AN EXAMINATION OF EURYPTERID OCCURRENCES
IN THE WILLIAMSVILLE FORMATION (BERTIE GROUP)
EXPOSED IN RIDGEMOUNT QUARRY

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INTRODUCTION

Eurypterids were chelicerate arthropods that lived through much of the Paleozoic Era (Early Ordovician to Early Permian), reaching their peak in diversity during the Late Silurian and Early Devonian. Their fossilized remains are found on every continent except Antarctica, with well-known occurrences in places such as Baltic Europe, Scotland, and New York State and adjacent Ontario.

The eurypterid body includes a prosoma followed by an opisthosoma ("abdomen") with twelve movable segments and a posterior telson (Fig. 1). The prosoma bears six pairs of appendages, most of which extend beyond its edge. A typical eurypterid has a pair of chelicerae anterior to the mouth, followed by three pairs of "walking legs," a pair of "balancing legs," and a pair of "swimming legs" that (in most forms) ends in a flattened palette or "paddle." The name "eurypterid" means "broad-winged," referring to the paddles. The basal parts of the legs, or coxae, have teeth on their inner edge that aid in mastication. Posterior to the mouth is the metastoma (postoral plate), a characteristic feature of eurypterids that covers the inner margins of the last pair of coxae and the space between them.

The opisthosoma is divided into a preabdomen and a postabdomen. The preabdomen includes the first six segments, each covered by a dorsal plate or tergite. The ventral side of the first two preabdominal segments is covered by the operculum, a pair of plates meeting at the median line, with a central genital appendage. The remaining four preabdominal segments bear movable ventral plates, or sternites, that cover the respiratory appendages. The six postabdominal segments, or caudal segments, are annular. The telson is styliform (long, pointed) in most eurypterids, but in some (such as the pterygotids) is broad and flattened (spatulate). In the genus *Eurypterus*, an angled ridge, or carina, is developed on the ventral side of the telson.

The eurypterid exoskeleton is thin and chitinous, and thus prone to decomposition. It has an average of 110 parts (Tollerton, 1997) that may separate after death. Eurypterids molted or shed their exoskeletons; most fossil specimens may actually represent cast-off moults (Clarke and Ruedemann, 1912; Tollerton, 1997). It is therefore no surprise that "the finding of well-preserved specimens of eurypterids is fortuitous or the result of diligent search" (Copeland and Bolton, 1985).

Eurypterids have been assigned to at least 59 genera and more than 236 species (Tollerton, 1997). Some controversy exists, however, as to what constitutes a species, especially in the genus *Eurypterus*, the most common in local Silurian rocks. The first eurypterid specimen ever described, from Oneida County, NY in 1818 (and originally misidentified as a fish), was named *Eurypterus remipes*: this species was designated in 1984 as the official "New York State Fossil." The second

species described was *Eurypterus lacustris*, found in Buffalo. Other species were assigned to this genus; some (such as *Buffalopterus pustulosus*) had since been placed in other genera. There seems to be a lack of agreement in the number of species of *Eurypterus* found in the Bertie Group. Four (*E. remipes*, *E. lacustris*, *E. dekayi*, *E. laculatus*) were listed by Tollerton (1997) (Fig. 2). Some authors, such as Copeland and Bolton (1985) and Ciurca and Hamell (1994), refer to the first two as subspecies of *E. remipes*, hence *E. remipes remipes* and *E. remipes lacustris*. Others question the distinction of *E. dekayi*. *E. laculatus*, previously misidentified by Copeland and Bolton (1985) as *E. remipes lacustris*, was described by Ciurca (1990) as characteristic of the Fiddlers Green Formation.

