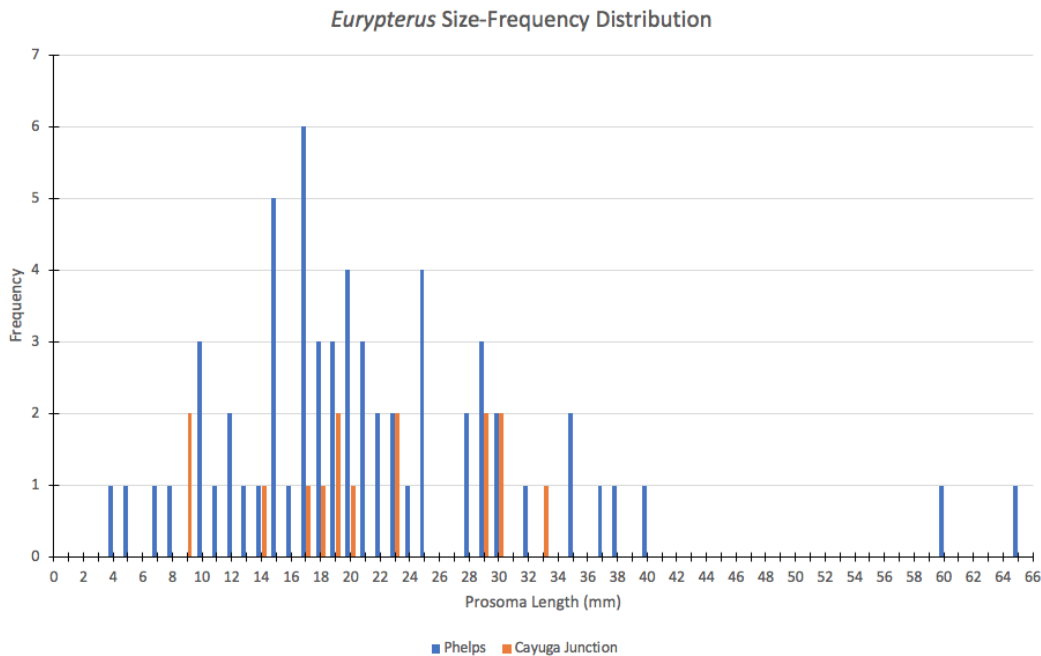


Figure 3. Size-frequency distribution of *Eurypterus remipes* carapaces from the Phelps Member at Phelps and Cayuga Junction, Finger Lakes region, New York.



## DISCUSSION

**Paleoecology:** Eurypterids are an extinct group of chelicerate arthropods with the majority of fossil specimens interpreted as being “cast exuviae (cuticle) from the frequent molting (ecdysis) of growing individuals” (Clarke and Rudemann, 1912; Braddy et al., 1995; Batt 1999; Tetlie et al., 2008, and Vrazo et al., 2014). Vrazo and Braddy (2011) have proposed an idea referred to as the “mass-mate-spawn-molt” hypothesis of eurypterid paleoecology. The interpretation is that males and females would have amassed in shallow water, possibly a lagoon, to mate similar to the modern-day horseshoe crab *Limulus polyphemus*. After mating, males left the area and returned to deeper water, whereas the females remained to spawn and subsequently molt before migrating back to deeper water. After their eggs hatched, eurypterid larvae and juveniles remained in these breeding grounds until they matured and then migrated basinward. Of course, the males molted as well but the researchers found a greater abundance of female exuviae at the different study sites.

The results from very thorough field collecting at Phelps showed a predominance of very small disarticulated and fragmentary body parts, as well as tiny specimens (Fig. 4A, B). The interpreted sequence of events in the ecdysis and disarticulation of *Eurypterus* (Tetlie et al., 2008) generates partial specimens with the prosoma remaining as the last intact tagma (Vrazo and Braddy, 2011). Moreover, these observations can be directly related to the mass-molt-mate-spawn hypothesis and it would be expected that a large number of juvenile and growing individuals would be found in a nearshore environment and Phelps appears to record one of these breeding grounds.



Figure 4 A) Partially disarticulated *Eurypterus remipes* with prosoma attached to the preabdomen.

