

# Fossils of Ontario

## Part 3: The Eurypterids and Phyllocarids

M. J. Copeland and Thomas E. Bolton


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and Phyllocarids



Diorama of a Late Silurian lagoonal environment and a confrontation between individuals of *Paracarcinosoma scorpionis* Grote and Pitt. (Photograph courtesy of the New York State Museum, Albany, N.Y.)

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Thomas E. Bolton

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# The Eurypterids

## Introduction

Palaeozoic rocks of Ontario contain abundant remains of invertebrate fossils that lived from 350 million to 500 million years ago. These fossils can be found in sedimentary rocks that occur throughout southern Ontario south of the Precambrian Canadian Shield and that are found in northern Ontario primarily in a large area south of Hudson and James bays (Ludvigsen, 1979, figs. 1–8). Representatives of some fossil groups such as brachiopods, corals, and cephalopods are common throughout these Ordovician to Devonian rocks; specimens of certain other fossil groups, however, are of very restricted occurrence. One of the rarer types of fossils found in Ontario are the Eurypterida, an extinct group of chelicerate arthropods related to the horseshoe crab, *Limulus polyphemus* (Linné), that lives along the central Atlantic seaboard of North America.

As is true with any group of rare fossils, the finding of well-preserved specimens of eurypterids is fortuitous or the result of diligent search. In Ontario only strata of Silurian and Devonian age have yielded identifiable eurypterid remains; these occur in southern Ontario in the vicinity of the Niagara Escarpment, from Niagara Falls in the south to Manitoulin Island in the north (Fig. 1). Lower and Middle Silurian eurypterid occurrences are limited to individual specimens or partial remains whereas Upper Silurian (Bertie Formation, Williamsville dolomite; Ciarca, 1975, 1982) occurrences in the Fort Erie–Port Colborne area have provided numerous well-preserved, complete specimens. These Late Silurian specimens represent the westward continuation of the famous Buffalo eurypterid faunule of western New York State (Clarke and Ruedemann, 1912; O’Connell, 1916; Williams, 1919; Caster and Kjellesvig-Waering, 1956). This eurypterid faunule in Ontario has not yet been the subject of extensive research but numerous specimens are preserved in collections of the Royal Ontario Museum (ROM), the Buffalo Museum of Science (BM), the University of Michigan Museum of Paleontology (UMMP), and the Geological Survey of Canada (GSC).

## Palaeoecology of Eurypterids

When the word “fossil” is mentioned, most people conjure up the image of a trilobite or a dinosaur, representatives of two dominant groups of extinct animals that have been made memorable in fact and fiction, the trilobite for its neat, well-defined, and symmetrical shape and the dinosaur for its immensity and imputed ferociousness. Unlike many other groups of animals, trilobites and dinosaurs may be pictured as moving about, the former placidly burrowing for food on the muddy bottom of an ancient Palaeozoic ocean and the latter running or plodding about the Mesozoic landscape searching for land- or aquatic-plant or -animal sustenance. In this way our mind’s eye sees such prehistoric, extinct animals and places them into specific palaeoecological settings. During their evolutionary development, the eurypterids are thought to have inhabited many of the ecological niches occupied by both trilobites and dinosaurs. During the Palaeozoic, the eurypterids may have evolved, with other

Chelicerata, as among the earliest nonmarine and semiamphibious arthropods known in the fossil record. It has been proposed by some (Clarke and Ruedemann, 1912; Størmer, 1955, 1976) that the eurypterids were originally marine creatures that invaded shallow, saline or brackish lagoons at the estuaries of rivers, became adapted to existence in open fresh water and coal-forming swamps, and may have spent short intervals on land. This sequence of palaeoecological adaptations is postulated from the association of eurypterid remains with Ordovician marine animals such as graptolites, cephalopods, and trilobites; Silurian euryhaline, lagoonal leperditicopid ostracodes (*Leperditia*, *Herrmannina*), phyllocarids (*Ceratiocaris*), and shallow water lingulid brachiopods; Devonian brackish or freshwater ostracoderms and arthrodires; and Permo-Carboniferous land plants, freshwater ostracodes and pelecypods, scorpions, insects, and amphibians. Other authors (Caster and Kjellesvig-Waering, 1964) have proposed that eurypterids were typically marine creatures that, like *Limulus*, were capable of living for extended periods in fresh water readily accessible to the sea. This is certainly a possible explanation, and some of the freshwater faunal and terrestrial floral assemblages associated with eurypterid remains may have been brought together by water action (currents, floods, storms, tides, etc.). It is acknowledged, however, that known Ordovician eurypterid remains are associated with undoubted marine fossils and Carboniferous eurypterid remains with nonmarine fauna and flora.

As noted earlier, eurypterids are known to have existed from relatively early in the Ordovician; they reached their greatest diversity in the Late Silurian and Early Devonian and declined rapidly thereafter to disappear in the Permian. A graph of their evolutionary development would be the reverse of that of the early jawless fish (Romer, 1933) with which their remains are often associated. This poses the possibility that the small, early, mostly bottom-dwelling fish were relatively defenseless against the prehensile chelicera and scorpionlike, possibly "poisonous" telson of the larger predacious eurypterids. As the primitive fish evolved into larger, more-agile-swimming (nektonic) forms and migrated seawards, the eurypterids' food supply diminished, and most carnivorous types became extinct. Many eurypterids, however, were adapted to a bottom-dwelling (benthic) existence, seeking food on the muddy bottoms of lagoons, rivers, and lakes or possibly along the moist banks of such bodies of water. These eurypterids with less-specialized adaptations could more readily react to changing conditions. As a result, a few groups of eurypterids outlived their fearsome cousins by as much as 100 million years.

Eurypterid remains have been found in Palaeozoic sedimentary rocks from many regions of the world. Of the more than four dozen genera now recognized, fewer than a dozen are known to occur in Canada. Specimens of three of these genera are more common in Canada than the others—*Eurypterus*, *Pterygotus*, and *Carcinosoma*. All three genera are from strata of Middle Silurian to Middle Devonian age in the Maritime Provinces; the Gaspé Peninsula, Québec; southern Ontario; and the Arctic Islands (Copeland and Bolton, 1960). Until recently, no undoubted Canadian eurypterid remains were known from southern Canada west of Manitoulin Island, Ontario, but Elias (1980) described an incomplete specimen from Upper Ordovician marine strata near Winnipeg, Manitoba. Undoubtedly other specimens will be found in western Canada, especially in the undisturbed strata marginal to the Canadian Shield, which was a relatively stable cratonic area throughout the Phanerozoic. Siluro-Devonian eurypterid-bearing localities will eventually be discovered in the central Canadian Arctic, to add to those known from marine-brackish dolomitic strata on Cornwallis,

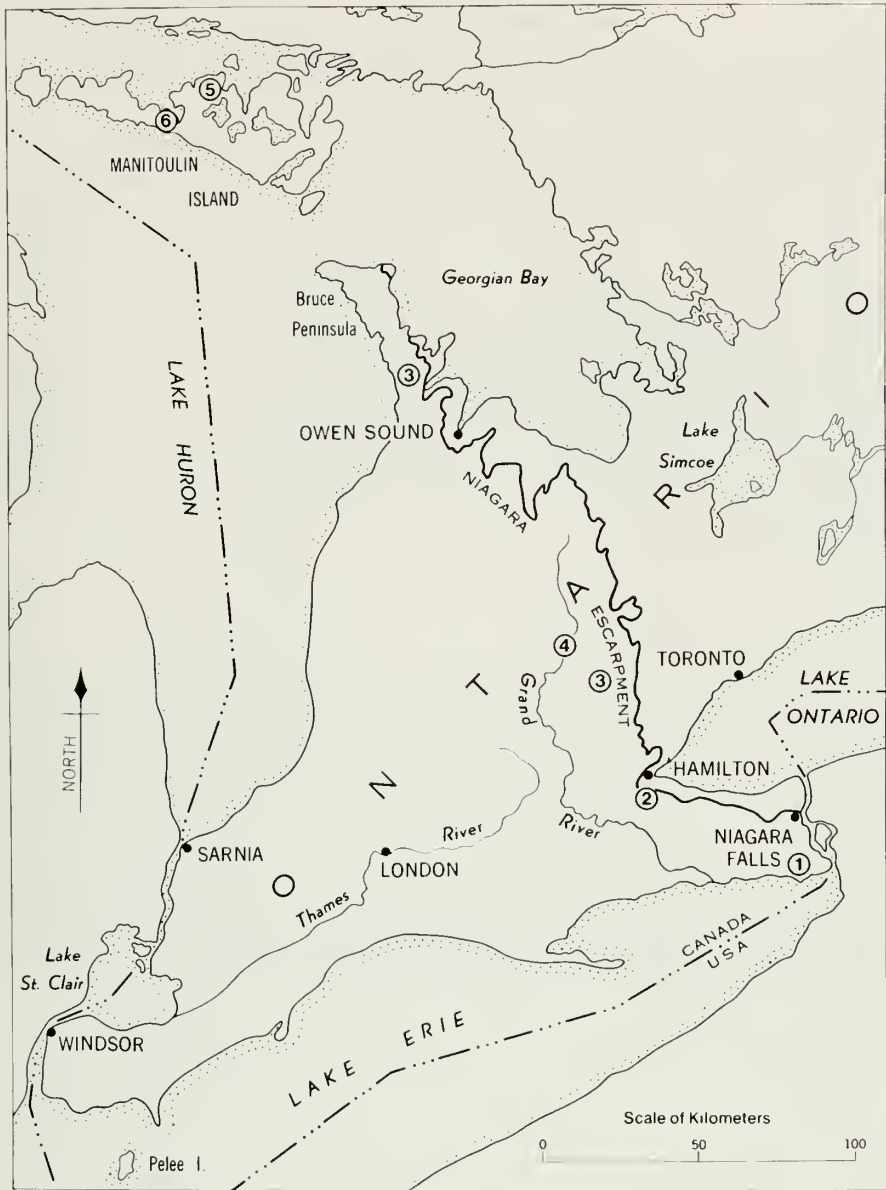


Fig. 1 Eurypterid localities of southern Ontario.

1. Bertie Formation, Fort Erie to Port Colborne and Cayuga area, Niagara Peninsula.
2. Goat Island Member, Lockport Formation, Corporation Quarry, Hamilton.
3. Eramosa Member, Lockport and Amabel formations, near Eramosa, Wiarton, and Sky Lake.
4. Guelph Formation, Elora.
5. Manitoulin Formation, quarry immediately west of Kagawong, Manitoulin Island.
6. St Edmund Formation, west of Gore Bay, Manitoulin Island.

Devon, and Somerset islands (Copeland and Bolton, 1960; Copeland, 1962, 1971). Upper Palaeozoic (Permo-Carboniferous) nonmarine strata are rare in Canada, and no undoubted eurypterid remains of this age have been discovered outside the Maritime Provinces (Copeland, 1957).

The sedimentary lithologies in which eurypterids are preserved vary greatly. In New York State, early Ordovician eurypterids are found at the interface between black, fossiliferous shale and tongues of sandstone. Those of the Late Ordovician of Ohio are associated with metabentonite (volcanic ash). One specialized eurypterid, *Tylopterella boylei* (Whiteaves), is found in calcareous reefal deposits of the Middle Silurian Guelph Formation of Ontario. Upper Silurian eurypterid species of the Bertie Formation (Williamsville) in Ontario occur in chemical dolomite (waterlime) precipitated under restricted, near-shore marine conditions off a land mass of low relief. In the Gaspé Peninsula, Québec, Devonian eurypterid remains occur in cross-bedded, possibly wind-blown sandstone associated with armoured fish and terrestrial plant remains; in the Maritime Provinces, eurypterids are found in black, fossiliferous, freshwater shale of Carboniferous age associated with coal seams, soil horizons, and thick-bedded sandstone.

## Morphology of Eurypterids

Eurypterids are often called “sea scorpions” because of their elongate shape and inferred ability to bend their usually horizontally oriented postabdomen, with its possibly poisonous terminal telson, above their backs in scorpion fashion. They must have presented a most ferocious aspect: eurypterids were the largest of known arthropods; some, as reconstructed, attained a length of 2 to 3 m (ca 6–9 ft). The name “eurypterid” refers to the paddlelike extremity of the sixth prosomal appendage of most members of the subclass and means “broad winged.” The “paddle” probably served several purposes: it may have been used for swimming, to propel the animal after prey or to help it to escape danger; for stirring up fine mud, to enable the animal to search for food or to create a “smoke screen” to confuse predators; for burrowing, to allow the animal to camouflage itself in soft bottom sediments.

The eurypterid body (Fig. 2) is divisible into a semicircular-to-subquadrate prosoma (bearing six pairs [I–VI] of appendages arranged about the central mouth), a body of 12 movable segments (VII–XVIII), and a posterior telson (XIX). The appendages include the anterior chelicerae (I), walking legs (II–IV), balancing legs (V), swimming legs (VI), the highly modified metastoma (VII, posterior of the mouth and the first preabdominal appendage), the operculum (VIII, bearing the genital appendage which is often long and narrow in male specimens and short and broad in female specimens), and four succeeding movable plates covering the respiratory appendages (IX–XII). These are followed by the last segment of the ovate preabdomen (XIII), five tapering postabdominal segments (XIV–XVIII), and the lanceolate or expanded telson (XIX). Segments (or somites) VIII–XVIII bear tergites (dorsal plates), and somites XIII–XVIII (the posteriors of the movable ventral plates covering the tuftlike or leaflike respiratory appendages) also bear sternites (ventral plates). This “streamlined” body form, with a relatively large “head” and posteriorly tapering body, permitted maximum mobility for this predacious or scavenging aquatic animal.