Part of the confusion appears to have arisen from the old separation of Bertie Group eurypterids into two geographic localities or "pools" (Clarke and Ruedemann, 1912; and others): the "Buffalo" and the "Herkimer." Forms from each were sufficiently distinct to some workers to merit different species names, while others viewed this as a multiplicity of names based on minor morphological variations. Thus some viewed *E. remipes* and *E. lacustris* as synonymous, and others called them subspecies. Ciurca (1982) demonstrated that *E. remipes* ("Herkimer pool") consistently occurs in rocks (Fiddlers Green Formation) that are older than those (Williamsville Formation) with *E. lacustris* ("Buffalo pool"). The present author believes that consistent differences (such as prosoma shape, expansion of the preabdomen in *E. lacustris*) exist to justify separate species status.

LIFE HABITS AND ECOLOGY

Studies of eurypterid ecology have usually involved comparison with the modern horseshoe crab (*Limulus polyphemus*) of our Atlantic coast, their closest living relative (Fig. 1). Eurypterids and *Limulus* share many morphological features that set them apart from other chelicerates (Clarke and Ruedemann, 1912; Robison, 1987), but it should be noted that eurypterids constitute a diverse group with varied shapes and sizes probably reflecting diverse modes of life.

Limulus is dimorphic, with females typically larger than males. Eurypterids are also dimorphic, with the genital appendage considered to be the key to identification of the sexes. Which type of appendage belongs to which sex, however, is still unclear. Clarke and Ruedemann (1912) considered eurypterids with a longer, more elaborate genital appendage to be females while those with shorter, simpler ones are males. Copeland and Bolton (1985) state the opposite. Tollerton (1997) refers to Type A and Type B without designating sex. Clarke and Ruedemann (1912) noted that in modern *Limulus* the appendage is larger and more elaborate in the female, which also tends to be larger than the male. Personal observation that the larger eurypterid specimens tend to have the longer genital appendage support a female designation consistent with comparison to modern *Limulus*.

Limulus comes ashore during the spring tide to mate, and eggs are laid in the sand. After hatching, individuals (which resemble adults) move to progressively deeper-water settings during ontogeny (Rudloe, 1979; Shuster, 1979), with small adults common at depths to about 30 m and mature adults living on the shelf at depths of less than 50 m (Prothero, 1998). When molting, *Limulus* flips onto its back and uses movements similar to those for burrowing. It exits through a split on the ventral side just behind the anterior edge of the prosoma. *Eurypterus* apparently molted in the same manner. *Limulus* can tolerate a wide range of temperatures and salinities, and can even crawl on land for short distances. It swims on its back by flapping its sternites, but usually crawls right-side up across the bottom. When flipped over, it easily rights itself by flexing its body and digging in the telson.

Limulus spends most of the day buried in the sand (Lockhead, 1950; Eldredge, 1979), and comes out to feed at night. Young animals eat polychaete annelids; adults eat bivalves and polychaetes (Fisher, 1984). They will also scavenge dead fish and mollusks.

Clarke and Ruedemann (1912) suggested that *Eurypterus*, like *Limulus*, fed on worms or dead organisms, and noted that members of the genus were not specialized, being neither wholly adapted to swimming, crawling, or digging. *Dolichopterus*, also found in the Bertie, appears to have been well adapted to swimming, with forward-facing compound eyes, longer and broader swimming legs, and long, spiny walking legs that may have aided in swimming. The much larger and apparently predaceous *Paracarcinosoma* and *Acutiramus* appear to have been more specialized, with the former possibly hiding beneath a thin layer of sediment until prey came close, and the latter adapted for swimming with its streamlined body and spatulate telson.

The habitats of eurypterids have been inferred by examination of associated faunas and the sediment containing their remains. The earliest (Ordovician and Early Silurian) eurypterids are found with typical marine organisms such as graptolites, brachiopods, cephalopods, and trilobites (Clarke and Ruedemann, 1912; Copeland and Bolton, 1985). Later Silurian forms are often associated with phyllocarids and leperditid ostracodes, and probably lived in marginal marine areas such as enclosed lagoons and estuaries. Devonian eurypterids are commonly associated with brackish or freshwater ostracoderms and arthrodire fish. Late Paleozoic forms are found with land plants, freshwater ostracodes, freshwater pelecypods, scorpions, insects, and amphibians, suggesting that eurypterids had by then moved into freshwater habitats and may have even ventured onto land.