B) Larval stage of *Eurypterus remipes* lacking appendages and telson. Note the tiny size of these immature specimens, Phelps Member, Phelps, New York.

McCoy and Brandt (2009) and Brandt and McCoy (2014) studied extant scorpions comparing their molts as well as carcasses to recurrent patterns observed in fossil scorpions in an attempt to distinguish the exuviae from the remains of dead animals for a more accurate assessment of the fossil record. They concluded that the position of the chelicerae, the position of the walking legs, the straightness or curvature of body plan, the presence or absence of telescoping thoracic segments as well as the position of the pedipalps were significant criteria and were directly applicable in differentiating molts from carcasses in the extinct eurypterids.

One complexity in determining the paleoecological record at Phelps, New York stems from the extensive disarticulation of the exoskeletons as well as poor preservation of many of the fossils. Commonly found disarticulated eurypterid elements include the prosoma, tergites and sternites, walking and swimming appendages as well as the telson. McCoy and Brandt (2009) experimented with modern scorpion molts and carcasses and concluded that there were no statistically significant differences in the length of time for their entire disarticulation. Their experiments further suggested that the molts were just as strong as the carcasses in water and dry conditions. Extrapolating these results to the abundant disarticulated exuviae compared to the paucity of intact fossil eurypterids at Phelps, it is very difficult to determine which are molts and which are the carcasses of dead animals. Thus, scattered parts could certainly be from the decomposition of decaying carcasses as well as from the disarticulation of the eurypterid exoskeleton after ecdysis and the few nearly complete fossils could either be molts or the remains of the eurypterids after death.

Discrete eurypterid instar classifications (i.e. molt stages) have been based on measurements and morphologies (Hunt and Chapman, 2001). Since the morphology of the eurypterid body plan changes little with growth, several different categories have been assigned (Clarke and Rudemann, 1912; Andrews et al., 1974; and Tollerton, 1992). In this study, Vrazo and Braddy's (2011) stages were utilized. The divisions are based on prosomal (carapace) length which gives a good approximation of the total length of the eurypterid. The stages are larval 0-14 mm, juvenile 15-30 mm and adult >30 mm.

Size-frequency distribution of carapaces from the Phelps site (Fig. 3) suggests that this locality may represent a eurypterid nursery with the greatest proportion of individuals being larvae (12) and juveniles (41) living among adults (8). No distinction could be made to determine if the larger eurypterids were male or female due to the disarticulated nature of most fossils but the Vrazo and Braddy (2011) "mass-mate-spawn-molt" hypothesis predicts that larger specimens were probably mostly molts of female individuals that had not yet returned to open marine water. Regardless, if the fossil was from a molt or a carcass, the great abundance of small body parts and small individuals may represent a growing population of *Eurypterus remipes* with many individuals having reached the juvenile stage.

The biofacies of the Phelps Member at Phelps, along the Thruway, is strikingly different from the faunal characteristics of the McBurney Road site, only 0.45 miles (0.72 Km) away, where eurypterids were

conspicuously absent. It is certainly possible that eventually some fossils may be found, but in this study none were discovered or available in collections. Possibly the precise horizons yielding specimens are missing or poorly exposed at this locality. Alternatively, there may have been differences in oxygen levels, salinity and/or substrate in the paleoenvironment, which prohibited eurypterids from inhabiting this area.

Moreover, at Cayuga Junction, 19.77 miles (31.82 Km) away from Phelps, it is difficult to determine to what extent the biofacies differed, if at all, due to the limited sample size. Size-frequency distribution data of carapaces showed larvae (3), juveniles (11) and adults (1), but quantitatively the individuals appear, on average, larger than those from Phelps due to the lack of very immature sizes. Although these data suggest that juveniles comprise the bulk of the population, further collecting is necessary to ascertain a clearer interpretation of the paleoenvironment.