The exterior surface of an eurypterid was covered with a chitinous exoskeleton that

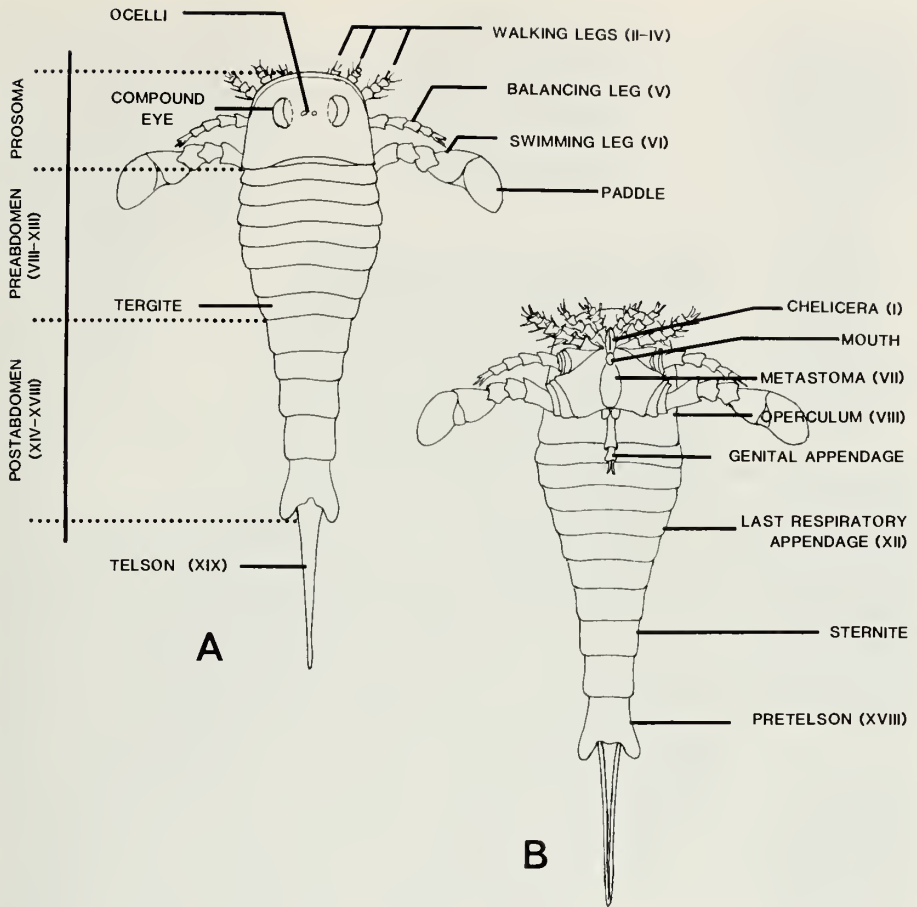


Fig. 2 Reconstruction of a typical eurypterid, *Baltoeurypterus tetragonophthalmus* (Fischer) showing the terminology used in this paper. (Adapted from Treatise on invertebrate paleontology, R. C. Moore, ed., part P, Arthropoda 2:25, 1955.)  
 A Dorsal view  
 B Ventral view

was smooth, scaly, tuberculate, or (rarely) spiny. This exoskeleton was relatively resistant to chemical change. Many eurypterid remains (especially those in chemically precipitated rocks such as those of the Bertie Formation) are deep amber-brown, which may be the original colour. In some cases pieces of the integument may even be flexible. Most specimens are compressed dorso-ventrally but some (Fig. 12D) are three-dimensional, the abdominal segments being slightly flattened or elliptical in cross-section. Specimens found in sedimentary rocks that are high in carbon (such as black shale) or that have been tectonically altered are invariably compressed, carbonized, and black.

Many eurypterid occurrences are known only from an individual abdominal segment, limb, prosoma, or telson. These and other somewhat more complete specimens probably represent portions of the exoskeleton that were cast off during moulting (ecdysis) rather than the remains of dead individuals. Eurypterids moulted several times during their life cycle (Fig. 3), increasing in size with each moult until the adult stage was reached. Moulting was accomplished by the rupturing of sutures on the ventral side of the prosoma (Størmer, 1955), after which the soft-bodied eurypterid crawled out of its exoskeleton head first, and a new, larger, hard exoskeleton began to form. One nearly adult specimen figured here (Fig. 4) shows a relatively complete moulted exoskeleton in dorsal aspect, the prosoma displaced from the abdominal segments, but with most of the ventral walking and swimming appendages (numbered II–VI on Fig. 2) still in position. Complete, undisturbed specimens may be considered as intact post-mortem individuals only if, when viewed in ventral aspect (Fig. 5), the prosoma and appendages are still in place attached to the preabdomen, or internal structures are preserved—such as the remains of intestine, as reported by Ruedemann (1921) for *Carcinosoma (Eusarcus)*, by Kjellesvig-Waering (1963) for *Adelophthalmus*, and by Heubusch (1962) for *Eurypterus*. The number of moults through which eurypterids passed from larva to adult probably varied from species to species as in most other arthropod groups. Andrews et al. (1974) identified nine moult stages each for the Silurian *Eurypterus remipes remipes* DeKay and the living *Limulus polyphemus* (Linné) (horseshoe crab), with up to seven moults in rapid succession in juvenile specimens and two later moults in more mature and adult specimens. Størmer (1955) reported that a larva of *Stylonurus*, 2 to 3 mm long, has a smaller number of abdominal segments (seven?) than the adult. This indicates that for *Stylonurus*, and possibly other eurypterids as well (Fig. 3C?), additional abdominal segments became differentiated

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Fig. 3 *Eurypterus remipes lacustris* Harlan

A relatively complete series (C–H) of immature moult stages, with C being the smallest specimen yet observed, and apparently with an incomplete number of abdominal segments on each.

A Bertie Formation, Port Colborne, Ontario;  $\times 1.4$ ; UMMP 62686.

B, C Bertie Formation, Fort Erie, Ontario;  $\times 1.4$ ; UMMP 62815, 62659.

D–F Bertie Formation, Erie County, New York;  $\times 1.4$ ; UMMP 62621B, 62624, 62623A.

G Bertie Formation, Erie County, New York;  $\times 0.8$ ; UMMP 62627B.

H An eurypterid burial ground, mostly of moulted exoskeletons washed together by currents; Bertie Formation, Port Colborne, Ontario;  $\times 0.9$ ; UMMP 62684B.

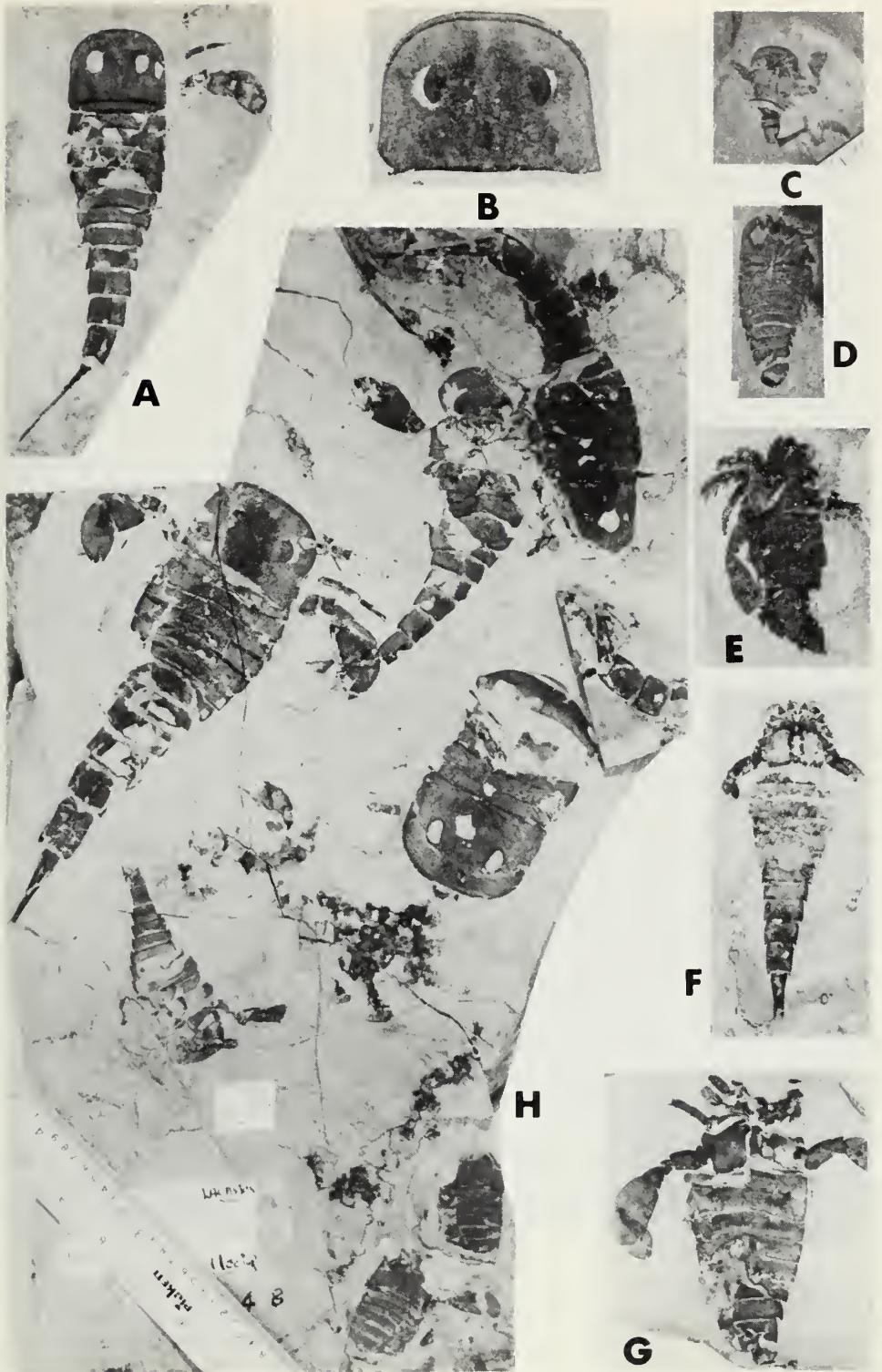


Fig. 3 *Eurypterus remipes lacustris* Harlan.



Fig. 4. *Eurypterus remipes lacustris* Harlan  
Dorsal view of moulted specimen. Because of its size, this specimen may represent the exoskeleton of a nearly adult individual; Bertie Formation, near Windmill Point, Bertie Township, Welland County, Ontario;  $\times 0.72$ ; BM E6468.





Fig. 5 *Eurypterus remipes lacustris* Harlan

Ventral view of a female specimen (note oval metastoma, short genital appendage, and central division of segments IX–XII covering respiratory appendages); Bertie Formation, quarry behind Ridgeway, Welland County, Ontario;  $\times 1$ ; gsc 13994.

as moulting progressed. It is impossible to estimate the life span of an eurypterid with any accuracy, but *Limulus* has survived for up to 15 years under controlled laboratory conditions (D. C. Fisher, pers. comm., 1981).

## Classification of Eurypterids

Eurypterids were extremely diverse arthropods (Figs. 6–8). In classifying families of this subclass, taxonomists place much significance on the form of the metastoma and the anatomy of the ventral shield of the carapace (Kjellesvig-Waering, 1966). These structures are important at higher taxonomic levels, but, generally, are not well enough preserved on most specimens to be readily distinguishable. Moreover, in many specimens only the dorsal aspect is preserved, so that the ventral structures are not visible at all. A few observations of disarticulated parts of some relatively common North American forms can lead to a generic identification (see Table 1).

Specific differences among congeneric representatives are based largely on measurements of numerous specimens, variation of prosoma shape, relative position of the eyes, ornamentation, shape of the "paddle," and strength of the telson, among other things. Drawings of representative North American eurypterids are included to indicate the variation in general form of several Ordovician-to-Devonian genera (Figs. 6–8).

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Fig. 6 Restorations of species of two eurypterid genera (from New York State Museum Memoir 14, 1912).

A, B Ventral and dorsal views of *Dolichopterus macrocheirus* Hall,  $\times$  ca 0.53.

C, D Ventral and dorsal views of *Paracarcinosoma scorpionis* (Grote and Pitt),  $\times$  ca 0.35.

Fig. 7 Restorations of species of three eurypterid genera (from New York State Museum Memoir 14, 1912).

A, B Dorsal and ventral views of *Pterygotus (Acutiramus) macrophthalmus cummingsi* (Grote and Pitt),  $\times$  ca 0.05.

C Dorsal view of *Kokomopterus longicaudatus* (Clarke and Ruedemann),  $\times$  ca 0.5.

D, E Dorsal and ventral views of *Hughmilleria socialis* Sarle,  $\times$  ca 0.5.

Fig. 8 Restorations of species of two eurypterid genera (A from New York State Museum Memoir 14, 1912; B, C from *Palaeontographica Americana*, IV, 1964).

A Dorsal view (the specimen reconstructed from several specimens possibly not of the same species) of *Hallipterus excelsior* (Hall),  $\times$  ca 0.06.

B, C Dorsal and ventral views of *Megalograptus ohioensis* Caster and Kjellesvig-Waering,  $\times$  ca 0.16.

