ABSTRACT

WHITEROCKIAN (MIDDLE ORDOVICIAN) GRAPTOLITES OF THE LOWER MEMBER OF THE VININI FORMATION, ROBERTS MOUNTAINS, EUREKA COUNTY, NEVADA

By Erin B Schuster

May 2015

The Ordovician strata of the Lower Member of the Vinini Formation comprise a sequence of greenstone, sandstone, shale, and siltstone representing the prograding and retrograding of submarine fans along the continental margin. Although graptolites are normally preserved within shale beds in the Lower Member of the Vinini Formation, the greatest abundance of well preserved graptolites is found within the sandstone turbidite beds. These graptolites are uniquely preserved in full relief as opposed to being flattened on shale. It is interpreted based on fragmentation and species composition within the sandstone that the graptolites flourished in an upwelling zone on the continental margin and that as their remains accumulated on the underlying seafloor, were swept downslope in turbidity currents.

Graptolites were collected from 10 beds within the stratigraphic section and represent 33 taxa from 17 genera. There are no new taxa. All taxa are described, illustrated, and compared to other collections.

# WHITEROCKIAN (MIDDLE ORDOVICIAN) GRAPTOLITES OF THE LOWER MEMBER OF THE VININI FORMATION, ROBERTS MOUNTAINS, EUREKA COUNTY, NEVADA

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# CHAPTER 1

# INTRODUCTION

Graptolites are a diverse group of marine organisms ranging from the Lower Ordovician to the Lower Devonian. These are divided into graptoloid and dendroid type graptolites. These cosmopolitan organisms are particularly useful for biostratigraphy (Finney and Ethington, 1992) and as environmental indicators because, although they are widespread, they also display vertical and lateral differentiation within the water column (Finney and Berry, 1997). The specimens collected from the Vinini Formation, Roberts Mountains, Nevada are abundant, diverse, and well preserved in full relief in quartzite and quartz arenite beds (Finney and Ethington, 1992). Thus, the Nevada specimens display exceptionally well the morphology of the species, in contrast to documented collections that were preserved as flattened specimens on shale surfaces (Cooper, 1973, 1979; Williams and Stevens, 1988). Graptolite genera are determined based on general morphological characteristics, as opposed to species, which require morphometric measurements for the identification. The graptolite collections from the Lower Member of the Vinini Formation were collected by Dr. Stanley Finney in the course of his research in the area. The purpose of this research is to illustrate and describe all the species collected from the Lower Member of the Vinini Formation. The process by which the graptolites are concentrated in the sandstone beds is considered.

# CHAPTER 2

## GEOLOGIC SETTING

The longest and most complete stratigraphic section of the Vinini Formation is located within the Roberts Mountains, in central Nevada. From the late Cambrian to latest Ordovician, the Vinini Formation was deposited as a succession of greenstone, shale, siltstone, sandstone, chert, and limestone on the sea floor adjacent to the Cordillera margin of Laurentia. During the late Devonian to early Mississippian Antler orogeny, the Vinini Formation, as part of the Roberts Mountain allochthon, was thrust onto coeval carbonate strata deposited on the western shelf of Laurentia (Finney et al., 2007).

The Vinini Formation is separated into informal Lower and Upper Members on the east side of the Roberts Mountains. The Lower Member is composed of a lower black siliceous shale unit 140 m thick and an upper sandstone unit 1832 m thick which consists of quartzite, quartz arenite, quartz wacke, calcareous sandstone, siltstone, shale, limestone, and rare chert and conglomerate (Finney and Perry, 1991). Within the upper sandstone unit, the sandstones, siltstones, and shales occur in nearly equal proportions. The shale outcrops are usually sparse, occurring in thin intervals (2-10 cm thick) between much thicker sandstone beds, and are only exposed after excavation. The shale is primarily black, or light brown when silty (Finney and Perry, 1991).

The base of the Lower Member on the west side of the Roberts Mountains is bounded by a thrust fault overlain by a channel of greenstone, including flows, flow breccias, and volcaniclastics, 10 m deep and 20 m wide. This channel is located with a sandstone bed and is filled with angular vesicular blocks 10-50 cm in diameter which float in volcanogenic sandstone matrix (Finney and Perry, 1991). The sandstone occurs in three roughly fining upward sequences with irregular bottoms. These are thought to be slope deposits on the flanks of seamounts. The presence of the greenstone within the sandstone provides evidence that the submarine fans encroached on the seamounts, prograding into the basin (Finney and Perry, 1991). Graptolites were collected from one of these fining upward sequences in three different collections, collections 92SF-16, 92SF-11, and 92SF-13 (Fig. 1).

