

Eurypterids and Associated Fauna at Litchfield, A Classic Locality in Herkimer County

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Introduction

The Upper Silurian Bertie Formation (Group of D.W. Fisher, 1960; Cieurca, 1973) of New York State and Ontario, Canada, is world renowned for its spectacular eurypterids. One of these, *Eurypterus remipes* DeKay, 1825, holds the distinction of being the first eurypterid in the world to be described. This species is also the state fossil of New York, as signed into law by Mario Cuomo on 27 June 1984. Another species, the second one in the world to be described, *Eurypterus lacustris* Harlan, 1834, has been figured on a postage stamp of Canada (as *Eurypterus remipes*).

Central New York is fortunate to boast of four localities where eurypterids can still be collected from the Bertie (Forge Hollow, Litchfield, Lang's Quarry, and Passage Gulf). Two others mentioned in the literature (Jerusalem Hill and Crane's Corners) are not currently accessible. The Litchfield, Herkimer County locality is a classic outcrop that displays both vertical and horizontal sections amenable for paleoecological study.

The main purpose of this trip is to examine the paleoecology of eurypterids. Too often, matters of their habit and habitat are studied without regard for both the stratigraphic and sedimentologic context, as well as ignoring evidence from associated fauna.

History

The Bertie Formation was named by Chapman (1864, p. 190-191) for a 50 foot thick section of "...thin-bedded grayish dolomites, interstratified towards the base with a few brownish shales, and with a brecciated bed composed chiefly of dolomite fragments" that were exposed near the Township of Bertie, Welland County, Ontario, Canada. The name was first used in New York State by Schuchert (1903) in his study of the Manlius Formation. A more complete historical perspective is found in Rickard, (1953, 1962). The unit was raised to the rank of group by D.W. Fisher (1960). The New York State Geological Survey currently uses the term formation (Rickard, 1975). Others use the term group (Cieurca, 1973, 1978, 1982, 1990; Hamell, 1981; Hamell and Cieurca, 1986; and Cieurca and Hamell, 1994).

In this paper, I prefer to use the term formation for the entire Bertie on the basis that the subunits are too thin to map as formations on a scale of 1:24,000 (the standard 7.5 minute topographic quadrangle). However, as shown by Hamell (1981), Hamell and Cieurca (1986), and Cieurca and Hamell (1994), the subunits are of utility for finer-scale interpretations of paleoenvironments within the entire unit.

The outcrop across from the Litchfield Town Hall is a classic locality for eurypterids and associated fauna. Specimens of eurypterids and other invertebrate fossils from this location have been cited in the works of Clarke and Ruedemann (1912), Ruedemann (1916; 1925), and Kjellesvig-Waering (1958).

In July and August 1992, this roadcut was cut back by the New York State Department of Transportation for road improvements. Although no blasting was done, an estimated 30,000 cubic feet of rock was removed and used for road fill. At present, 9.5 feet of section are exposed. Prior to the road work, only 5.5 feet of section was exposed (Leutze, 1959).

Age

Historically, the age of the Bertie formation has been considered to be Pridoli (Late Silurian). Rickard (cited in Berry and Boucot, 1970, p. 122) found the conodont *Spathognathodus*, perhaps *S. steinhornensis remscheidensis* from the basal part of the Bertie in the Syracuse, New York area. Recently, Johannessen, et al. (1997) reported a sparse and fragmentary fauna of ozarkodinid conodonts from the Fiddlers Green Member at Litchfield. Their identifications suggested to them a Ludlow age (Late Silurian) for the Bertie Formation. Considering the long temporal range of the species encountered and the fragmentary nature of the conodont elements, it might be prudent to take a more conservative view and consider the Bertie as Late Silurian (Ludlow-Pridoli). More study on the conodont faunas of the entire Bertie from the entire geographic range is definitely required. How the conodont faunas correlate with the inferred unconformities within the Bertie (Ciurca and Hamell, 1994) is unknown.