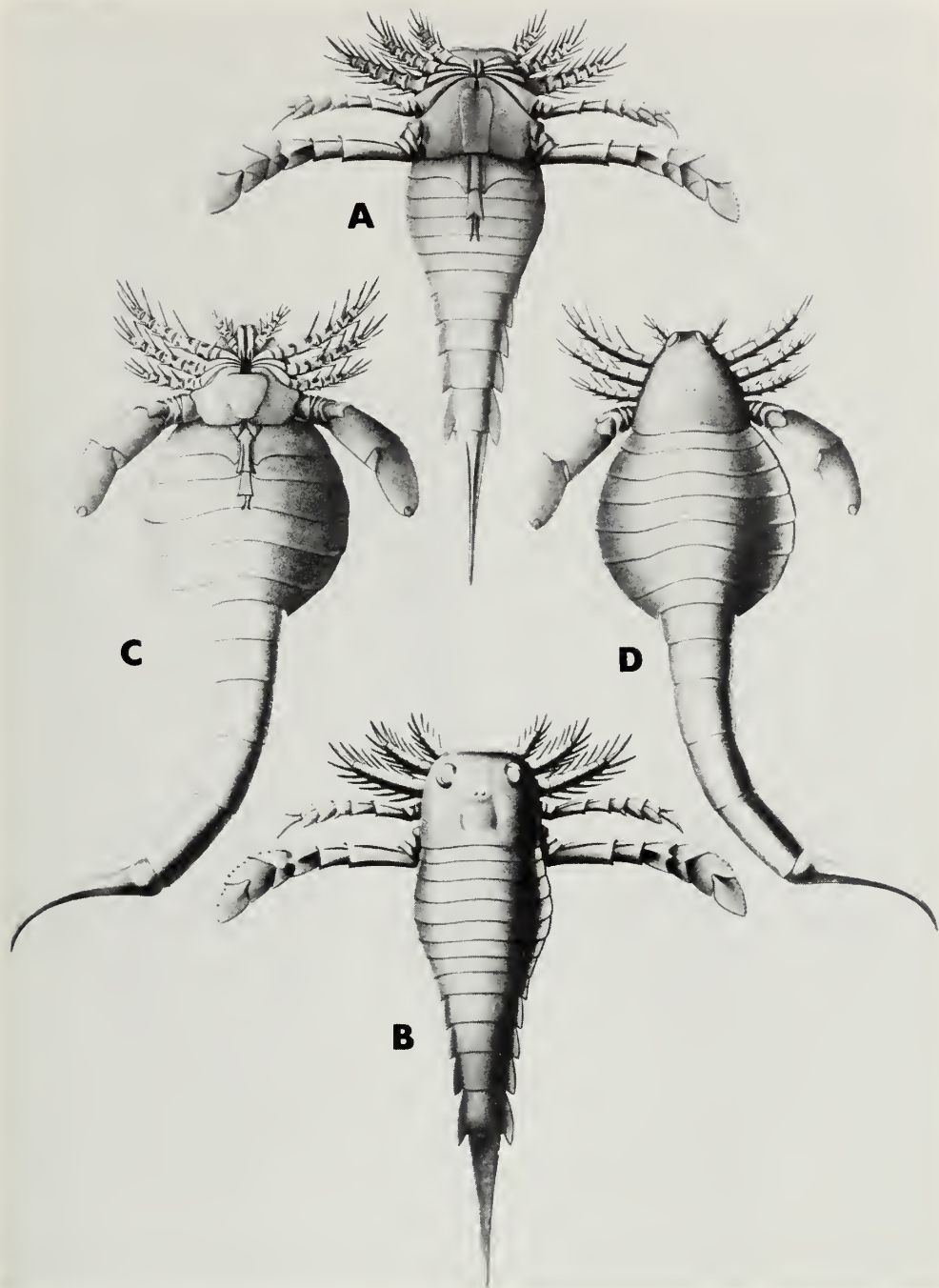


Fig. 6 Restorations of species of two eurypterid genera.



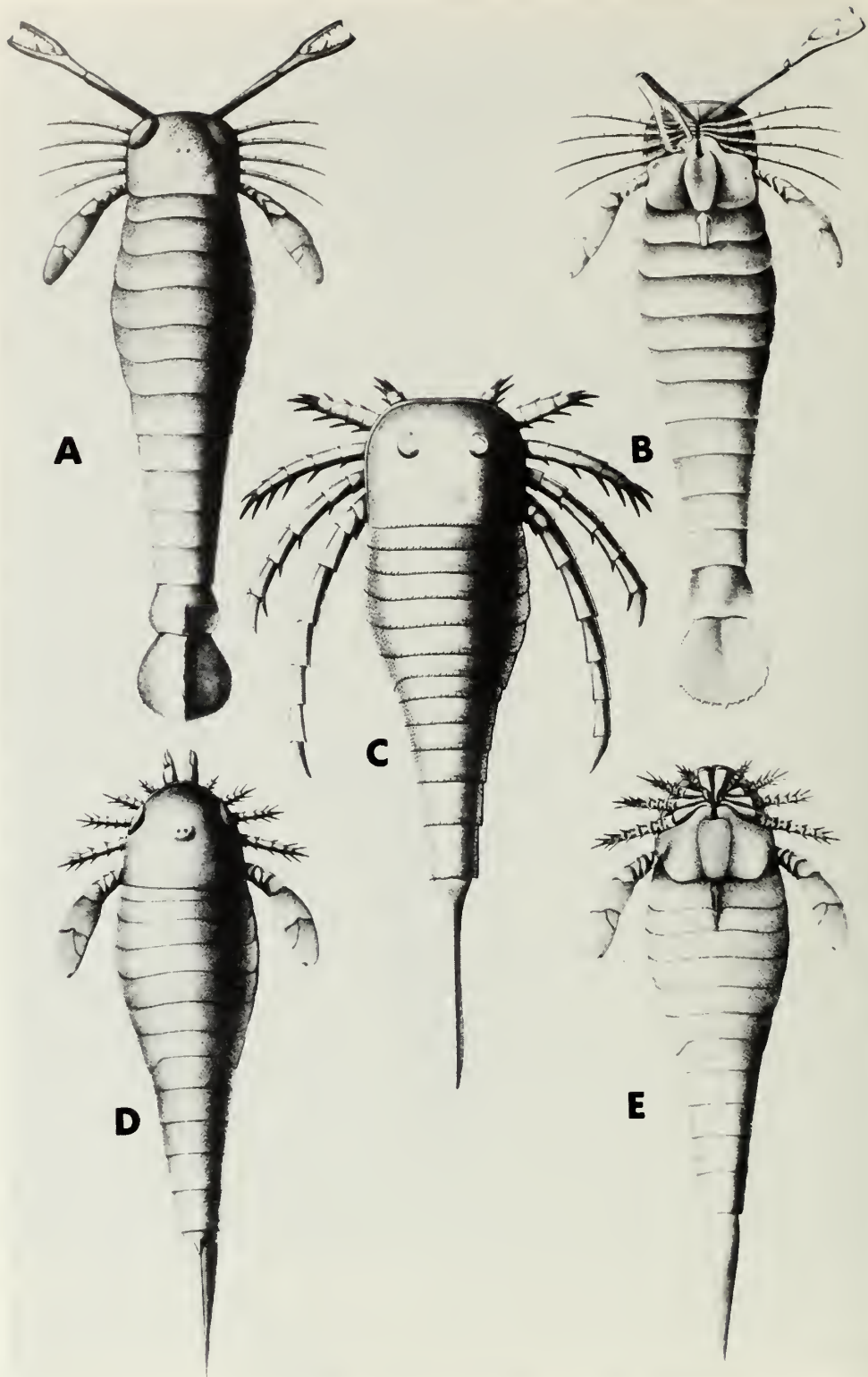


Fig. 7 Restorations of species of three eurypterid genera.

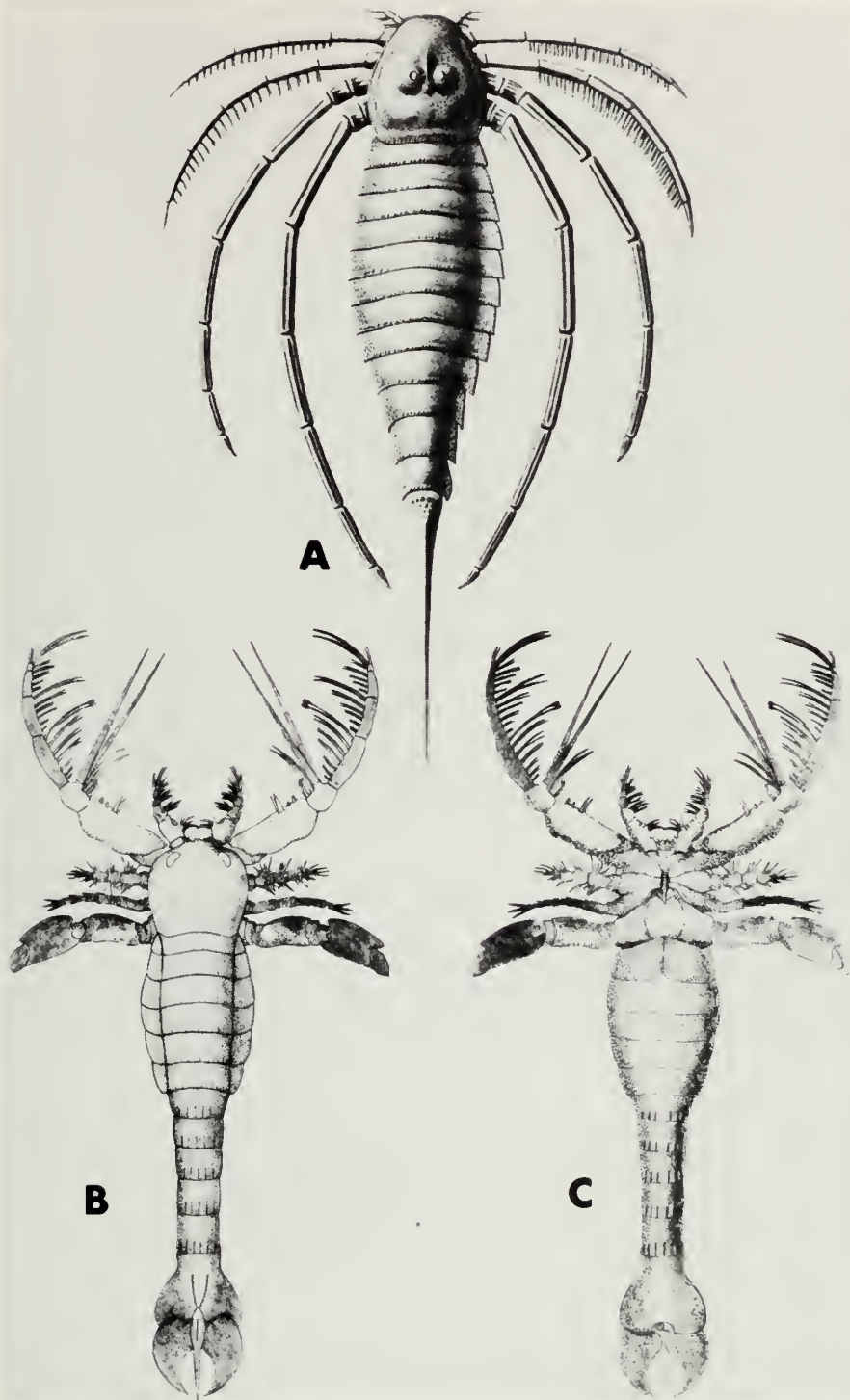


Fig. 8 Restorations of species of two eurypterid genera.

Table 1 Disarticulated Parts of North American Eurypterids

Genus	Prosoma Shape	Eye Position	Appendages II-V Differentiation	Appendage VI Shape	Preabdomen Shape	Telson Shape
<i>Eurypterus</i> (cf. Fig. 2A, B)	subquadrate	dorsolateral	V elongate	paddle	ovate	lanceolate
<i>Dolichopterus</i> (Fig. 6A, B)	subquadrate	anterolateral	V elongate	paddle	ovate	lanceolate
<i>Paracarcinosoma</i> (Fig. 6C, D)	subtriangular	anterior	—	paddle	circular	curved lanceolate
<i>Hughmilleria</i> (Fig. 7D, E)	semiovate	anterolateral	I somewhat strongly developed	paddle	semiovate	lanceolate
<i>Pterygotus</i> (Fig. 7A, B)	subquadrate	anterolateral	I very strongly developed	paddle	semiovate	expanded
<i>Sylonurus</i> (cf. Fig. 8A)	semiovate	dorsomedian	—	long, slender	—	lanceolate
<i>Drepanopterus</i> (cf. Fig. 7C)	subquadrate	dorsolateral	—	long, slender	ovate	lanceolate
<i>Megalopterus</i> (Fig. 8B, C)	globular	anterolateral	III very strongly developed, V elongate	paddle	semiovate	appendage XVIII with cerci

## Silurian Eurypterids Figs. 3–7, 9–20

At least eight genera of eurypterids are known from Silurian strata of southern Ontario (Fig. 9). Undoubtedly others will be identified there and in the Hudson Bay Lowland as palaeontological investigations become more refined. As yet no undoubted Ordovician eurypterid remains have been found in Ontario, but genera such as *Megalograptus* S. A. Miller, 1874 from Upper Ordovician strata of Ohio (Fig. 8B, C) may well occur. Genera from Silurian strata of southern Ontario are as yet only moderately well documented, and none are known from northern Ontario. Ciurca (1982) has reported *Erieopterus* from basal Devonian? strata in the Hagersville, Ontario, area; more research on this occurrence is required. For references to genera and species of eurypterids in Canada, the reader is referred to Copeland and Bolton (1960).

### *Carcinosoma* Claypole, 1890 Figs. 14C, 17, 18A, 19

Prosoma subtriangular, eyes anterolateral, walking limbs undifferentiated but decreasing in length from III to V, swimming legs (VI) paddle shaped. Preabdomen expanded, semioval; postabdomen narrow for entire length. Telson lanceolate and curved. The expanded shape of the preabdomen of *Carcinosoma* is distinctive; other features such as the length of the walking limbs and curved telson are of less value in identification.