The base of the Lower Member on the east side of the Roberts Mountains is also bounded by a thrust fault, but there is no greenstone. The east side is the longest exposed section of the Vinini Formation showing the characteristic alternation between sandstone and shale and siltstone. Collections 88MM-4, 88BP-5, 89BP-10, 87SF-10, 87SF-69, and 87SF-70 came from this section. A final locality to the north is an isolated sandstone outcrop, collection 87SF-1, correlated to collection 87SF-70 (Fig. 1).

The sandstone beds include nearly pure quartzites and quartz arenites with little matrix, matrix-supported quartz wackes with a clay matrix, and calcareous sandstones containing quartz grains in a micrite or sparite matrix (Finney and Perry, 1991). Bedding varies in thickness from 5 cm to 3 m, but averages 10-30 cm. Thick beds (1-3 m) form ledges ranging in length from a few tens to several hundred meters along strike before

pinching out abruptly. Sedimentary structures include cross-bedding, graded beds, parallel lamination, and flute casts. However, many of the sandstone beds are massive and lack these structures due to the sandstone being very well sorted.

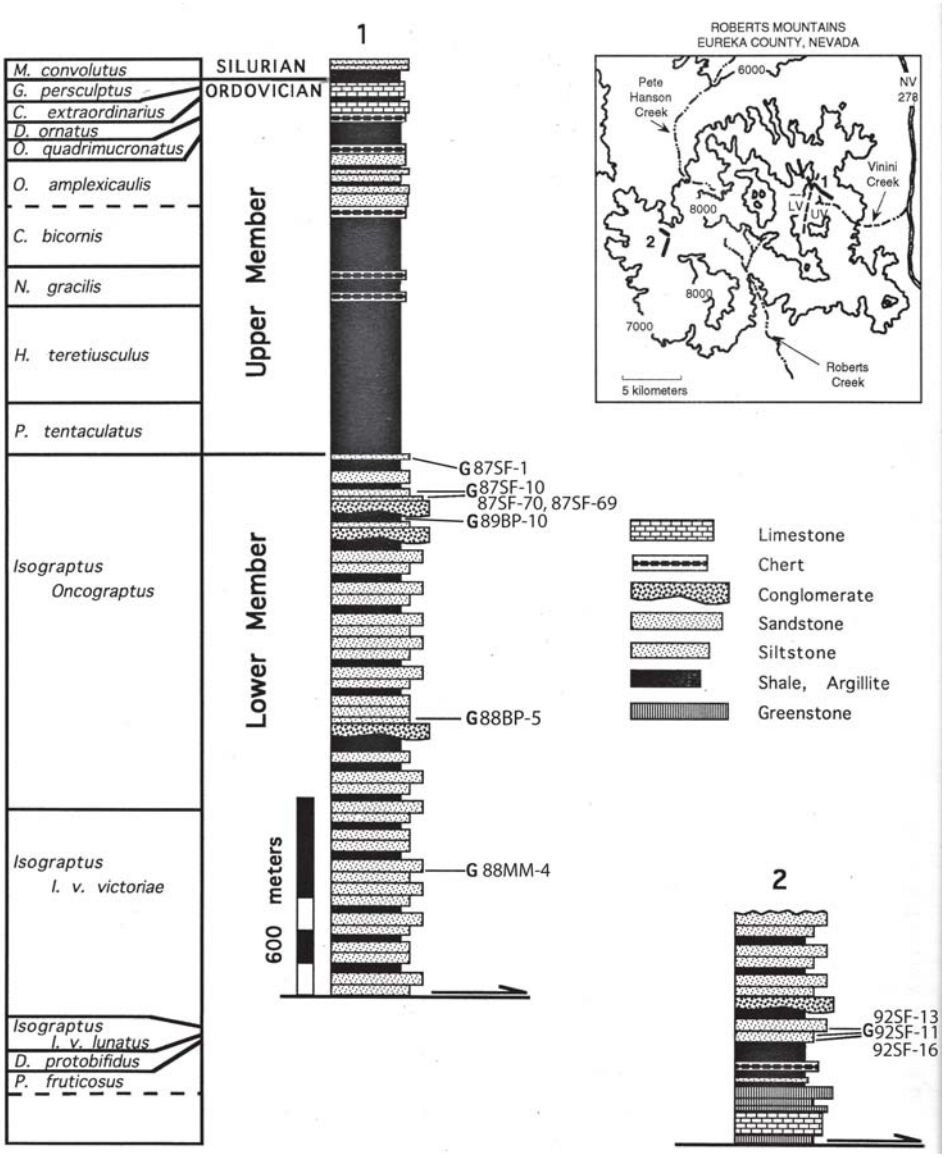



FIGURE 1. Stratigraphic column of the Vinini Formation in the Roberts Mountains showing collection levels. Modified from Ethington et al. (1995, Fig. 18).