Eurypterids

Eurypterids are extinct aquatic chelicerate arthropods. Growth, as in all arthropods, was accomplished after the hard exoskeleton was moulted. It is generally accepted that most specimens represent cast-off exoskeletons (Clarke and Ruedemann, 1912; Størmer, 1934; Selden, 1984). The exact number of instars (periods between moults) is unknown. Statistical analyses of measurements of prosomas (heads) reveals nearly isometric growth (Kaneshiro, 1962; Andrews, et al., 1974). Examination of bivariate graphs of various measurements show no discrete clusters (Tollerton, 1993) indicative of instar groups. However, work by Sekiguchi, et al. (1988) on horseshoe crabs suggests that the instar groupings identified by Andrews, et al. (1974) for *E. remipes* may be correct.

As of May 1997, there are 59 genera and 236 named species within the Order Eurypterida. Another 108 specimens remain in open nomenclature. The most recent classification of the Order is by Tollerton (1989). Eurypterids are sexually dimorphic, with the two sexes denoted as either Type A or Type B. Which type is which sex has yet to be unequivocally determined. Depending on the species and sexual type, there are on average 110 parts to a complete eurypterid.

The temporal range of the Order is from the lower Upper Ordovician (Harnagian Stage, Caradoc Series; approximately 460 mya (absolute ages from Harland, et al., 1990)) to the upper Lower Permian (Artinskian Stage, Rotliegendes Series; approximately 265 mya). The range is therefore about 195 million years, or a little more than half of the Paleozoic. The oldest and youngest eurypterids known so far (from the stages given above) are, respectively, *Brachyopterus stubblefieldi* Størmer, 1950, from Wales, and *Adelophthalmus sellardsi* (Dunbar), 1924, from Kansas. The acme of the Order is the Silurian.

Eurypterids are found on every continent except Antarctica. They occur in most sedimentary lithologies except conglomerates and coarse sandstones. Only two groups of invertebrates never occur with eurypterids; crinoids and sponges. Five groups of invertebrates rarely occur with eurypterids; barnacles, bryozoans, scaphopods, corals, and trilobites. Table 1 lists the invertebrate groups known to occur with eurypterids. Various plants are known to occur with eurypterids, especially from the Late Silurian to the Early Permian. The record of vertebrate associations, besides conodonts, is not reliable and needs further study.

TABLE 1. Invertebrate groups known to occur with eurypterids.

Nautilid cephalopods	Pelecypods	Gastropods	Conularids
Tentaculites	Ostracods	Worms	Insects
Inarticulate Brachiopods	Articulate Brachiopods	Graptolites	Scorpions
Phyllocarids			

Paleoecology

The literature on the paleoecology of eurypterids is varied and sparse. Two different approaches have been followed. One is based on evidence from external factors of occurrences (lithology, trace fossils, associated fauna, etc.). The comprehensive summaries of all the then known eurypterid occurrences by O'Connell (1916), and the identification of ecological phases for Silurian eurypterids by Kjellesvig-Waering (1961) are examples of this approach.

The second, more common approach is based on evidence from functional morphology. These studies have inferred (among other things) the mechanics of swimming (Selden, 1981; Plotnick, 1985; Knight, 1996), walking (Hanken and Størmer, 1975; Waterston, 1979), and feeding (Kjellesvig-Waering, 1964; Selden, 1984); and respiration (Selden, 1985; Manning and Dunlop, 1995); and the biomechanics of the cuticle (Dalingwater, 1985).

I prefer the first approach because I feel it is subject to closer scrutiny, and relies on fewer ambiguous assumptions. However, both approaches are necessary, as is some reliance on what Plotnick (1983, p. 218) calls the *Limulus* paradigm (the interpretation of eurypterid paleoecology based in large part on the ecology of horseshoe crabs). Some of the more pertinent aspects of this paradigm follow.