The eurypterids of the Late Silurian Bertie Group, the focus of this paper, are found in a chemical dolostone (waterlime) that was precipitated under restricted, near-shore marine conditions off a landmass of low relief under the influence of an arid to semi-arid climate (Copeland and Bolton, 1985). Ciurca and Hamell (1994) interpreted the various environments represented by different parts of the Bertie Group; the Williamsville Formation is believed to represent intertidal conditions.

DISCUSSION

The author has collected fossils from the Williamsville Formation at Ridgemount Quarry beginning in October of 1997. To date more than 180 eurypterid specimens (mostly disarticulated remains) have been collected and recorded, including 28 "complete" (prosoma through telson, with at least some appendages present) individuals plus 10 lacking the telson.

Tollerton (1997) presented a table listing species found in the Bertie Group across New York State and adjacent Canada. Those from the Williamsville Formation in Ontario quarries: eurypterids: *Acutiramus cummingsi* (*Pterygotus* in many papers), *Dolichopterus macrocheirus*, *Eurypterus dekayi*, *E. lacustris*, *Paracarcinosoma scorpionis*; brachiopods: *Eccentricosta jerseyensis*, *Lingula* sp.; gastropods (undifferentiated); cephalopods: orthoconic nautiloids; phyllocarids: *Ceratiocaris* sp. (probably *C. acuminata*); ostracodes (undifferentiated); plants: *Cooksonia*.

Personal collecting experience adds the following to this list of species found in the Williamsville Formation at Ridgemount Quarry: eurypterids: *E. laculatus* (previously reported for Fiddlers Green Formation), *Buffalopterus pustulosus*; nautiloids: *Mitroceras gebhardi*, *Pristeroceras*

timidum; conularids: *Metaconularia perglabra*; xiphosurans: *Pseudoniscus clarkei*; *Bunaia woodwardi*; Algae: *Medusaegraptis gramminiformis*.

Fossils are most abundant in the upper 20 cm of the lower part of the Williamsville Formation ("Williamsville A Submember" of Ciurca and Hamell, 1994), in a waterlime (chemical dolostone) that in places readily splits into slabs 1 to 4 cm thick but elsewhere may be quite blocky and splits conchoidally. The upper surface of this interval is presently exposed over much of the quarry floor in the southwest corner. Eurypterid remains are often concentrated at two general levels: from the surface to a depth of about 5 cm; and below a depth of about 10 cm.

Eurypterid specimens often consist of a "part," showing either the dorsal or ventral surface, on one slab, and the synjacent slab bearing a corresponding "counterpart" or imprint. Many of the complete and nearly complete specimens were found to include a dorsal counter-part, a ventral counter-part, and a compressed "part" representing the animal itself, which breaks free of the matrix. Most if not all specimens appear to represent cast-off exoskeletons (moults). Several exhibit a distinct separation of the dorsal and ventral surfaces of the prosoma, with a gap of up to 1 cm along the anterior edge where the animal crawled out. The moults, after reaching their final resting places, were apparently filled by precipitated dolomite in the preservation process.

Perhaps the most common of the disarticulated remains to be found are prosomas, which tended to be thicker than the abdominal segments and thus more likely to be preserved (Clarke and Ruedemann, 1912). These are usually still connected to the first tergite, probably reflecting strong articulation between the prosoma and the abdomen. In *Limulus* this aids in burrowing and pushing through the sediment in search of food.

The upper part of the "Williamsville A Submember" tends to be very straticulate, with fine, varve-like bedding visible on the edges of slabs. The interval, however, exhibits rapid lateral facies changes. Areas where the rock splits readily into flat, laminated sheets grade abruptly into areas where it breaks with a more irregular, commonly conchoidal surface. In other areas, the rock splits along very irregular surfaces covered with low domal structures which appear to be similar to certain stromatolitic structures observed in the Fiddlers Green Formation.