### *Pterygotus (Acutiramus)* Ruedemann, 1935 Figs. 7A, B, 10D, 16

Prosoma subquadrate, eyes anterolateral. Chelicerae (I) strongly developed, chelate, with an acute distal margin and major teeth directed distally. Telson broad, leaflike with a central carina.

The pterygotids were among the largest arthropods that ever lived, reportedly reaching a length of some 3 m. Their remains are not common; the pincerlike chelicerae and broad telson (Figs. 16G, H) are extremely distinctive features.

### *Tylopterella* Størmer, 1951 Fig. 15D

Prosoma rounded with prominent marginal rim and small median eyes. Abdomen compressed, telson lanceolate. Exoskeleton thickened, ornamented with confluent tubercles and large knobs near median line. Ventral side and appendages unknown.

Only one specimen of *T. boylei* (Whiteaves), the only species of the genus, is known. It was found in reefal strata of the Guelph Formation near Elora, Ontario. The thickened, partly calcareous exoskeleton was particularly adapted to hypersaline conditions.

### *Eurypterus* DeKay, 1825 Figs. 3–5, 10A–C, E, F, 11–13, 14A, 15C, 18B–D

Prosoma subquadrate with narrow marginal rim, walking limbs differentiated, balancing legs (V) long and narrow, swimming legs (VI) strongly developed, metastoma notched anteriorly. Male genital appendage long. Telson lanceolate.

This genus is represented by the greatest number of well-preserved individuals found in the Bertie Formation of the Fort Erie–Hagersville area of southern Ontario.

### *Dolichopterus* Hall, 1859 Figs. 6A, B, 14B, 15A, B

Like *Eurypterus* but with anterolateral eyes on the prosoma, spinose walking limbs, and swimming legs (VI) with two distal joints forming the paddle. The metastoma is subrectangular and slightly concave anteriorly (Fig. 6A, B). The male genital process

is exceptionally long. Without the prosoma or limbs, specimens of this genus are very difficult to distinguish from *Eurypterus*.

*Buffalopterus* Kjellesvig-Waering and Heubusch, 1962 Fig. 14D

Prosoma wide, without marginal rim; eyes centrally situated; appendages unknown. Telson expanded, circular. Integument of tergites strongly pustulose. The pronounced pustulation of the tergites is the most notable feature of this genus. The telson is also distinctive but is rarely preserved.

*Erieopterus* Kjellesvig-Waering, 1958

Prosoma rounded, wide, with rim of varying width; eyes small; walking limbs undifferentiated; swimming legs (VI) broad, strongly developed. Telson lanceolate. Ventral side poorly known. Integument smooth or slightly pustulose.

Ciurca (1982) reports *E. microphthalmus* (Hall) from strata near Hagersville and Cayuga, Ontario. The present authors are not familiar with specimens of this genus from Ontario.

*Kokomopterus* Kjellesvig-Waering, 1966 Figs. 7C, 2O

Small size, prosoma subquadrate, eyes arcuate and anteriorly located. Ventral shield of prosoma bandlike and lacking an epistoma; metastoma broadly pyriform, very wide posteriorly and notched anteriorly. Walking appendages long, spiny, terminating in a single spine. Abdomen narrow, little differentiated into a preabdomen of seven segments and postabdomen of five. Telson narrow, spinelike.

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Fig. 9 Stratigraphic distribution of eurypterids in southern Ontario.

Fig. 10 A *Eurypterus remipes lacustris* Harlan

Dorsal view of an immature moult; Bertie Formation, Erie County, New York;  $\times 1.32$ ; UMMP 62638.

B *Eurypterus remipes lacustris* Harlan

Dorsal view of a prosoma; Bertie Formation, Lot 5, Concession 10, Bertie Township, Welland County, Ontario;  $\times 0.97$ ; gsc 13989.

C *Eurypterus remipes lacustris* Harlan

Dorsal view of a more mature individual than A; Bertie Formation, Fort Erie, Ontario;  $\times 1.05$ ; UMMP 62579.

D *Pterygotus* sp.

Integument, probably from an abdominal segment; Bertie Formation, Port Colborne, Ontario;  $\times 1.36$ ; UMMP 62605.

E *Eurypterus remipes lacustris* Harlan

Dorsal view of a prosoma; Bertie Formation, Ridge Road, near Ridgemount, Bertie Township, Welland County, Ontario;  $\times 0.96$ ; ROM 36296.

F *Eurypterus remipes lacustris* Harlan

Dorsal view of a complete, immature individual intermediate in moult stage between A and C above; Bertie Formation, Erie County, New York;  $\times 1.33$ ; UMMP 62635.

Fig. 11 *Eurypterus remipes lacustris* Harlan

Dorsal view of a large specimen showing parts of appendages III–VI and the two



parallel rows of mid-dorsal pustules crossing the tergites; Bertie Formation, Lot 5, Concession 10, Bertie Township, Welland County, Ontario;  $\times 1$ ; gsc 3224e.

Fig. 12 *Eurypterus remipes lacustris* Harlan

- A Dorsal view of nearly complete specimen; Bertie Formation, quarry behind Ridgeway, Welland County, Ontario;  $\times 0.94$ ; gsc 13995.
- B Dorsal view of immature specimen; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Welland County, Ontario;  $\times 1.88$ ; ROM 39334.
- C Dorsal view of prosoma and four preabdominal segments of an immature specimen; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Welland County, Ontario;  $\times 5.76$ ; ROM 39333.
- D Lateral view of uncompressed specimen (preabdominal and postabdominal segments XI(?)–XVIII); Bertie Formation, Campbell Quarry, Lot 8, Concession 7, Bertie Township, Welland County, Ontario;  $\times 0.95$ ; gsc 24837.

Fig. 13 *Eurypterus remipes lacustris* Harlan

- A Posterior segments XIV (part)–XVIII, and telson; Bertie Formation, Lot 4, Concession 10, Bertie Township, Welland County, Ontario;  $\times 1.15$ ; gsc 13990.
- B Dorsal view of nearly complete specimen; Bertie Formation, Lot 5, Concession 10, Bertie Township, Welland County, Ontario;  $\times 0.88$ ; gsc 3224c.

Fig. 14 A *Eurypterus remipes lacustris* Harlan

Ventral view of an excellently preserved male specimen showing the spinose nature of the anterior appendages, jointed paddle appendages (VI), ovate metastoma, and long genital appendage; Bertie Formation, Fort Erie, Ontario;  $\times 0.87$ ; UMMP 62582A.

B *Dolichopterus siluriceps*? Clarke and Ruedemann

Dorsal view of a prosoma with anterolateral eye position; Bertie Formation, Erie County, New York;  $\times 0.70$ ; UMMP 62645B.

C *Carcinosa*? sp.

Curved telson; Bertie Formation, Port Colborne, Ontario;  $\times 1.56$ ; UMMP 62600.

D *Buffalopterus* cf. *pustulosus* (Hall)

Abdominal segment showing the pustulose ornamentation from which the species name is derived; Bertie Formation, CNR tracks, Fort Erie, Bertie Township, Welland County, Ontario;  $\times 1.74$ ; ROM 35671.

Fig. 15 A *Dolichopterus macrocheirus* Hall

Ventral view of a female(?) specimen showing the spinose appendages II–IV, balancing appendage (V), and multijointed paddle appendage (VI); Bertie Formation, Erie County, New York;  $\times 1$ ; UMMP 62648.

B *Dolichopterus* cf. *macrocheirus* Hall

Metastoma showing the slight anterior indentation and posterior truncation typical of *D. macrocheirus*; Bertie Formation, Erie County, New York;  $\times 1.4$ ; UMMP 62642.

C *Eurypterus remipes lacustris* Harlan

Female (above) and male specimens; both are preserved in living position but, in both, the carbonaceous integument comprising the abdominal segments has broken away revealing impressions of the ventral sternites; Bertie Formation, Lot 5, Concession 10, Bertie Township, Welland County, Ontario;  $\times 0.5$ ; gsc 13987, 13987a.

D *Tyloptarella boylei* (Whiteaves)

Cast of only known specimen; Guelph Formation, Elora, Ontario;  $\times 1$ ; gsc 2910.

- Fig. 16 *Pterygotus (Acutiramus) macrophthalmus cummingsi* (Grote and Pitt)  
 Refer to Figure 7A, B for dorsal and ventral reconstructions of this species.
- A Integument showing scalelike ornamentation; Bertie Formation, Port Colborne, Ontario;  $\times$  1.35; UMMP 62605.
  - B Metastoma, showing the semiovate shape; Bertie Formation, Fort Erie, Ontario;  $\times$  1.36; UMMP 62581.
  - C Elongate walking appendage; Bertie Formation, Port Colborne, Ontario;  $\times$  1.35; UMMP 62606.
  - D, E Portions of the chelate chelicera (appendage I); Bertie Formation, Port Colborne, Ontario;  $\times$  1.72; UMMP 62602A, B.
  - F Coxa of appendage VI, showing toothed portion (on left) that lies immediately adjacent to the mouth; Bertie Formation, Port Colborne, Ontario;  $\times$  0.77; UMMP 62604.
  - G Expanded "leaflike" telson in dorsal view; Bertie Formation, North Buffalo, New York;  $\times$  0.96; gsc 13991.
  - H Chela and segments of the chelicera (appendage I); Bertie Formation, Clarence Center, Erie County, New York;  $\times$  1.35; UMMP 62801.

Fig. 17 Reconstructed ventral view of *Carcinosoma libertyi* Copeland and Bolton (from Geological Survey of Canada Bulletin 60,  $\times$  ca 2).

- Fig. 18 A *Carcinosoma libertyi* Copeland and Bolton  
 Ventral view of only known specimen; St Edmund Formation, Ontario Highway 540, west of Lake Wolsey, Manitoulin Island, Ontario;  $\times$  0.96; gsc 13984.
- B *Eurypterus remipes lacustris* Harlan  
 Ventral view of a male specimen showing the genital appendage; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Welland County, Ontario;  $\times$  0.97; ROM 35673.
  - C *Eurypterus remipes lacustris* Harlan  
 Ventral view of a presumed female specimen; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Welland County, Ontario;  $\times$  0.97; ROM 35659.
  - D *Eurypterus remipes lacustris* Harlan  
 Dorsal view of a well-preserved specimen lacking the telson; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Welland County, Ontario;  $\times$  0.97; ROM 37836.

Fig. 19 *Carcinosoma* sp. nov.  
 Ventral view of a male specimen showing a semiovate prosoma; a long genital appendage; appendages III; long, forward-directed appendages IV; appendages VI with short paddles; a broad preabdomen with seven segments; a very long, narrow postabdomen with five segments; and the anterior part of telson. Eramosa Member, Amabel Formation, Owen Sound Ledgerock Limited quarry, ca 5 km (3 miles) west of Wiarton, lat. 44°45'10"N, long. 81°11'40"W, Ontario;  $\times$  0.43; H. E. Stobbe collection.

Fig. 20 *Kokomopterus* sp. nov.  
 Ventral view of a male specimen showing a subquadrate prosoma wider than long, an anteriorly located eye, long appendages III–VI, narrower preabdominal and stubbier postabdominal segments than in younger *K. longicaudatus* (Clarke and Ruedemann), and a long narrow telson; Eramosa Member, Amabel Formation, Owen Sound Ledgerock Limited quarry, ca 12 km (7 miles) northwest of Owen Sound, lat. 44°37'25"N, long. 81°02'40"W, Ontario;  $\times$  0.75; H. E. Stobbe collection.