Limulus polyphemus (Linnaeus), 1758, is generally considered the closest (phylogenetically) living marine relative of eurypterids. Most of the literature on the ecology of *Limulus* cannot be applied to eurypterids because the soft parts (muscles, nerves, etc.) are not preserved, and many behaviors or responses to stimuli cannot be observed in the fossils. However, the following ecological aspects of *Limulus* are probably applicable to eurypterids.

Limulus comes ashore to sandy beaches to mate, with the male attached to the back of the female. The female burrows into the sand and deposits her eggs, but not all in one nest (Sekiguchi and Nakamura, 1979). The male then fertilizes the eggs. Fertilization is external. When the eggs hatch, the larvae are morphologically very similar to the adults.

During the course of its life cycle from hatching to mature adult, *Limulus* inhabits progressively deeper water settings (Rudloe, 1979; Shuster, 1979). Hatchlings are found in the supralittoral setting where the nests were dug by the mature female. Larvae and small juveniles occur in the intertidal sand and mud flats. Larger juveniles are found in subtidal settings. Small adults occur in deeper water (up to about 30 meters (Rudloe, 1979), while the mature adults occur on the continental shelf (Shuster, 1979).

According to Shuster (1979, p. 13), the usual mode of locomotion of large juveniles and adults is an ambling stiff-legged gait along the bottom. Aspects of swimming and burrowing have been described in several papers (Vosatka, 1970; Eldredge, 1970; D.C. Fisher, 1975). Moulting in *Limulus* has been described by Laverock (1927) and Jegla (1982). Of particular interest is the similarity of movements in both burrowing and moulting, the only significant difference being the position of the animal; when burrowing, it's oriented dorsal up and when moulting, ventral up.

Limulus is normally a nocturnal animal, spending most of its time buried just below the surface (Lochhead, 1950; Eldredge, 1970). The diet of the young animals is polychaete worms, while bivalves and polychaetes constitute the diet of larger individuals (D.C. Fisher, 1984). According to Reynolds and Casterlin (1979), *Limulus* is tolerant of a wide range of temperatures (less than 0 C to 40 C) and salinities (5‰ to fully marine), under both artificial and natural conditions.

Taphonomy

The taphonomy of eurypterids is virtually an open topic for study. With one exception (O'Connell, 1916), none of the papers that deal specifically with the paleoecology of eurypterids consider aspects of taphonomy except in a cursory fashion. Minor comments and observations have been made, but without reference to context of in situ occurrences. Here, information that may be of value for the study of eurypterids has been gleaned from the more abundant literature on trilobites, and on arthropod fossils in general (e.g., Mikulic, 1990).

As noted by Brett and Baird (1986), the position of the fossil in the sediment and the arrangement of the skeletal elements are important in determining the condition of the animal at the time of its burial. In this way, the fossil is treated as a primary sedimentary structure, and its preservation (or lack of it) can provide clues to infer depositional environments.

The multi-element skeletons of arthropods can only be preserved intact if individuals are buried rapidly (Brett and Baird, 1986), because the decay process occurs very rapidly (Plotnick, 1986). However, the decay rate in carbonate environments is slower than in fine-grained clastic environments (Plotnick, et al., 1988).

According to Størmer (1934), Henningsmoen (1975) and Mikulic (1990) moulted exoskeletons are much less attractive to scavengers than are dead individuals. Moulted exoskeletons are also lighter than corpses and are more likely to float, and be moved by currents (Mikulic, 1990).

A number of studies have emphasized the instability of concave-up orientations of various skeletal parts (e.g., Seilacher, 1973), in even weak (<10 cm/sec) currents (Brett and Baird, 1986, p. 209). Furthermore, concave-down or concave-up orientations suggest current action or lack of, respectively, prior to or during burial (Brett and Baird, 1986).

Application

It is generally agreed that the Phelps beds of the Fiddlers Green Member reflects a low energy intertidal setting of an epeiric sea (Hamell, 1981; Tollerton and Muskatt, 1984; Hamell and Ciurca, 1986; Ciurca and Hamell, 1994). More detailed analyses have not, as yet, appeared.