The author has noted a lack of specimens in areas with flat, laminated beds, and only few remains have been found in areas with the other extreme. Even where the rock has the "proper texture," eurypterid remains are not evenly distributed. While isolated specimens do occur, a majority of the specimens collected were found to be concentrated in widely-spaced, elongate windrows, attributed by Ciurca (1978) and Ciurca and Hamell (1994) to current activity that accumulated remains in the troughs of large, shallow ripple-like features. The author has collected numerous parts, complete individuals, and representatives of other groups from four recognizable windrows to date. These windrows were found to be parallel to each other, with the long axis oriented at roughly N44W.

It is interesting to note that the shallow, horseshoe-shaped depressions ("boomerangs" of Ciurca and Hamell, 1994) found at the top of the "Williamsville A Submember" in various places on the quarry floor are generally oriented perpendicular to these windrows (trailing edges roughly N45E). If the Williamsville Formation represents the intertidal zone (Ciurca and Hamell, 1994), the windrows may have been shallow depressions oriented parallel to shore in which cast-off moults and the remains

of other organisms were accumulated during tidal processes. The "boomerangs" may have been scoured during tidal currents, possibly by local turbulence in front of some curved obstruction.

Of 188 eurypterid specimens collected and catalogued to date, *Eurypterus lacustris* is the dominant species represented (153 specimens), followed by *E. dekayi* (17), *Acutiramus* ("*Pterygotus*") sp. (9), *Paracarcinosoma scorpionis* (3), and two specimens each of *Buffalopterus pustulosus*, *Dolichopterus* sp., and *Eurypterus laculatus*. Because many specimens of *E. lacustris* were not collected (usually due to poor preservation or occurrence as isolated segments), the proportion of that species is probably far greater. It should be noted that because most specimens represent moults and most are separated parts or partial individuals, these numbers do not necessarily reflect a depiction of the actual proportions of living animals, but merely provide an idea of the likelihood of finding specimens of a particular species.

The three species of *Eurypterus* are represented by complete specimens (or specimens lacking the telson). Those of *E. lacustris* were measured to determine the size distribution (approximate telson length was added for those lacking that part). Results are presented in Table I, along with orientation data (dorsal-up or ventral-up) for these specimens. From the size distribution data, most complete specimens are between 4 and 8 inches (10 to 20 cm) in length, with both smaller and larger individuals relatively rare. The paucity of large specimens may reflect a progression toward deeper, offshore habitats during ontogeny like that observed for *Limulus*: the likelihood of moults from large individuals being carried intact into the intertidal zone would be low.

The up/down orientation data indicate that more than two-thirds of the (nearly) complete specimens were upside-down (ventral side up) when they reached their final resting place (10 dorsal-up; 23 ventral-up). In his examination of orientation of six specimens of *E. remipes* from the Litchfield locality, Tollerton (1997) suggested that a ventral-up orientation may result from either a ventral-up molting position or a more stable orientation in the presence of weak currents. No speculation is here made on the reasons for the orientations.

ACKNOWLEDGEMENTS

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TABLE 1. Size distribution and orientations of specimens of *Eurypterus lacustris*. Specimens either complete or lacking only the telson. Orientations: U dorsal-up; D ventral-up.

Size (inches)	Complete	Lacking telson
<1	0	1 (U)
1-2	0	0
2-3	0	2 (D)
3-4	0	0
4-5	4 (2-U,2-D)	1 (U)
5-6	3 (D)	2 (D)
6-7	5 (D)	1 (D)
7-8	7 (2-U,5-D)	0
8-9	2 (U)	0
9-10	1 (U)	2 (1-U,1-D)
>10	2 (D)	0
TOTAL:	24	9