**Taphonomy:** By comparing recurrent taphonomic patterns in scorpions and eurypterids, McCoy and Brandt (2009) and Brandt and McCoy (2014) explained some contortions in these arthropods and they reported various body orientations taken on during ecdysis. However, the manner in which the exuviae come to rest on the seafloor after exuviation but prior to disarticulation and fragmentation is not well studied and nothing less than remarkable considering the nature of the exoskeleton. Contortion of the intact exuviae or carcasses includes flexure, or flexed, twisted postures, of the exoskeleton by some external environmental factors, which affected the final resting position. Slow moving paleocurrents, wave ripples and tides that came into restricted lagoons (see Vrazo et al., 2014 for further discussion) created a wide variety of skeletal flexures.

Measurements were taken of the degree of curvature of the metasoma and telson in relation to the prosoma and mesosoma. This was done by drawing an axis through the center of the prosoma and mesosoma and a second axis through the telson in the direction the telson is pointing. Then the angle was measured between the two axes resulting in the degree of body curvature.

Fossil contortions can be categorized from 1) the most commonly occurring orientation, with bodies non-contorted, 2) bodies contorted commonly up to 90°, 3) U-shaped flexure with metasoma and telson parallel to the pre-abdomen and prosoma, and 4) rarely with the opisthosoma and telson flipped above or below the pre-abdomen of the body and forward of the prosoma. Various contortion patterns are illustrated in Figure 5. These pre-burial resting positions contrast with later distortion of some exoskeletons (Fig. 6) that were buried edgewise by sediments and subsequently compacted and crushed.

Figure 5. →

A) *Eurypterus remipes* displaying extreme contortion of  $180^{\circ}$  with the opisthosoma and telson bent under the ventral side and above the prosoma.

B) Same as A but with carapace and mesosoma flipped over to show opisthosoma.

C) *Eurypterus remipes* with metasoma and telson bent  $50^{\circ}$  from pre-abdomen (YPM IP 213385).

D). *Eurypterus remipes* approaching U-shape body posture with metasoma and telson twisted  $126^{\circ}$  in relation to the prosoma and mesosoma (YPM IP 210717).

E) *Erieopterus sp.* with metasoma and telson bent  $65^{\circ}$  from pre-abdomen (YPM IP 206794).

F) *Erieopterus sp.* with metasoma and telson bent  $41^{\circ}$  from pre-abdomen(YPM IP 206815).

Specimens A-C are from Phelps Member, Phelps, New York State Thruway;

Specimen D is from Phelps Member, Passage Gulf, Herkimer County immediately east of the study area;

Specimens E-F are from Split Rock Quarry, Olney Member, Onondaga County.

Specimens C-F courtesy of the Yale Peabody Museum of Natural History, Division of Invertebrate Paleontology. Images courtesy of Jessica Utrup (Yale Peabody Museum of Natural History).

Figure 6.→

*Eurypterus remipes* distorted edgewise with prosoma obliterated and right swimming arm and paddle elongated as well as parallel to body, from float, suspected Victor Member, Cayuga Junction.



A



B



C



D



E



F

Figure 5.



Figure 6.

During the time that the eurypterids inhabited the lagoons and nearshore environments many became contorted, although countless others laid flat and straight on the substrate possibly aligned with their long axes parallel to the current. Moreover, the scarcity of complete, intact eurypterids in these facies as exemplified at Phelps suggests that bacterial decay and paleocurrents acted on the shed exuviae and carcasses causing extensive disarticulation of the exoskeletons. These fragmentary fossils along with moderately common microbial mats (see microbialite structures of Ciurca, 2013) typically occur in the center of conchoidal dish-like depressions in certain layers. These dishes are actually scalloped fractures that develop during weathering probably owing to differential freezing-thawing cycles or pressure release but are influenced by the inhomogeneity of the embedded features.

The microbial mats may have also had an influence on the contortion of the eurypterid exuviae and carcasses. Different types of orientation are interpreted as resulting from lodging of the slightly heavier prosoma and mesosoma into the sediment and/or possibly attached to sticky microbial mats while the lighter metasoma and telson rotated around as currents pushed the exoskeleton down current. Alternatively, the contortion could have resulted from the telson initially becoming stuck into the sediment and/or microbial mats and the entire body would have been pushed in a down current direction. In certain cases, the telson may have become stuck in the substrate and there was sufficient current to cause the rest of the body to be pushed over and flopped down on top of the opisthosoma and telson (Figs. 5 A & B). In this case, the body appears to have fragmented near the midpoint without completely disarticulating the exoskeleton. The specimens in Figures 5 C-F also clearly demonstrate that paleocurrents acted upon the exuviae and carcasses by twisting the eurypterid into these contortion postures.