Earlier this year (February, March and May 1997) I collected five specimens of eurypterids in situ from two different layers of the Phelps beds at the Litchfield locality. Jim Pospichal collected a sixth specimen in situ. The top/bottom orientations of all six specimens were recorded. Three specimens are from the lowest layer of the Phelps beds and the other three are from the uppermost layer. Approximately 18 inches separate these two layers. The different orientations, and contrasts in preservation and taphonomy between the specimens from the two layers are remarkable and suggest differences in micro-depositional histories, with different causes for the orientations of the eurypterids.

The three specimens (to date) from the lowest layer are unusual in that all are oriented ventral up (dorsal down). Two are incomplete specimens, being prosomas articulated with 2 and 7 body segments. They are oriented at nearly right angles to each other. The carapace and posterior segments of *Ceratiocaris aculeatus* Hall, 1859, also occurs on the slab. The third specimen on another slab is an incomplete Type A individual with legs V and VI preserved. This specimen is unusual in that it is a 3-dimensional specimen removable from the matrix. It is, however, much flattened. All three specimens are undoubtedly moulted exoskeletons.

There are no indications of predation or scavenging on these specimens, even though they are poorly preserved. The poor preservation suggests decayed exoskeletons, although it may also be due to extreme weathering along the bedding plane. There are no signs of bioturbation. Sedimentary features of tidal action (flaser and lenticular bedding) are located 1cm above the plane of the eurypterids, while massive bedding is seen below the plane of the eurypterids.

The three specimens (to date) from the uppermost layer are unusual, relative to those from the lowest layer, in that two are oriented dorsal up while the third is oriented ventral up. Two are prosomas articulated with the first body segment, and it is one of these that is ventral up. The third specimen is an incomplete individual, missing the telson, and all the legs. The telson is missing only because the pretelson (12th body segment) abuts a joint plane. The rest of the bed (with the telson) was missing when the specimen was collected.

These specimens from the uppermost layer are preserved better than those from the lowest layer. The uppermost layer shows flaser and lenticular bedding, which are absent about 1cm above the plane of the eurypterids. These three specimens were separated from each other by about 9 inches. The gross orientations of the prosomas to each other was almost parallel, but in opposite directions.

To use the line from Yul Brenner in the movie *The King and I*, the contrast in orientations of the eurypterids between the two layers is a puzzlement. I believe that the specimens from the lowest layer represent one of two situations. First is that they represent re-settling of moulted exoskeletons after a storm. The consistent ventral up orientation would be expected because the convex dorsal surface is more hydrodynamically stable in this position (Seilacher, 1973; Brett and Baird, 1986; Mikulic, 1990). The articulated nature of the exoskeletons is in partial agreement with the results of Allison (1986, p. 981) whereby the state of preservation (including degree of articulation) is not an indicator of distance of transport or duration of agitation.

The second explanation is that after moulting (where eurypterids may have turned on their backs to moult, like *Limulus*), the partly anchored, cast-off exoskeletons were undisturbed by tides, currents, or scavengers. They probably remained in this position until buried by precipitated carbonate sediment.

The three specimens from the uppermost layer may represent moulted exoskeletons that were turned over by low velocity currents or by tidal action. The good preservation indicates fairly rapid burial, in contrast to those specimens from the lowest layer. Furthermore, the near parallel orientation also suggests some current or tidal activity.

Unfortunately, the associated fauna known to occur with eurypterids in the Phelps beds (Table 2) only indicate near shore, shallow marine intertidal conditions (see Tollerton and Muskatt, 1984, for a fuller discussion of the paleoecology of the associated fauna). However, more detailed analyses of the associated fauna are possible, if the orientations are recorded when they are found.

Table 2 is also a revision of the associated fauna listed in Tollerton and Muskatt (1984), and provides both a stratigraphic and geographic overview. Several forms previously listed are omitted here (e.g., the pelecypods, and the cephalopod *Mitrocera gebhardi*) because they occur in the stratigraphically lower Syracuse Formation or stratigraphically higher Cobleskill Formation, respectively. Both of these units are lithologically similar to parts of the Bertie Formation.