With few exceptions, all the sandstones are dark colored, brown to gray (Finney and Perry, 1991). Graptolites were found only in a few beds of the calcareous sandstone. However, where they were found, the graptolites were abundant and well preserved.

Within the Lower Member, graptolites occur sporadically in the sandstone interval, and the shale yielded few species. However, three of the sandstone beds (collections 87 SF-1, 87 SF-70, 88 BP-5) contain unusually well preserved and abundant graptolite specimens, representing the isograptid fauna. Collections 88 BP-5 and 87 SF-70 are from 899 m and 1750 m above the base of a long exposure of the Lower Member of the Vinini Formation located along Vinini Creek on the east side of the Roberts Mountains (Fig. 1). Collection 87 SF-1 is from an outcrop of the Vinini located in Gable Canyon on the north side of the Roberts Mountains; it correlates with the uppermost part of the Lower Member (collection 87SF-70) in the measured section (Finney and Ethington, 1992). These collections occur as thin intervals within beds of medium thickness, all of which are quartz wackes composed of medium to coarse, well-rounded, well-sorted quartz grains suspended in a calcareous or clay matrix (Finney and Ethington, 1992). Additional collections were made at 27 m, 56 m, 60 m, and 420 m in the stratigraphic section, as well as a shale collection at 1720 m. These were collections 92SF-16, 92SF-11, 92SF-13, 88MM-4, and 89BP-10, respectively. Collections 87SF-69 and 87SF-10 were collected at the same stratigraphic height as collection 87SF-70 (Finney, personal communication).

Within the stratigraphic section the appearance of the sandstone beds is episodic (Finney et al., 2000), recording the initially prograding, then retrograding conditions in

submarine fan deposits on the continental slope (Finney and Ethington, 1992). These beds are characteristic of partial (ab, abc, or bc) to complete a-d Bouma turbidites (Finney and Perry, 1991). The majority of the quartz and calcite grains that comprise the Lower Member were derived from emergent and shallow-shelf, respectively. The quartzites and quartz arenites that comprise the Lower Member are composed of medium- to coarse-grained , well-sorted, well-rounded quartz grains with abraded overgrowth rims and undulose extinction. This indicates quartz with a plutonic or metamorphic origin that has been reworked (Finney and Perry, 1991). In addition, the calcareous sandstones are composed of well rounded quartz grains, skeletal debris, ooliths, and peloids with a matrix of micrite and illite clay. The skeletal grains include ostracods, trilobites, brachiopods, echinoderms, and sponge spicules all of which are common in coeval shelfal strata of the miogeoclinal suite (Finney and Perry, 1991).

The interbedded siltstone and shale between the sandstone beds suggests that the sandstone was deposited as a turbidity flow. While quartzite and quartz arenite is the dominant lithology in much of the Lower Member, in some parts of the section quartz wacke and calcareous sandstone are also common (Finney and Perry, 1991). The quartzite and quartz arenite are massive to horizontally stratified, but rarely cross stratified, while the beds of quartz wacke and calcareous sandstone have both types of stratification, with horizontal stratification in the lower part of a bed replaced by cross stratification in the upper part of the bed (Finney and Perry, 1991). Bedding within the sandstones gradually thickens to as much as 3 m upsection. Within several outcrops there is a gradational change from massive, coarse quartzite to cross-bedded, finer grained

calcareous sandstones capped by thinly bedded mudstone, which represent complete turbidites. However, most of the turbidites have sharp contacts, separated by 2-30 cm of shale beds (Finney and Perry, 1991). Flute and groove casts are present on the sole of the turbidite sandstone beds. The turbidites coarsen and thicken upsection and are interbedded with what is suggested to be shale of pelagic origin, suggesting that the section was deposited during an interval of sea fan progradation, from a lower fan to an upper mid fan or upper fan environment (Finney and Perry, 1991). After this interval, above 900 m, the bed thickness decreases, becoming more uniform, with the fewer thick massive beds being able to be traced laterally instead of pinching out. This suggests that the sands were no longer confined to channels, the channels were instead filled and abandoned and the sands spread across the surface of the fan (Finney and Perry, 1991).