## SUMMARY

New research focused on the paleoecology and taphonomy of eurypterid-bearing horizons within the Upper Silurian Fiddlers Green Formation as well as the Lower Devonian Olney Member in the Finger Lakes region of New York State. Field studies concentrated on the large eurypterid sample from the Phelps Member at the Thruway roadcut near Phelps and comparable horizons from Cayuga Junction. Additionally, eurypterids were examined at Split Rock Quarry, southwest of Syracuse, New York.

Despite strong disarticulation and fragmentation of almost all fossil specimens coupled with the complication in determining eurypterid exuviae from carcasses at Phelps, size-frequency distribution evidence suggests that this area may have been both a breeding ground and nursery for *Eurypterus*. Size-frequency histogram was also compiled for Cayuga Junction, but interpretations must be cautionary due to the limited sample size. Large numbers of fragmentary, tiny, larvae to juvenile sized body parts, whether from molts or carcasses, appear to comprise most of the Phelps fossil record. Although it is very difficult to assess the population, clearly larvae and juveniles lived among adult eurypterids at both sites.

*Eurypterus remipes* and *Erieopterus microphthalmus* exuviae and carcasses were affected by currents, which produced a variety of contorted patterns. Examining two different species that lived in different localities, as well as different time periods, demonstrated that contorted postures were not limited to *Eurypterus*. These recurring taphonomic patterns may be in the form of minimal to significant bending and twisting of the opisthosoma and telson in relation to the rest of the body. In more severe cases the opisthosoma and telson may flip over the prosoma or oppositely the prosoma and mesosoma may flip over the metasoma and telson. A common theme in these cases of flexure is the anchorage of heavier or more projecting parts of the exoskeleton to the muddy sediment and/or sticky microbial mats on the lagoon bottom while the rest of the exoskeleton pivoted freely about this point or further fragmented prior to sediment burial.

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I would like to thank the New York State Thruway Authority for giving me access to the highway road cut in Phelps. Although it was a very tedious process securing the necessary Liability Insurance needed by the Thruway, the Wayne County Gem and Mineral Club patiently worked with me and provided the required insurance. This proved to be a key locality to further research of eurypterid paleoecology and taphonomy.

I would like to extend my sincere appreciation to Susan Butts for granting access to the Samuel J. Cieurca Eurypterid Collection at the Yale Peabody Museum of Natural History and Jessica Utrup for eagerly assisting my search through thousands of fossils and photographing key specimens.

I would also like to thank my wife, Tammy Mayer, for her unending support while she assisted in measuring fossils, compiling data and listening to my ideas.

Further thanks go to Emily Underwood at Hobart and William Smith Colleges for her assistance in using Excel to construct the size-frequency distribution diagram and Nikki Gottshall Chase for assisting at field localities.

#### DEDICATION

Dr. Carlton Brett of the Department of Geology, University of Cincinnati was a professor of mine whose support was fundamental in the completion of my graduate program many years ago. Thirty years later, he is still an important mentor to me. Our continued contact through the years has made geology that much more interesting. Dr. Brett continues to make important suggestions and provide thoughtful criticism for the preparation of this manuscript. Contributing his unbelievable knowledge of paleontology and stratigraphy coupled with his insight into research projects, this study evolved from simply collecting eurypterids in the field to better understanding the paleoecology and taphonomy of this fascinating group of fossils. It is to this extent that words, more than just a transparent "Thank You", are not enough. Therefore, I would like to dedicate this manuscript to him as his support was invaluable for its completion.