As it is, many forms whose life position is normal to bedding are observed oriented parallel to bedding (e.g., the lingulid brachiopods, and the conularids). These observed orientations are another indication of some sort of disturbance of the sediment. Predation can be ruled out by the absence of damage caused by predators.

In summary, the study of the paleoecology of eurypterids collected *in situ* and based on external factors of the environment (lithology, taphonomy, and associated fauna) is wide open for study.

Apology

I intended to include a measured section, but I've had problems with collectors (?) Who have continually removed the numbers I have placed on the beds.

Acknowledgment

I express my deepest and most sincere thanks to my wife, Mary, for her support, and for her help with the computer.

Table 2. (Continued).

		Quarries in Ontario, Canada	Buffalo, NY area	Black Creek, Morganville, NY	East Victor, NY	Phelps, NY	Jamesville, NY area	Forge Hollow, NY	Jerusalem Hill Herkimer County	Litchfield Herkimer County	Lang's Quarry Herkimer County	Passage Gulf Herkimer County
	<i>C. aculeata</i>							3		p 13		
	<i>C. maccoyana</i>		3									
	<i>C. minuta</i>		3									
	unidentified	w 9	w 8		w 6		w 7					p 8
Xiphosurans	<i>Bunaia woodwardi</i>		3									
	<i>Hemiaspis eriensis</i>		3									
	<i>Pseudoniscus clarkei</i>		wd 11							3		
Ostracodes	<i>Eukloadenella umbilicata</i>		w 4							v 13		
	<i>Herrmannia alta</i>		3							?v 13		?v 13
	<i>Leperditia scalaris</i>		1							v 13		p 13 v 13
	<i>Zygobeyrichia regina</i>		w 4							v 13		
	unidentified	9	w9 ECB 9 v9		v 12	p 7	p 7		5			v 7
Plants	<i>Cooksonia sp.</i>	w 12										p 7
	<i>Medusaegraptis gramminiformis</i>		3				w 7					p 13
	<i>stromatolites</i>	12						p 13		p 13	p 13	p 13

Notes for Tables 2 and 3.

1. Geographic occurrences are arranged from west (left) to east (right).

2. Stratigraphic units: w = Williamsville beds

ECB = Ellicott Creek Breccia

P = Phelps beds

V = Victor beds

FG = Fiddlers Green Member

3. Taxonomy of species as in Leutze (1959) and Tollerton and Muskatt (1984).

4. References: 1=Clarke and Ruedemann, 1912

8=Hamell, 1981

2=Ruedemann, 1916

9=Ciurca, 1982

3=Ruedemann, 1925

10=Hamell and Ciurca, 1986

4=Monahan, 1931

11=Ciurca, 1990

5=Leutze, 1959

12=Ciurca and Hamell, 1994

6=Ciurca, 1973

13=Personal observation and/or collection

7=Ciurca, 1978

14=Johannessen, et al., 1997

Table 3. Geographic and stratigraphic occurrences of the eurypterids.