walking
legs

balancing
leg

swimming
leg

prosoma

chelicerae

metastoma

palette

operculum

genital
appendage

preabdomen

postabdomen

telson

Limulus
polyphemus
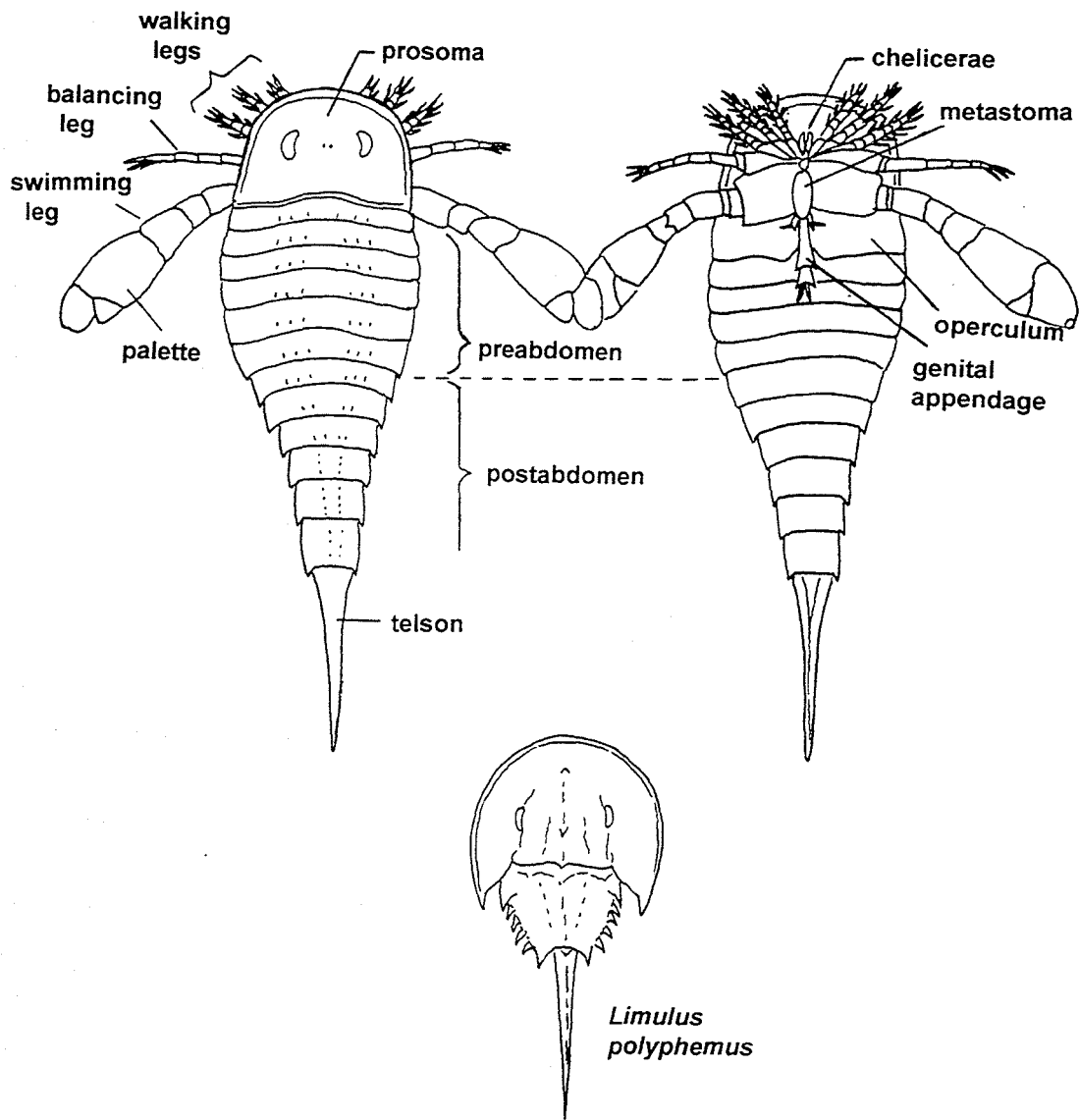
Figure 1. Drawing of *Eurypterus lacustris* with parts labeled. Modern horseshoe crab (*Limulus polyphemus*) shown for comparison.