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## REVISITING SOME CLASSIC EURYPTERID LOCALITIES

### ROAD LOG AND STOP DESCRIPTIONS

Meeting Point: Hobart and William Smith Colleges

Meeting Point Coordinates: 42.860<sup>0</sup> N, -76.985<sup>0</sup> W

Meeting Time: 8:30 AM

Cumulative Miles	Incremental Miles	Route Description
0	0	Leave Hobart and William Smith Colleges
		Turn left from Pulteney Street onto Routes 5 & 20 W
1.3	1.3	Turn right onto Pre-Emption Rd., County Rd. 6 N
7.5	6.2	Turn left onto Rt. 96 W
10.8	3.3	Turn right onto Newark Street, Rt. 88 N
11.5	0.7	Proceed north under NYS Thruway
11.6	0.1	Turn left onto McBurney Rd., park vehicle in 500 ft.

#### STOP 1: McBurney Road cut – Phelps and Victor Members

Location Coordinates: (42.973<sup>0</sup> N, -77.078<sup>0</sup> W)

An outcrop only one-half mile away from the Phelps type section will provide the first stop. Here the Phelps Member lies at the top of the embankment overlying the Victor Member of the Fiddlers Green Formation. The upper submember of the Victor is a dark gray, thin to medium bedded, argillaceous dolostone, which lacks normal marine fossils. Thickly bedded Phelps layers have eroded from above and slid downslope forming large float blocks at the base adjacent to McBurney Road. Weathered blocks are light beige to tan,

however, when the very hard and dense limestone is broken along a fresh surface, the micritic waterlime is medium gray, laminated and displays a distinctive conchoidal fracture.

Fossils are scarce to absent at this site possibly indicating a subtidal to intertidal depositional environment. This contrasts with a common eurypterid fauna associated with pervasive laminated bedding and mudcracks at the Phelps type section, which indicates a supratidal to lowermost sabkhal depositional zone (Ciorca and Hamell, 1994). Moreover, the contact between the Victor and Phelps is moderately gradational and conformable possibly indicating that sedimentation was steady but the depositional environment was transitioning from a deeper water marine environment to a shallow lagoonal environment.

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11.7	0.1	Return back to Rt. 88 S
12.1	0.4	Park behind Phelps Town Court

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## Stop 2: Restricted Access – New York State Thruway – Phelps Member Type Section

Location Coordinates: (42.969<sup>0</sup> N, -77.071<sup>0</sup> W, mileposts 331.73 – 331.88)

Although this locality along the Thruway (I-90) provided the bulk of the fossil material used in this study, access to this road cut requires special permission from the New York State Thruway Authority. Liability insurance in the amount of \$1,000,000, along with other documents are needed before the Authority will grant a permit enforcing certain rules and regulations. Therefore, it would not be practical or possible for everyone to obtain the necessary documentation to get a permit. Moreover, the Thruway Authority will not allow a large group to visit the site as they believe it would be a significant safety risk to everyone. Only a brief description of the cut will be given here for those who wish to drive by it on the Thruway.

Seen from the Thruway, the Victor Member consists of thin to medium bedded dolostones approximately 7-8 feet from the road level upwards and forms the steep sides of the cut. The contact is gradational and conformable with the overlying Phelps Member. Extensive weathering of the Phelps waterlimes have resulted in rock talus strewn across most inclined surfaces but upon closer inspection discrete bedding is recognizable. There are at least two horizons, midway and towards the top of the roadcut, containing eurypterids and associated fauna interbedded with intervals lacking fossils. Moreover, microbialites, desiccation cracks, and relict halite structures are found throughout the stratigraphic section.

Post-depositional tectonic stresses produced stylolites (pressure solution features) which are commonly parallel to the bedding throughout the section. They are characterized by an irregular and interlocking teeth-like projections where one side fits into their counterpart on the other side. These slickensides were presumably formed diagenetically by differential movement as the rock is pushed laterally under the force of compression. These surfaces are often coated with a carbonaceous residue (anthraxolite) which has been concentrated by solution of the carbonate rock.

Near the top of the outcrop, perfectly circular as well as irregular shaped chert nodules are prevalent (Fig. 7) but the manner in which they formed is problematical. Cephalopods do occur in the Phelps Member and some other parts of the Bertie Group and these rounded nodules may be the chambers of broken nautiloids. However, this seems unlikely since the nodules are relatively common. Alternatively, they could be chalcedony chert formed by replacement of gypsum nodules, although they are not expected to be so perfectly circular.