Eurypterids	Quarries in Ontario, Canada	Buffalo, NY area	Black Creek, Morganville, NY	East Victor, NY	Phelps, NY	Jamesville, NY area	Forge Hollow, NY	Jerusalem Hill Herkimer County	Litchfield Herkimer County	Lang's Quarry Herkimer County	Passage Gulf Herkimer County
<i>Acutiramus cummingsi</i>	w 9	1 w 8				w 7					
<i>A. macrophthalmus</i>							1	1	1 P 13	P 13	P 13 V 7
<i>A. sp. (=Pterygotus in many papers)</i>	ECB 9			w 7	P7						V 7
<i>Buffalopterus pustulosus</i>		1									
<i>Dolichopterus herkimerensis</i>								1			
<i>D. jewetti</i>							1	1	P 13		P 13
<i>D. macrocheirus</i>	w 9	1 w 8									
<i>D. siluriceps</i>		1								P 13	
<i>D. testudineus</i>	ECB 9							1			
<i>D. sp.</i>	ECB 9	w 9		w 9	P7						P 8
<i>Erettopterus grandis</i>		1								P 13	
<i>Eurypterus dekayi</i>	w 9	1					P13		P 13	P 13	P 13
<i>E. laculatus</i>	ECB 12		V 6								
<i>E. lacustris</i>	1 w 9	1 w 9		w 7							
<i>E. remipes</i>	ECB 9	1 ECB9 FG 6			P6	P6	1 P13 V13	1	P 13 V 13	P 13	P 6 V 7
<i>E. sp.</i>											V 7
<i>Paracarcinosoma scorpionis</i>	w 9	1 w 8				w7					
<i>Pterygotus cobbi</i>		1								P 13	
unidentified fragments	V 9		V 10	V 12					V 13		V 10

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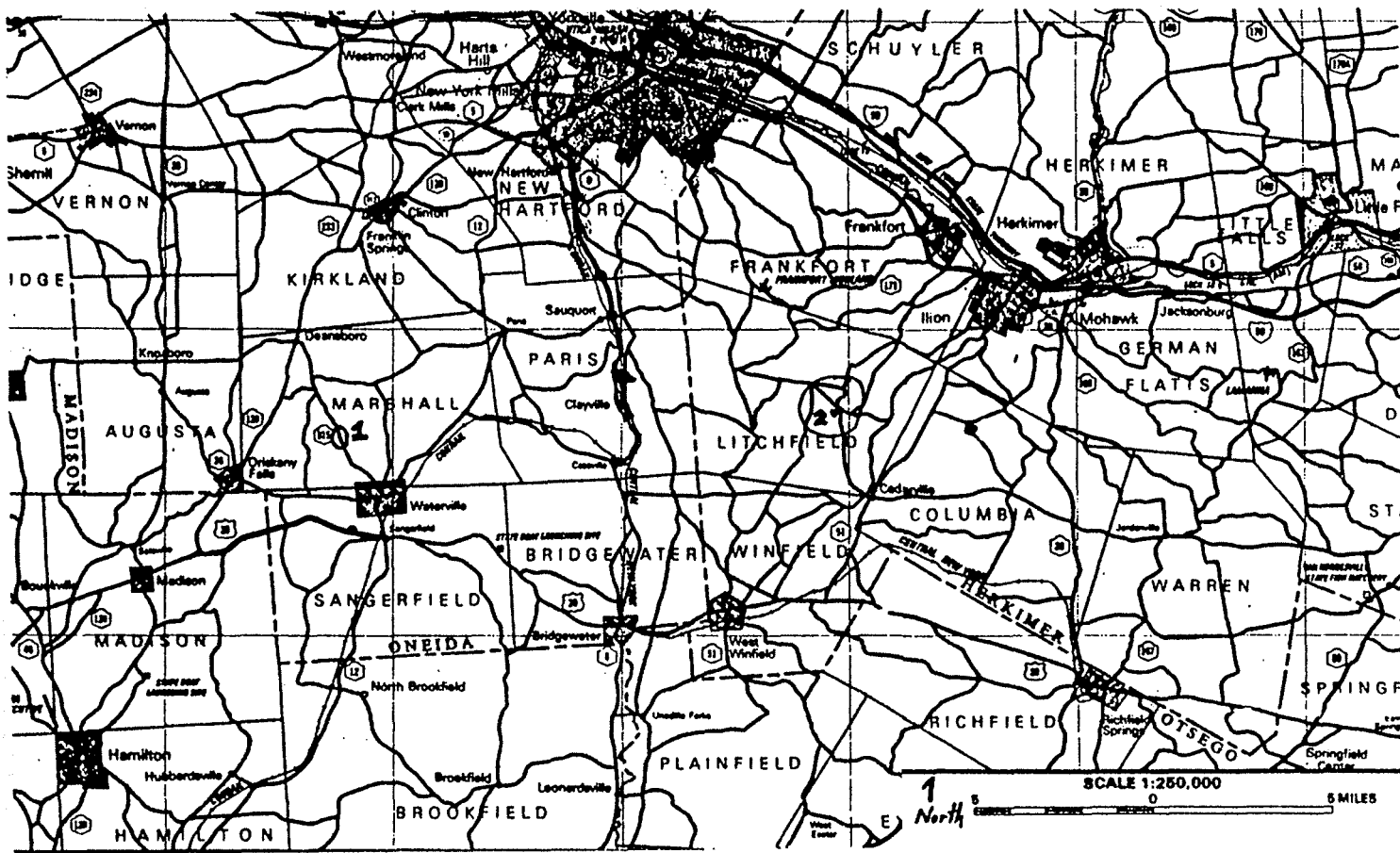