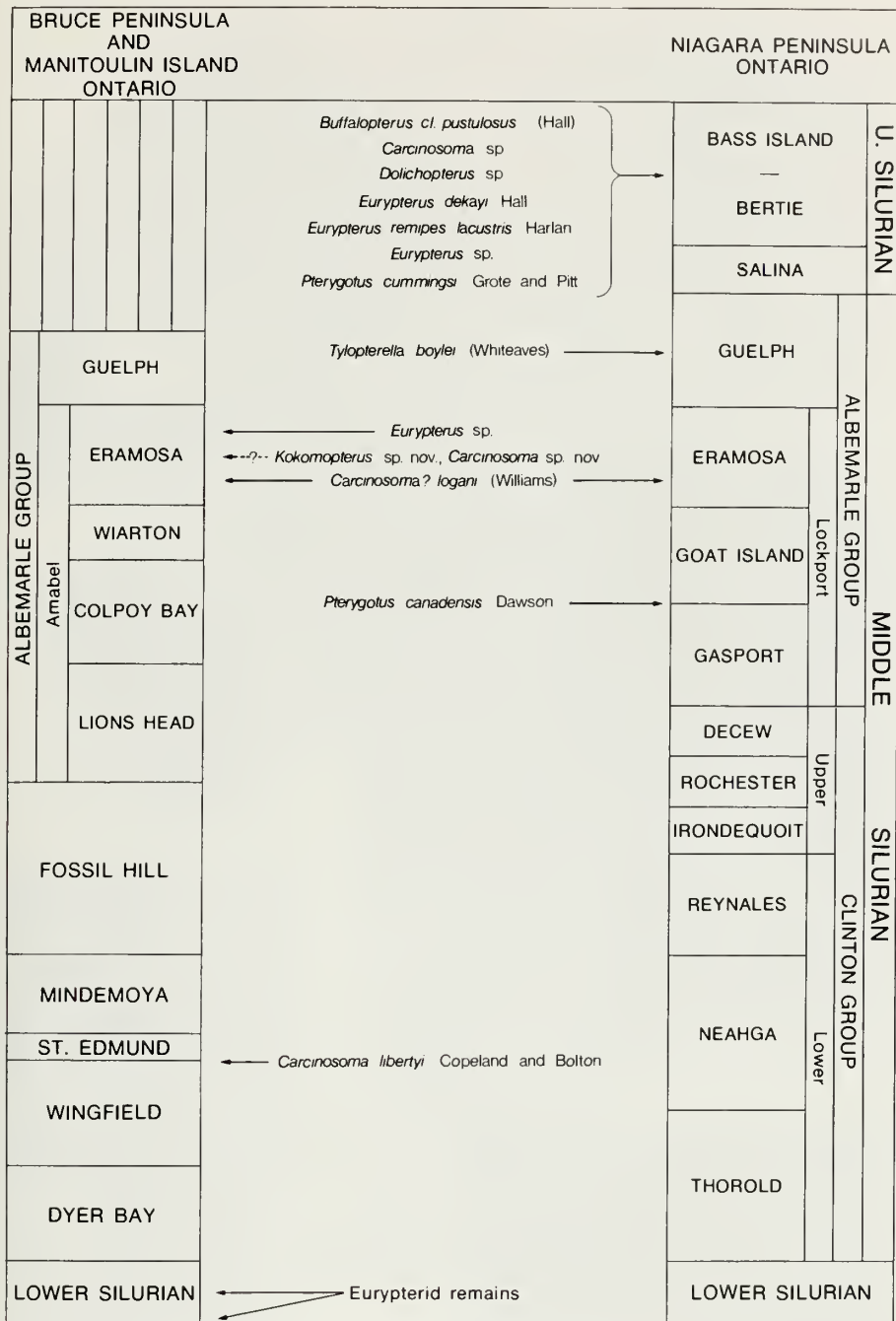
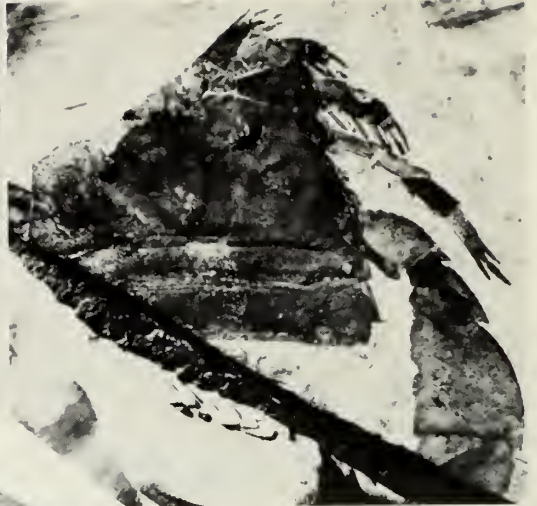


Fig. 9 Stratigraphic distribution of eurypterids in southern Ontario.



**A**



**B**



**C**



**D**



**E**



**F**

Fig. 10 *Eurypterus remipes lacustris* Harlan; *Pterygotus* sp.



Fig. 11 *Eurypterus remipes lacustris* Harlan.

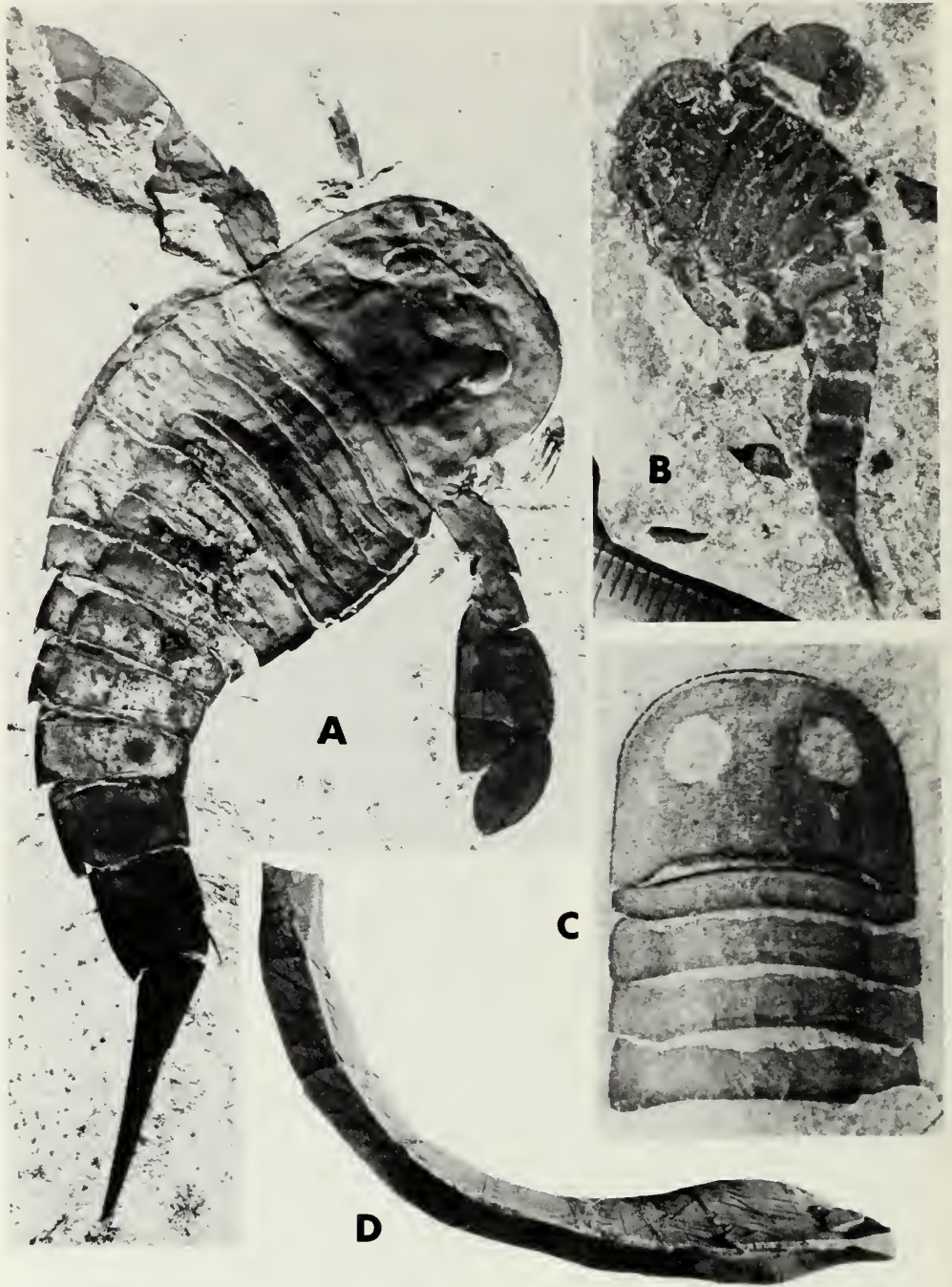


Fig. 12 *Eurypterus remipes lacustris* Harlan.

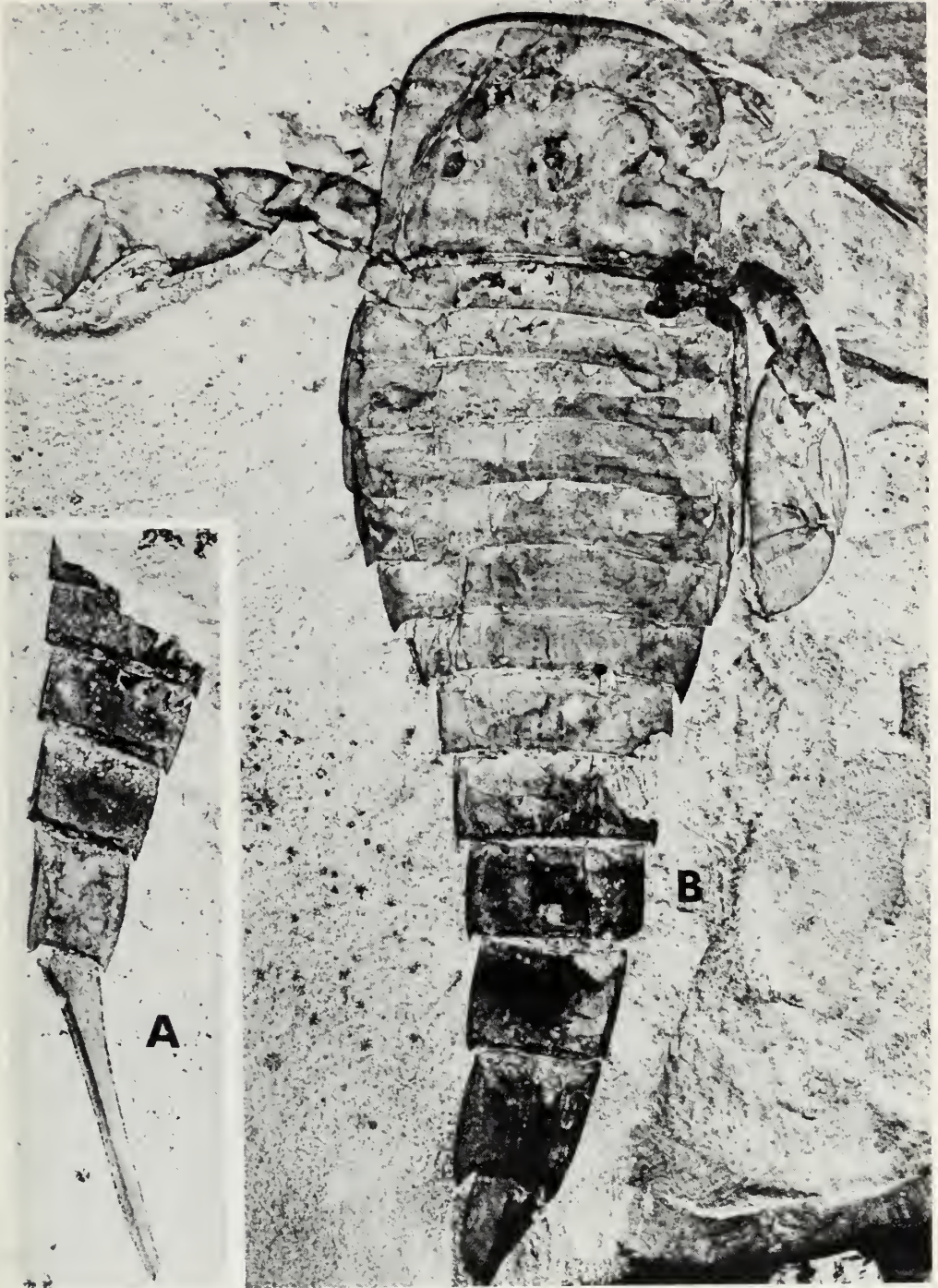


Fig. 13 *Eurypterus remipes lacustris* Harlan.

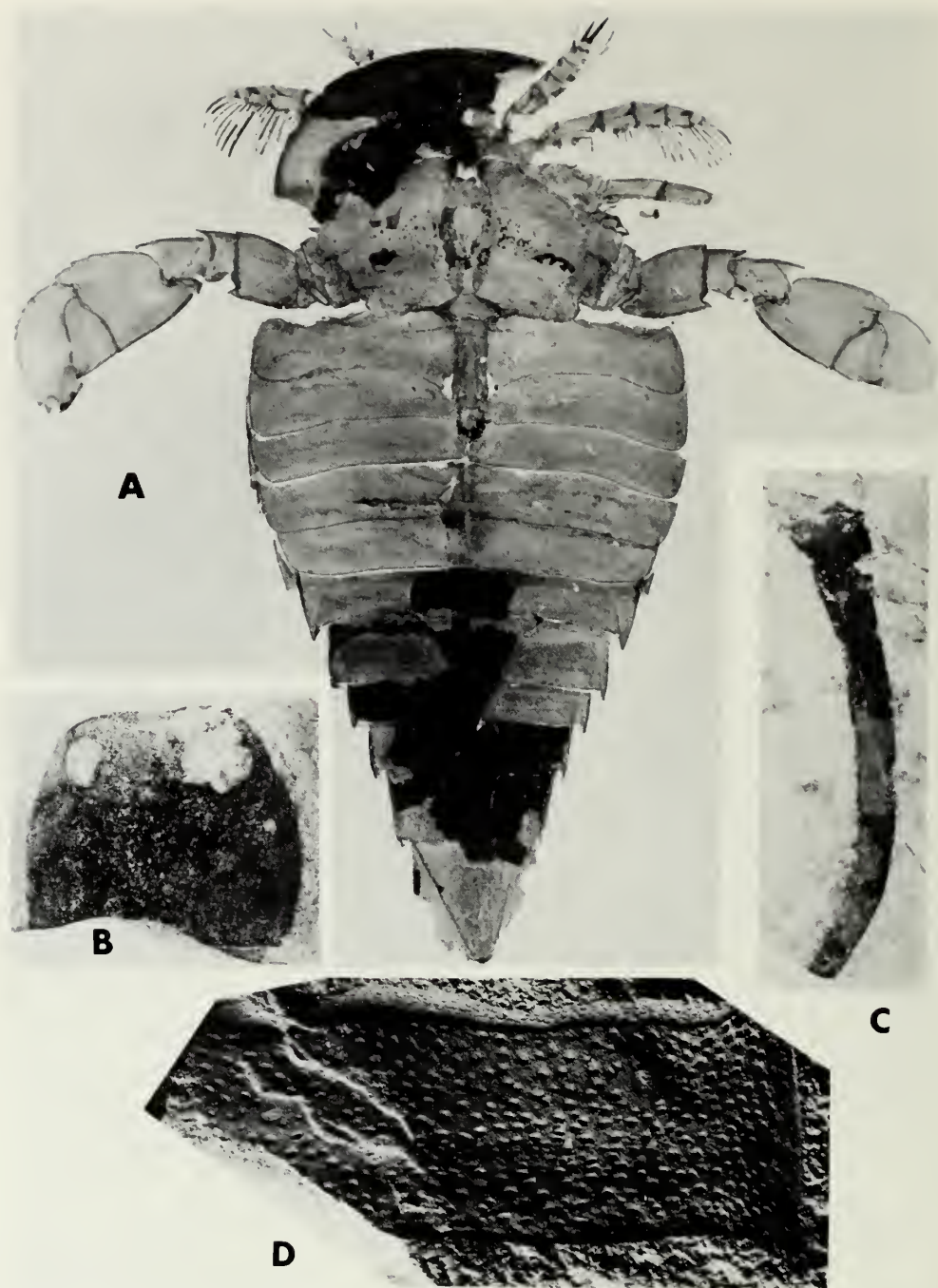


Fig. 14 Four eurypterid genera.