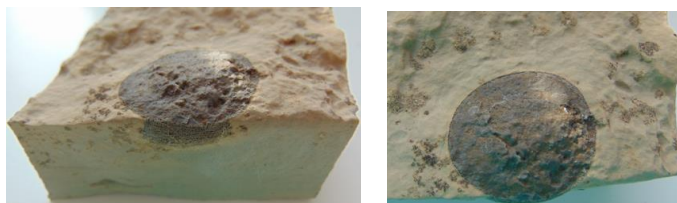


Figure 7. Chert nodule ( 2 cm diameter) from the upper beds of the Phelps Member, Phelps, NYS Thruway.

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12.4	0.3	Turn left onto Rt. 96 E
17.4	5.0	Proceed east on Rt. 96, take clover leaf to Rt. 14 N
17.8	0.4	Turn right onto Rt. 318 E
28.7	10.9	Proceed east, then turn left onto Routes 5 & 20 E
30.8	2.1	Turn right onto NY Rt. 90
37.6	6.8	Turn right onto Fire Lane 14 (opposite Kelley Marine)
37.7	0.1	park vehicles in 1000 ft.

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Stop 3: Cayuga Junction

Location Coordinates: (42.871<sup>0</sup>N, -76.700<sup>0</sup>W)

Cayuga Junction was once the place where the Lehigh Valley railroad diverged into north and south routes along the east side of Cayuga Lake. Today, Fire lane 14 follows the abandoned rail line. Partial sections of each member of the Fiddlers Green Formation are exposed, although their contacts are obscured by overburden. The uppermost Phelps Member is intermittently visible on the north side of the gravel road and the Victor Member forms a steep gradient leading into a ravine south of the road. The Phelps and Victor Members exhibit similar lithologies to the waterlimes and dolostones observed at the Phelps type section. The strata contain the typical *Eurypterus remipes* fauna along with widely scattered *Lingula sp.* brachiopods. Cieurca and Hamell (1994) have additionally reported the occurrence of the athyrid brachiopod *Whitfieldella* in the Victor Member. At the base of the slope forming the floor of a small creek, the underlying Morganville Member is present (Cieurca, 1973). This unit has been traced from western New York eastward to Cayuga Junction. This waterlime also bears a *Eurypterus* fauna.

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37.8	0.1	Return to NY Rt. 90 S
38.7	0.9	Turn left onto Rt. 326
40.1	1.4	Bare left, stay on Rt. 326



45.1	5.0	Turn right onto West Genesee St. (stay on Rt.326)
46.7	1.6	Turn left onto Veteran's Memorial Pkwy (stay on Rt.326)
47.4	0.7	Turn right onto Routes 5 & 20 E
49.2	1.8	Stay on Rt. 5
65.2	16.0	Stay straight, merge onto Rt. 174, W Genesee St., Auburn, NY
66.4	1.2	Turn right onto Rt. 98, W Genesee Street
68.2	1.8	Turn left into McDonald's

This is a Lunch/Restroom stop

69.2	1.0	Continue on W Genesee Street and turn right onto Whedon Rd
69.7	0.5	Turn left onto Semloh Drive
70.1	0.4	Turn right onto Whedon Rd.
70.5	0.4	Turn left onto Onondaga Blvd, park and walk to barricade.

#### Stop 4: Split Rock Quarry

Location Coordinates: (43.027<sup>0</sup> N, -76.238<sup>0</sup> W)

The fourth stop is an abandoned quarry southwest of Syracuse near the hamlet of Split Rock in the town of Onondaga, NY. Split Rock Quarry is both historically significant as well as geologically important.

In the late nineteenth century, the site was an active limestone quarry (Fig. 8) but with the advent of World War I, it had become the Semet-Solvay munitions factory. About a quarter of the TNT used by American soldiers in the war was produced there. On July 2, 1918, a fire broke out, followed by one of the worst explosions in the history of New York killing 50 people and injuring dozens more (Syracuse Post-Standard, 1918). By the end of the year, any remaining buildings were scrapped leaving only the original stone crusher behind (Figs. 9, 10).