Figure 1

Road Log

Cumulative Mileage	Miles From Last Point	Route Description
0.0	0.0	Start at the flashing traffic light at the bottom of Hamilton College road. This is the intersection of Routes 233 and 412. After coming down the hill, turn right onto Route 233.
1.2	1.2	End of Route 233. "T" intersection with Route 12B. Turn right onto Route 12B (south).
3.8	2.6	Village of Deansboro highway sign.
4.2	0.4	Intersection of Route 315 and 12B. Turn left onto Route 315 (south).
7.1	2.9	STOP 1. Park on the right. Outcrop on the right. BE CAREFUL...blind curves at both ends of the outcrop.

STOP #1. Forge Hollow, Oneida County, New York.

This locality is the type locality for the eurypterid *Eurypterus remipes* Dekay, 1825, and the scorpion *Proscorpius osborni* (Whitfield), 1885. It is also the type locality for a new genus and species of eurypterid being described.

This outcrop exposes the following units (in ascending order): Camillus Shale; the Morganville, Victor, and Phelps beds of the Fiddlers Green Member, Bertie Formation; Scajaquada Member (= Rickard's 1962 Forge Hollow Member), Bertie Formation; Williamsville Member, Bertie Formation; Cobleskill Formation; and Manlius Formation.

Continue south on Route 315.

7.2	0.1	Bogan Road on the right, at the extreme southern edge of the outcrop. Road cuts on the right of this road expose the higher units. Continue south on Route 315.
9.0	1.8	Village of Waterville highway sign
9.55	0.55	End of Route 315. Flashing traffic light and stop sign. Intersection of Routes 315 and 12 (south). Turn right onto Route 12 (south).
9.65	0.1	Route 12 (south) curves left. Stay on Route 12 (south).
9.7	0.05	Route 12 (south) curves left. Stay on Route 12 (south).
10.6	0.9	Township of Sangerfield highway sign.
10.9	0.3	Intersection of Routes 12 and 20. Turn left onto Route 20 (east).
17.0	6.1	Village of Bridgewater highway sign.
17.35	0.35	First of two traffic lights. Continue straight on Route 20 (east).
17.45	0.1	Second traffic light. Intersection of Routes 8 and 20. Continue straight on Route 20 (east).
20.2	2.75	Village of West Winfield highway sign.
20.6	0.4	Intersection of Routes 20 and 51 (south). Continue straight on Route 20 (east).
22.65	2.05	Village of East Winfield highway sign.
23.5	0.85	Intersection of Routes 20 and 51 (north). Turn left onto Route 51 (north).
26.5	3.0	Village of Cedarville highway sign.
26.7	0.2	Village of Cedarville. Turn left onto Route 51 (north).
26.85	0.15	Intersection of Jerusalem Hill Road and Route 51 (north). Continue straight on Jerusalem Hill Road.
29.6	2.75	STOP 2. Park in the small parking lot on the right, in front of the Litchfield Town garage. Outcrop on the left.

STOP # 2. Litchfield eurypterid locality.

End of trip.