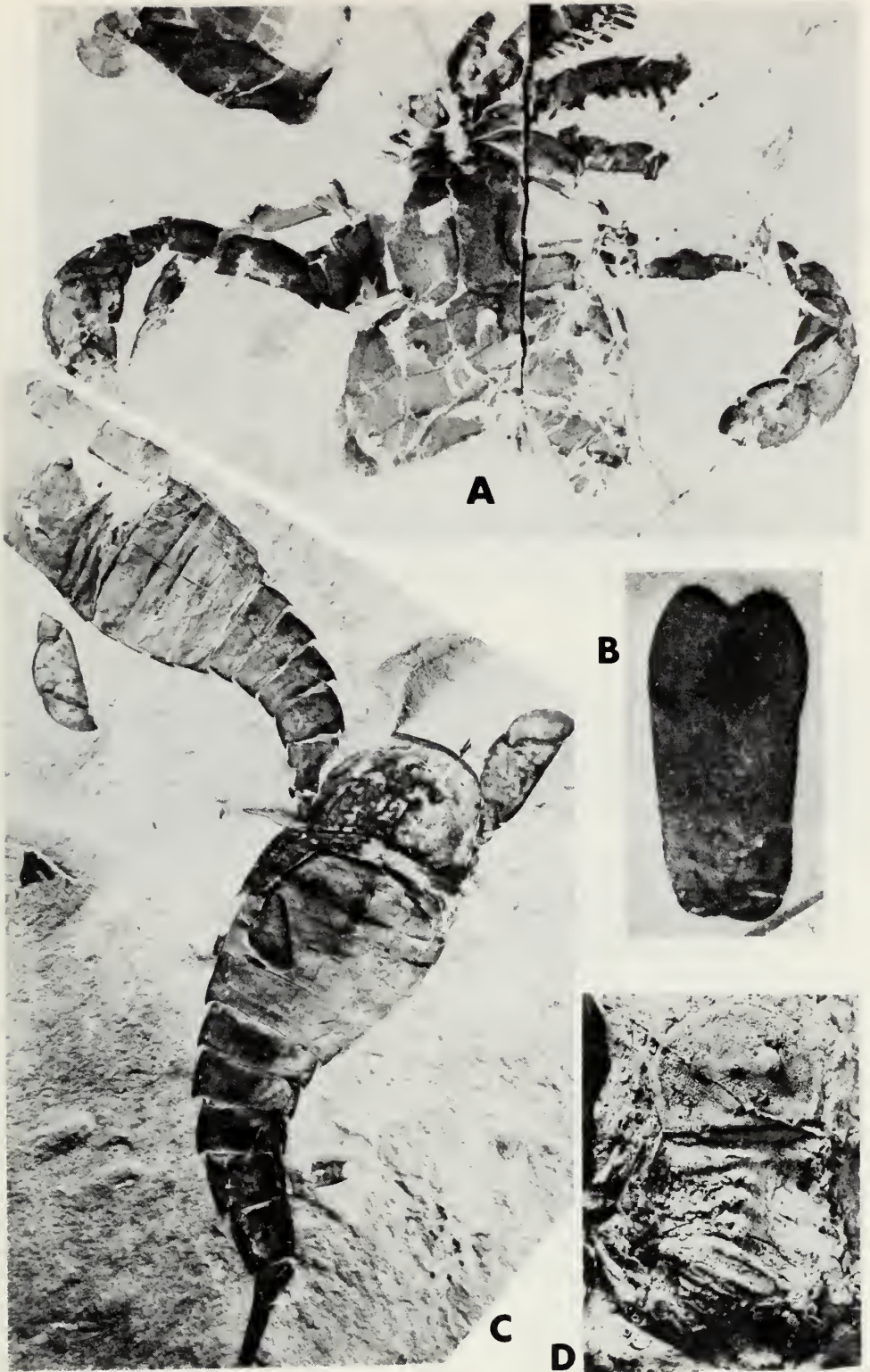


Fig. 15 Three eurypterid genera.

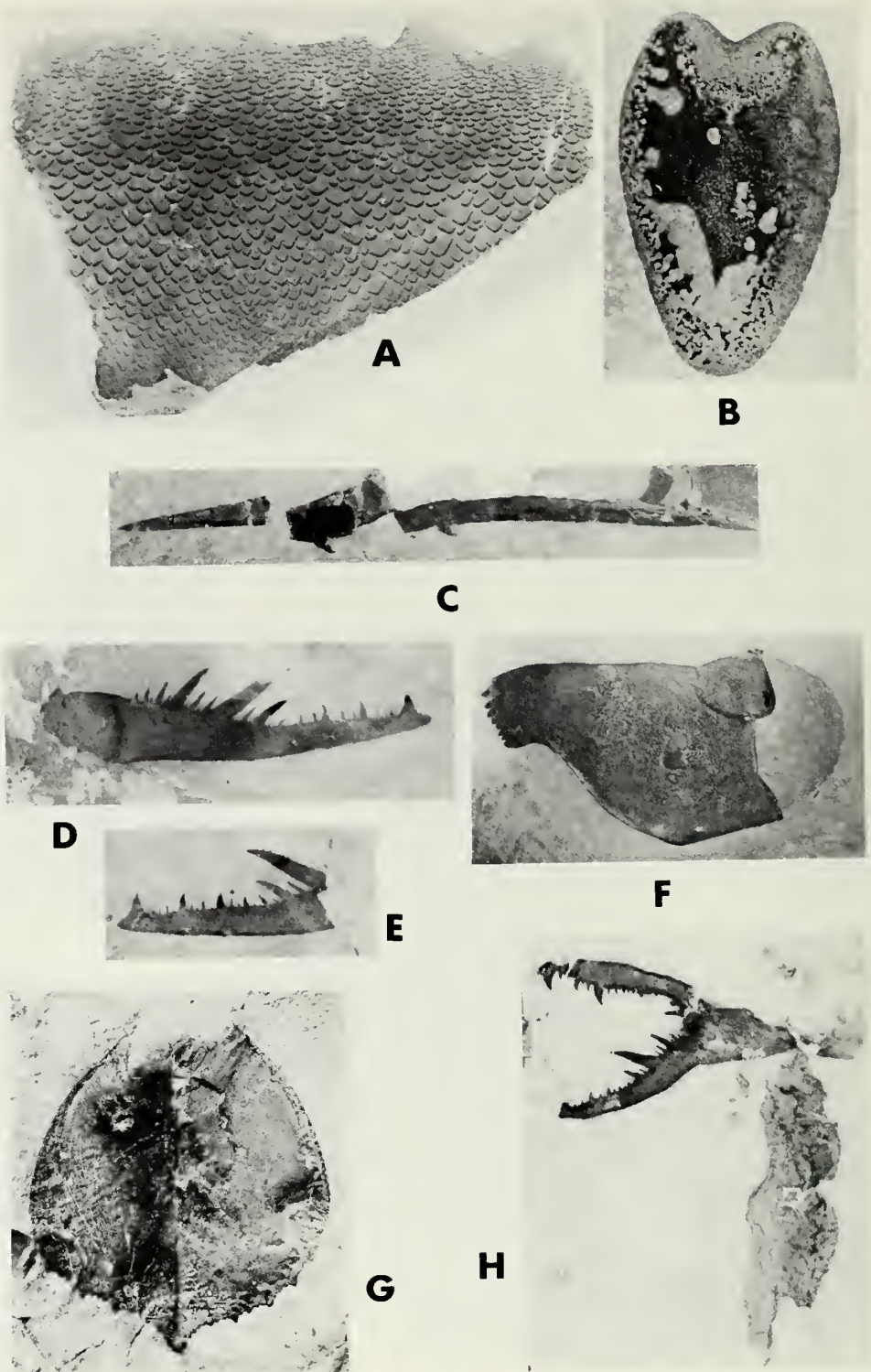


Fig. 16 *Pterygotus (Acutiramus) macrophthalmus cummingsi* (Grote and Pitt).

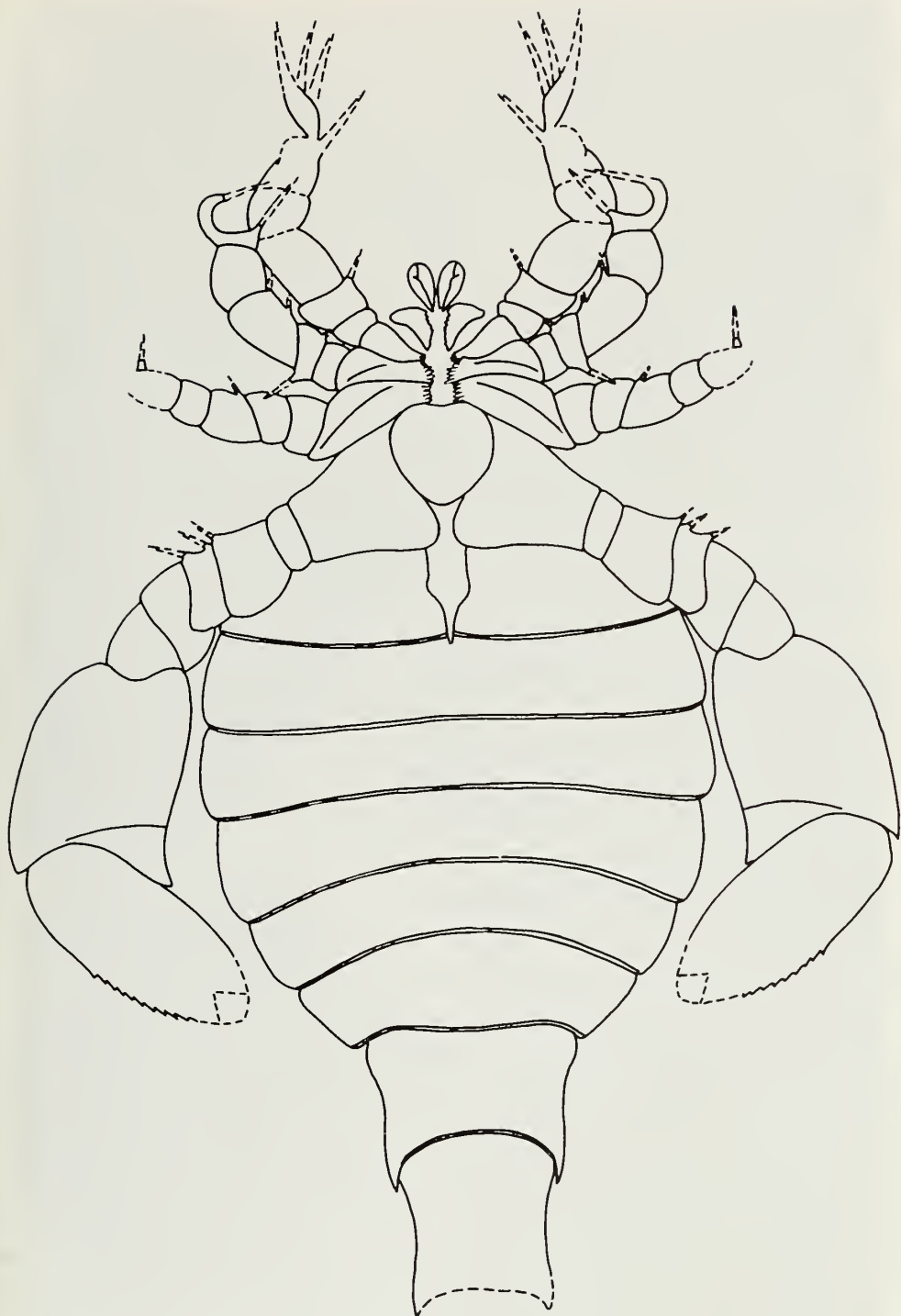


Fig. 17 *Carcinosoma libertyi* Copeland and Bolton.

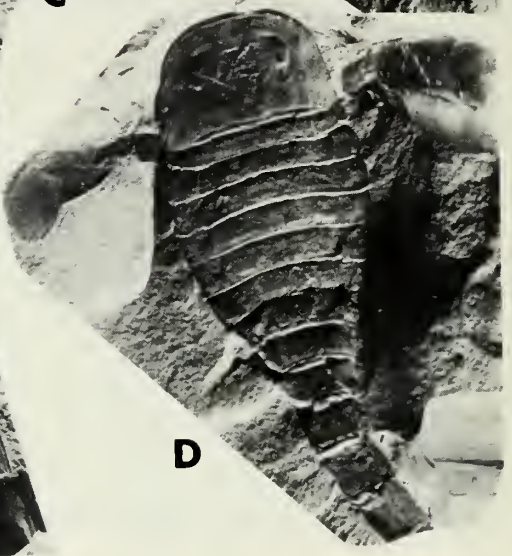
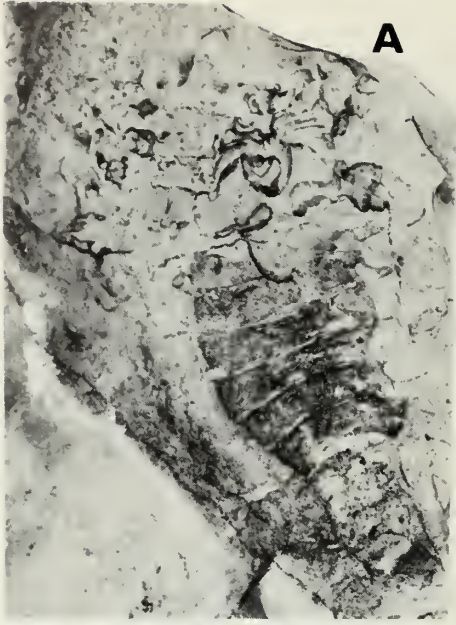


Fig. 18 Two eurypterid genera.