Eurypterus remipes (Fiddlers Green only)

Eurypterus laculatus (< 5 cm)

Eurypterus lacustris (Williamsville only)

Eurypterus dekayi

Dolichopterus macrocheirus
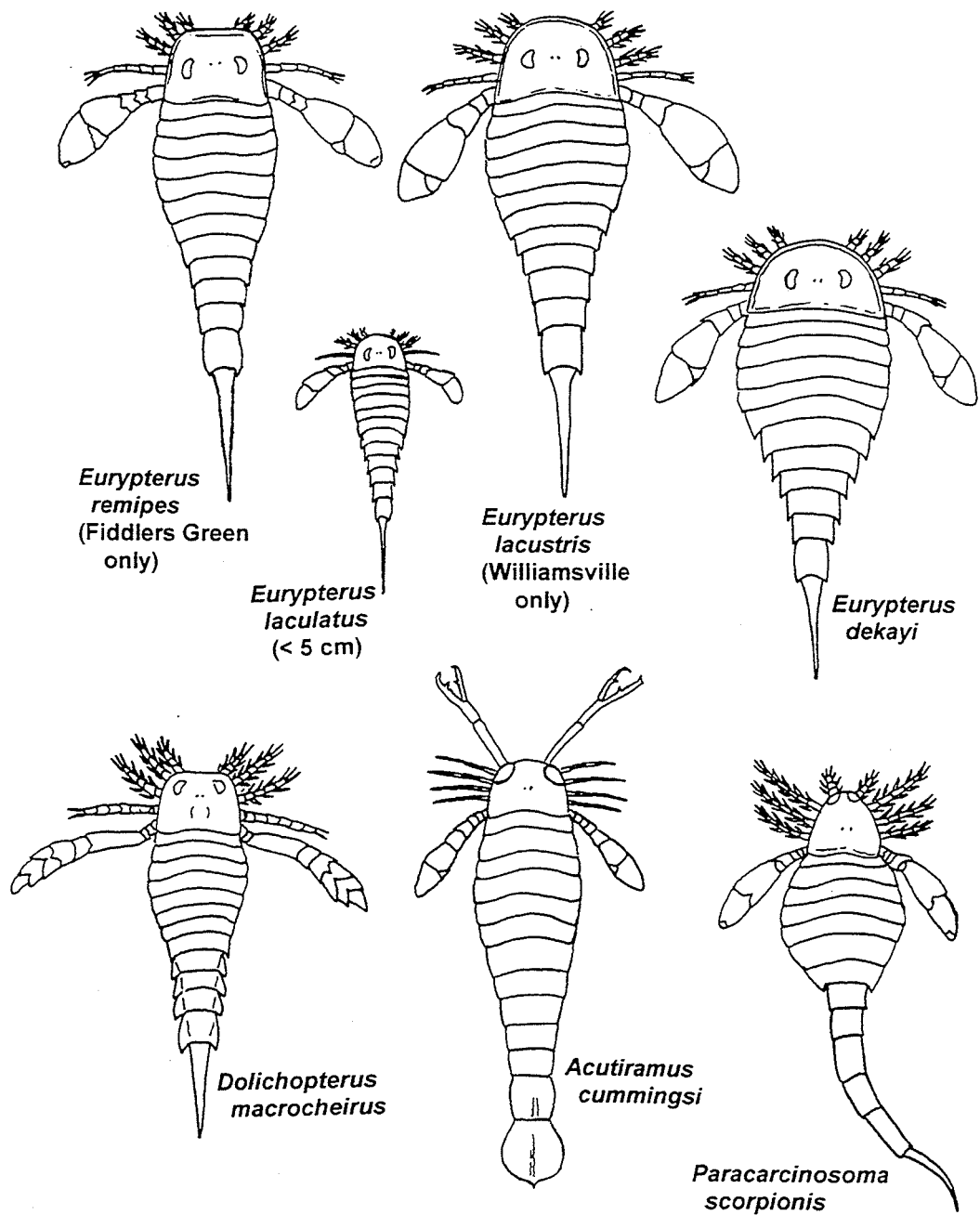
Acutiramus cummingsi

Paracarcinosoma scorpionis

Figure 2. Some of the eurypterid species found at Ridgemount Quarry.