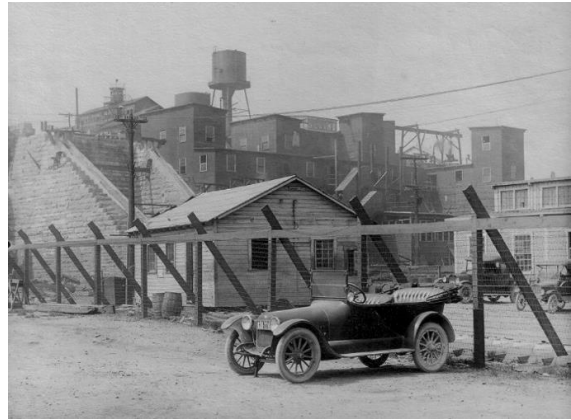


Figure 8. Limestone quarry 1889.      Figure 9. Original stone crusher on left with munitions buildings.



Figure 10. Devastation after horrific explosion. Today some people claim the locality is haunted.

The Split Rock stone crusher was originally built against the vertical rock wall comprising the Upper Silurian Chrysler Formation. Approximately 10 ft (3 m) below the top of the Chrysler dolostones, Ciurca (1978, 1994) has observed the abrupt appearance of the eurypterid *Erieopterus microphthalmus*. Moreover, *Eurypterus*, so characteristic of the Bertie Lagerstätten, is absent stratigraphically above this level.

These strata are overlain by the Olney Member of the Manlius Formation. The Olney limestone forms a distinct shelf-like ledge on top of the Chrysler dolostones. This surface may be partly due to differential erosion but also may be a relic from the early quarrying days of the region. Furthermore, Split Rock is the type locality for the Olney. At the base, the Olney is an argillaceous limestone, which weathers into very dark gray thin sheets. These beds are gradationally overlain by massive, light gray, thickly bedded limestone with abundant brachiopods. Approximately 2 meters (6.5 ft.) below a widespread layer of mud cracks of the overlying Elmwood Member, Czurca (1978) described the occurrence of *Erieopterus microphthalmus* (Fig. 11) in conjunction with the prolific spiriferid brachiopod *Howellella vanuxemi*. Deposition of these sedimentary units stopped with an abrupt change in the environment into the oolitic limestone of the Clarke Reservation Member. However, this and higher units of the Manlius Formation are locally removed by an erosional unconformity between the Lower Devonian and the carbonates of the Middle Devonian Onondaga Limestone.

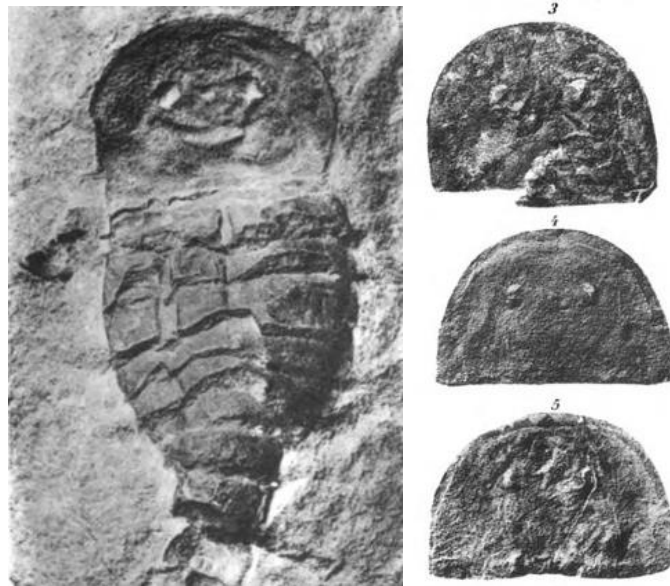


Figure 11. *Erieopterus microphthalmus* showing different outlines of the prosoma from Clarke and Rudemann (1912).

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End of Trip: Return to Hobart and William Smith Colleges.