Fig. 19 *Carcinosoma* sp. nov.



Fig. 20 *Kokomopterus* sp. nov.

## Occurrence of Silurian and Devonian Eurypterids in Southern Ontario

The greatest number of well-preserved eurypterids from Ontario have been found in the Upper Silurian Bertie Formation (Fig. 9). In recent years, however, occasional specimens have been obtained from various localities, in beds much lower in the Silurian sequence. The oldest eurypterid fragments are from a shaly dolomitic bed 15 cm above the Ordovician-Silurian contact exposed in a quarry off Ontario Highway 540, west of Kagawong, Manitoulin Island (loc. 5, Fig. 1).

With the exception of some telson spines? and appendage markings from the Manitoulin dolomite of Manitoulin Island, no other identifiable eurypterid remains have been reported from the Ontario Lower Silurian Cataract or the Middle Silurian Clinton strata of the Niagara Peninsula. The known distribution of Middle Silurian eurypterids has been extended, however, with the discovery on Manitoulin Island of a well-preserved specimen of *Carcinosoma libertyi* Copeland and Bolton (Figs. 17, 18A). This specimen was collected from the basal beds of the St Edmund Formation exposed on the south side of Ontario Highway 540, just west of Lake Wolsey, Manitoulin Island (loc. 6, Fig. 1).

Eurypterid remains are more abundant in the upper Middle Silurian strata of Ontario. Fragments of *Pterygotus canadensis* Dawson were collected from the Corporation quarry of the city of Hamilton, in the lower cherty beds of the Niagara limestone and associated with a large conulariid and graptolites. At this locality (loc. 2, Fig. 1) the Ancaster chert beds form the basal unit of the Goat Island Member of the Lockport Formation (Bolton, 1958, p. 49). Sponges, graptolites, and brachiopods are abundant in these chert beds. All of these eurypterid fragments appear to belong to the genus *Pterygotus* because of their large size and semilunate scales.

Fragments of eurypterids are widely distributed in the Eramosa Member of the Lockport and Amabel formations (loc. 3, Fig. 1; Fig. 9). This member consists principally of thick-to-thin-bedded, dark brown to black and grey, fine-grained bituminous dolomite and represents a transitional inter-reef facies deposited during late Lockport-Amabel and early Guelph sedimentation. Brachiopods and cephalopods are commonly associated with the eurypterid remains. *Carcinosoma?* (*Eusarcus*) *logani* was described by Williams (1915) from poorly preserved fragments collected south of Eramosa, Ontario. Somewhat similar fragments have since been discovered in the upper beds of the Eramosa Member exposed west of Warton and near Sky Lake on the Bruce Peninsula. It is difficult to determine to what genus of Eurypterida these fragments should be assigned. The presence of eurypterids in the Eramosa was verified by the discovery of a poorly preserved specimen of the genus *Eurypterus* in the bituminous beds underlying the Guelph Formation at Cook's quarry west of Warton. This specimen (GSC hypotype 15380), 18 cm long, lacks only the telson and appendages. In addition, a well-preserved specimen of the genus *Carcinosoma* has been collected from a quarry west of Warton (Fig. 19), and a stylonurid of the genus *Kokomopter* from a quarry northwest of Owen Sound (Fig. 20). *Tylopterella boylei* (Whiteaves) (Fig. 15D), which is represented by one well-preserved specimen collected from the buff, porous Guelph Formation exposed at Elora, Ontario (loc. 4, Fig. 1), completes the Middle Silurian record of Eurypterida in Ontario.

The Upper Silurian Bertie eurypterid fauna of western New York State and the adjacent part of Ontario has been the subject of numerous studies (Clarke and

Ruedemann, 1912; O'Connell, 1916; Williams, 1919). The fauna figured in this paper, collected from the grey, fine-grained, finely laminated upper Bertie Formation exposed near Fort Erie and Port Colborne, Ontario (loc. 1, Fig. 1), consists of *Eurypterus remipes lacustris* Harlan, *Eurypterus dekayi* Hall, *Pterygotus (Acutiramus) macrophthalmus cummingsi* (Grote and Pitt), *Buffalopterus* cf. *pustulosus* (Hall), *Carcinosoma* sp., and *Dolichopterus* sp. The Bertie eurypterids have been demonstrated by the several authors listed above as occurring in two separate geographic localities or "pools". This explanation was necessitated by the apparent lack of strictly comparable species between the "Buffalo" and "Herkimer" eurypterid faunules of New York State. Apparently minor morphological variations between comparable elements of both faunules have given rise to a multiplicity of specific names. Attempted explanation of this speciation has been given by Clarke and Ruedemann (1912, p. 92, footnote 1), O'Connell (1916, pp. 20–21), and Caster and Kjellesvig-Waering (1956, pp. 19–21). The eurypterid fauna from Bertie Township, Ontario, as stated by Clarke and Ruedemann, represents an extension of the "Buffalo" pool, which contains species not present in the "Herkimer" pool. (The above discussion is abstracted and emended from Copeland and Bolton, 1960, pp. 17–19.)

Recently, Ciuca (1982) proposed an eurypterid zonation for late Middle Silurian to Lower Devonian(?) strata of western New York State and the Niagara Peninsula of Ontario. In Ontario he recognized the occurrence in Late Silurian rocks of an *Eurypterus remipes remipes* fauna, overlain by an *Eurypterus remipes lacustris* fauna, which in turn is succeeded by a Lower Devonian(?) *Erieopterus microphthalmus* fauna. Previously, neither *Eurypterus remipes remipes* Dekay nor *Erieopterus microphthalmus* (Hall) had been recorded from Ontario.

Recent findings of large black chitinous fragments bearing loosely aligned pterygotid-like crescentic scales (Fig. 24C) in the Arkona shale of the Hungry Hollow area has extended the eurypterid record into the Middle Devonian of southwestern Ontario.



# The Phyllocarids

Occurring with the *Eurypterus* fauna in the Upper Silurian Bertie Formation of the Niagara Peninsula are large, shrimplike arthropods of the phyllocarid genus *Ceratiocaris* (Figs. 21–23). These bivalved crustaceans are generally referred to as *Ceratiocaris acuminata* Hall (Figs. 22–23), but more than one species may be present. As shown in Figure 21, *Ceratiocaris* bore a large, rostrate carapace covering the anterior two-thirds of the body, with the posterior body segments and trifold terminal segment extended behind the carapace. All specimens are found laterally compressed; few show the carapace associated with the posterior segments, and, to date, limbs have not been reported on any Canadian specimen known to the authors.

The family to which *Ceratiocaris* belongs, the Ceratiocarididae, had much the same time span, that is, Ordovician to Permian(?), as did the eurypterids, and both may be found associated in strata of marine or restricted-marine deposition. Unlike the Permo-Carboniferous eurypterids, however, ceratiocaridids are not presumed to have inhabited a freshwater habitat. In Ontario, *Ceratiocaris* occurs only in Upper Silurian rocks; other species of the genus are found in slightly older Silurian rocks of the Arctic islands (Copeland, 1971).

A second phyllocarid, *Elymocaris hindei*, was described by Jones and Woodward (1894, p. 292) from undifferentiated strata of the Middle Devonian Hamilton Group at Arkona, Lambton County, Ontario (Figs. 24A, B). This genus is somewhat similar to *Ceratiocaris* but bears a dorsal plate separating the valves behind the rostrum. Only the type specimen has been reported to date, and so this species must be considered extremely rare.

The same Middle Devonian beds have produced recently a third phyllocarid, *Echinocaris* sp. (Fig. 25). This genus, within the family Echinocarididae, has a shorter time span than *Ceratiocaris*, ranging from Lower Devonian to Lower Mississippian only. *E. pustulosus* (Hall) is the typical Middle Devonian representative in New York State. A nonrostrate, anterodorsally rounded, carinate carapace with prominent anterodorsal and mid-dorsal tuberculated lobes distinguishes this genus from *Ceratiocaris* and *Elymocaris*.

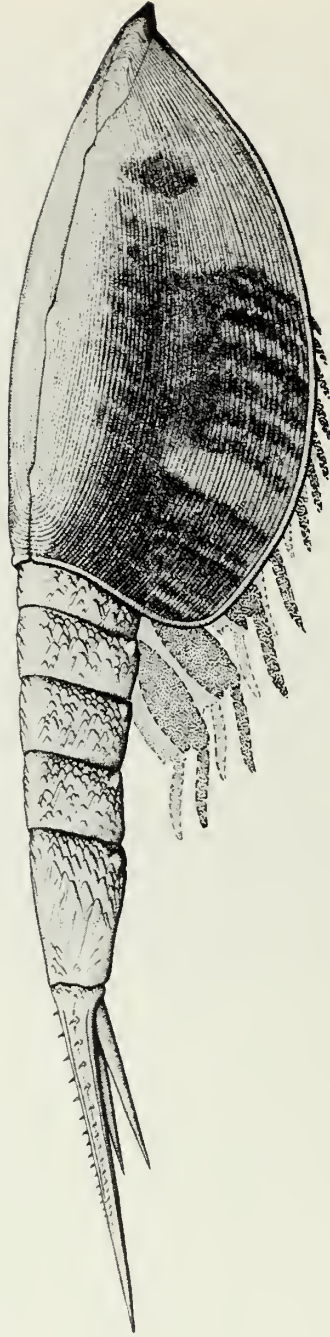


Fig. 21 *Ceratiocaris papilio* Salter in Murchison

Middle Silurian, Scotland; reconstruction ca  $\times 1.62$ , as illustrated in W. D. I. Rolfe, 1962, p. 913. The bivalved, striated carapace (with anterior rostral plate) covers the head, the thorax (of eight segments), and the first two + of the abdominal segments. Abdominal segments 3 to 7, the posterior telson (segment 8), and furcal rami are uncovered. Traces of limbs are visible on some specimens, but their exact nature is uncertain.

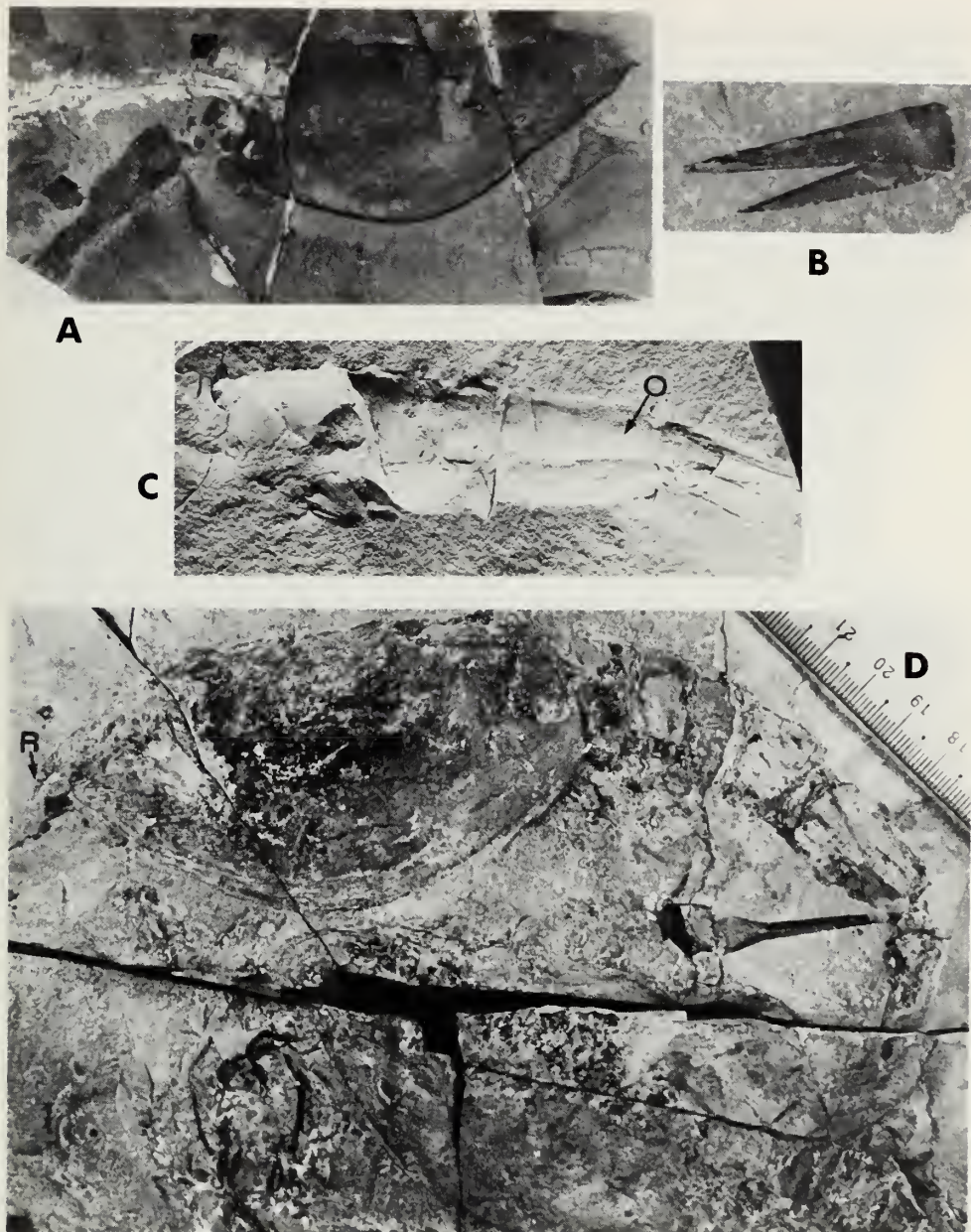


Fig. 22 *Ceratiocaris acuminata* Hall

- A Right view of a carapace with several abdominal segments; Bertie Formation, Erie County, New York;  $\times 0.43$ ; UMMP 62607A.
- B Telson and furcal ramus; Bertie Formation, Fort Erie, Ontario;  $\times 1.07$ ; UMMP 62679.
- C Posterior abdominal segments ornamented (O) by etching out of cuticular prisms on abdominal segment 7; Bertie Formation, Rattlesnake Falls near Cayuga, Haldimand County, Ontario;  $\times 0.86$ ; gsc 3231.
- D Left lateral view of a complete, though indistinct, specimen with well-preserved rostral plate (R); note the associated eurypterid telson; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Welland County, Ontario;  $\times 0.69$ ; ROM 39335.

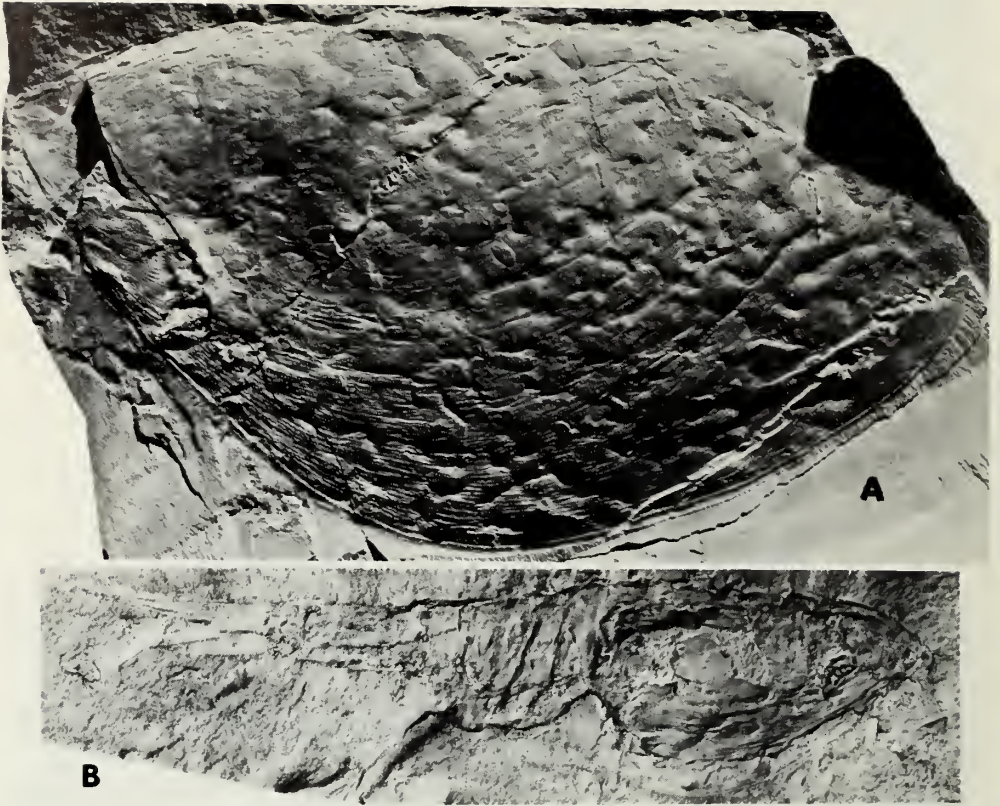


Fig. 23 *Ceratiocaris acuminata* Hall

- A Left lateral view of a very large carapace showing typical longitudinal striations; Bertie Formation, G. C. Campbell Quarry, Ridgemount, Bertie Township, Ontario;  $\times 0.74$ ; ROM 35853.
- B Right lateral view of a complete specimen showing the mandible; Bertie Formation, possibly Bennett quarry, Buffalo, New York;  $\times 0.55$ ; BM 11468/3983. Ceratiocaridid mandibles are frequently found as isolated fossils.

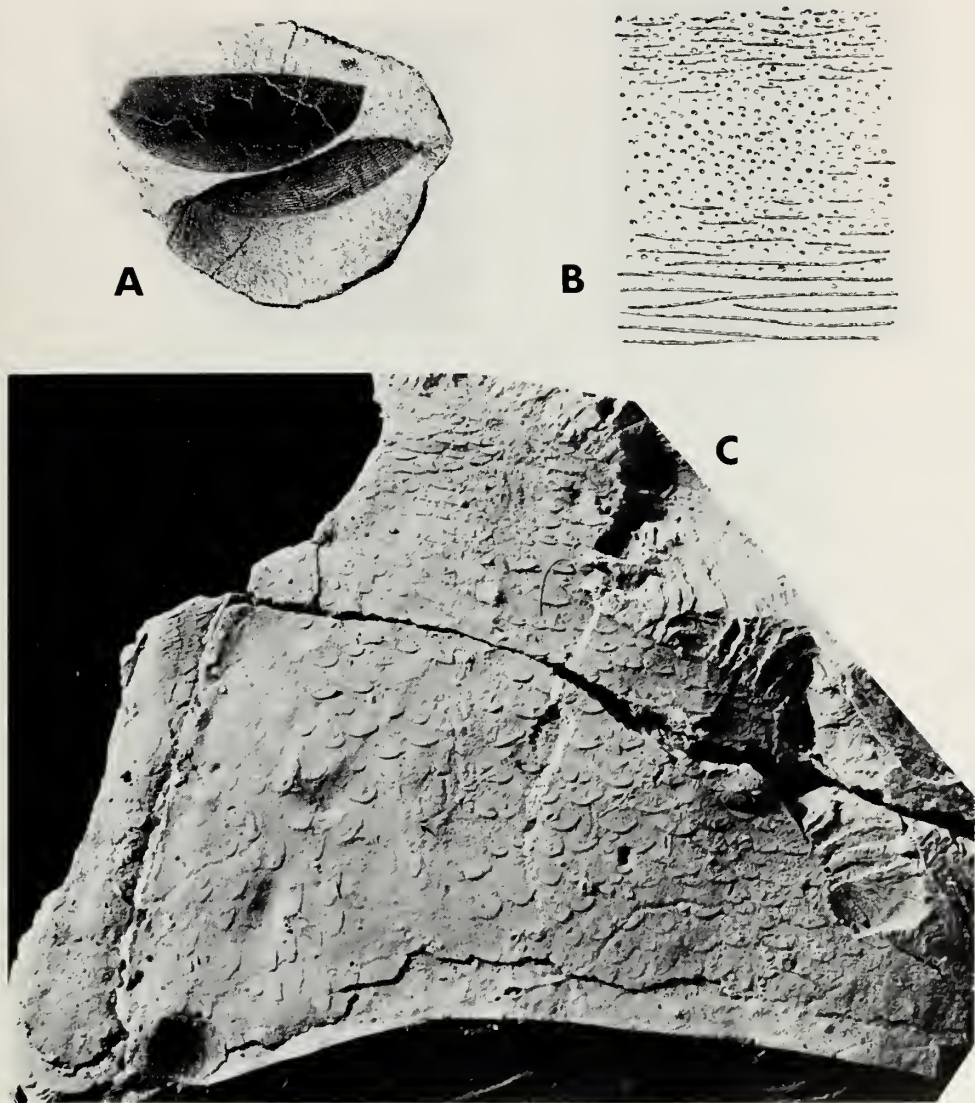


Fig. 24 A, B *Elymocaris hindei* Jones and Woodward

A Reproduction of pl. IX, fig. 7, 1894; Devonian; Arkona, Ontario;  $\times 1.44$ .

B Reproduction of fig. 2, 1894. Ornament on the valve of *Elymocaris hindei*;  $\times 14.65$ .

C Eurypterid genus and species indeterminable.

Large fragment bearing pterygotid-like crescentic scales; Arkona Formation, 0.70–0.76 m (23–25 ft) below top, Hamilton Group, Middle Devonian, east side of Ausable River across from old pit and upstream, Hungry Hollow, Ontario;  $\times 1.16$ ; ROM 43551.

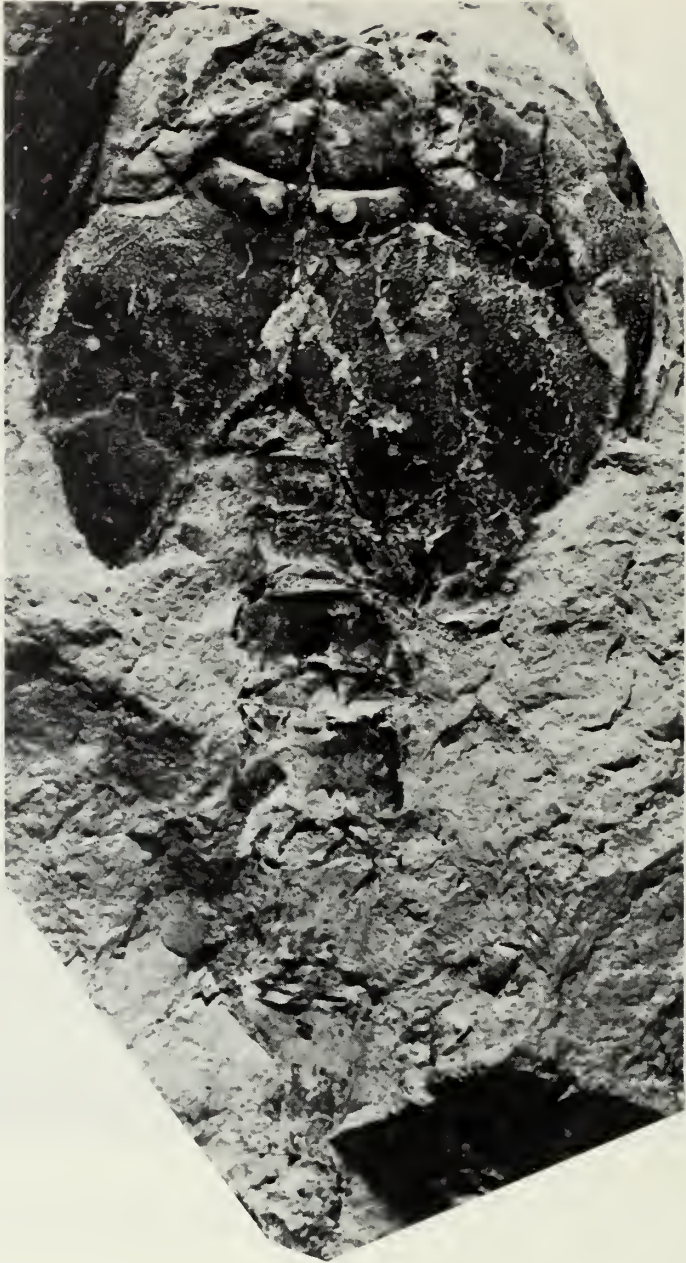


Fig. 25 *Echinocaris* sp.  
Dorsal view of a slightly crushed specimen showing lobed carapace (ventral posterior node lacking tubercle), long hinge, and seven abdominal segments; Arkona Formation, Hamilton Group, Middle Devonian, Hungry Hollow, Ontario;  $\times 2.35$ ; ROM 40262.

# Glossary of Morphological Terms

- carapace** dorsal outer skeletal covering of the prosoma, extending onto ventral side in a narrow inflexed border.
- carina** a ridge or keel-like structure.
- carinate** having a ridge or keel-like structure.
- cerci** pair of appendages projecting from posterior body segment.
- chelate** bearing a pincerlike terminal claw on an appendage.
- chelicerae** preoral appendages modified for piercing or biting, composed of three or four joints, with distal ones forming a pincerlike claw, or chela.
- chitin** inelastic, flexible, hornlike substance found in hard parts of all articulated invertebrates.
- epistoma** median plate on ventral rim of carapace, in front of mouth.
- exoskeleton** resistant, more or less mineralized, chitinous covering of body and appendages.
- integument** outer protective covering of the body.
- lanceolate** a form several times longer than it is wide, broadest towards the base, and narrowed to the apex.
- metasoma** body region consisting of posterior six segments of abdomen and lacking appendages.
- metastoma** plate at posterior side of mouth.
- ocelli** median visual organs located on prosoma.
- operculum** plate adjoining appendages of genital segment.
- postabdomen** narrow, nearly cylindrical part of abdomen consisting of the posterior five segments.
- preabdomen** broad part of abdomen consisting of the anterior seven segments.
- prosoma** forepart of body in front of abdomen.
- rostrate** bearing a rostrum.
- rostrum** anteriorly projecting, unpaired, usually rigid median extension of the carapace between the eyes or eyestalks.
- somite** ring-shaped segment of the body generally covered by a dorsal (tergal) and a ventral (sternal) portion.
- sternite** plate forming ventral cover of somite.
- suture** line of union, or seam, in immovable articulation; consisting of a very narrow, unmineralized band visible on external side of the exoskeleton.
- telson** postanal spine or plate.
- tergite** plate forming dorsal cover of somite.
- tuberculate** bearing small knoblike prominences.
- ventral shield** cuticular elements covering the ventral part of the body.





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