The uppermost 75 m of the sandstone interval is fine grained and grades into the Upper Member. The highest sandstone bed is 100 m below the top of the Lower Member. Upsection, the sandstone beds decrease in thickness and abundance; siltstone and shale begin to dominate the lithology. Due to weathering of the shale, the siltstone is more prominent in the float (Finney and Perry, 1991). The siltstone beds are of uniform thickness, finely laminated, with abundant trace fossils, but decrease in thickness upsection as the intervals of shale between the siltstone beds thicken. It is thought that these shales and siltstones represent flooding of the Laurentia platform and the shutoff of sand transport to the continental rise and adjacent ocean floor (Finney et al., 2007). The base of the Upper Member is placed at the top of the highest siltstone bed, located at 1832 m in the measured section (Finney and Perry, 1991).

# CHAPTER 3

## NATURE OF GRAPTOLITE COLLECTION

The graptolites from the Lower Member of the Vinini Formation are preserved in both sandstone and shale beds. However, graptolites have rarely been collected from sandstone before; generally they are preserved as flattened carbon films on shale surfaces. Within the Lower Member, the majority of the graptolites were collected from sandstone beds (collections 92SF-16, 92SF-11, 92SF-13, 88MM-4, 88BP-5, 87SF-10, 87SF-69, 87SF-70, and 87SF-1), with only four of the 33 species coming from shale (collection 89BP-10). The specimens from the shale bed represent *Didymograptus extensus*, *Xiphograptus svalbardensis*, *Pseudisograptus gracilis*, and *Isograptus victoriae* sp. With the exception of *D. extensus* and *I. victoriae* sp., all of the species found in shale beds are also found in sandstone beds (Fig. 2).

The graptolites were collected by Dr. Stanley Finney over the course of his research and come from both the east and west sides of the Roberts Mountains and range through the measured section. Collections 92SF-16, 92SF-11, and 92SF-13 were collected from the east side of the Roberts Mountains at 27 m, 56 m, and 60 m in the stratigraphic section, respectively. Collections 88MM-4, 88BP-5, 89BP-10, and 87SF-70 were collected from the west side of the Roberts Mountain at 420 m, 899 m, 1720 m, and 1750 m in the stratigraphic section, respectively. Collections 87SF-69 and 87SF-10 were

| Graptolite Species | 92SF-16 | 92SF-11 | 92SF-13 | 88MM-4 | 88BP-5 | 89BP-10 | 87SF-10 | 87SF-69 | 87SF-70 | 87SF-1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dendrograptus sp. | | | | | X | | | | X | X |
| Desmograptus sp. | | | | | | | | | | X |
| Dictyonema sp. | | | | | X | | | | | X |
| Cactograptus sp. | | | | | | | | | | X |
| Dichograptus sp. | | | | | X | | | | | X |
| Tetragraptus serra serra | | | | | X | | | | X | X |
| T. taraxacum | | | | | | | | | | X |
| T. bigsbyi | | | | | X | | | | X | |
| T. quadribrachiatus | | | | | X | | | | X | X |
| Phyllograptus anna | | | | | | | | | | X |
| Didymograptus bifidus | | | | | X | | X | X | X | |
| D. extensus | | | | | | X | | | | |
| D. paranidentus | | | | | | | | | | X |
| D. v-deflexus | | | | X | X | | | | X | X |
| Xiphograptus svalbardensis | | | | | X | X | | | X | X |
| X. cypselo | | | | | | | | | | X |
| Pseudotrigonograptus ensiformis | | | | | X | | | | X | X |
| Cardiograptus sp. | | | | | | | | | | X |
| Oncograptus upsilon biangulatus | | | | | X | | | | X | X |
| Isograptus victoriae lunatus | X | | | | | | | | | |
| I. v. victoriae | | X | X | X | X | | | | X | |
| I. v. maximus | | | | | X | | | | X | |
| I. v. divergens | | | | | | | | | | X |
| I. victoriae sp. | | | | | | X | | | | |
| I. caduceus australis | | | | | X | | | | X | X |
| I. subtilis | | | | | | | | | | X |
| Pseudisograptus gracilis | | | | | | X | | | | X |
| P. dumosus | | | | | X | | | | X | X |
| P. manubriatus koi | | | | | X | | | | X | |
| Holmograptus sp. | | | | | | | | | | X |
| Undulograptus austrodentatus americans | | | | | | | | | | X |
| Undulograptus sp. | | | | | | | | | | X |
| Glossograptus acanthus | | | | | | | X | X | | X |

FIGURE 2. Graptolites from the Lower Member of the Vinini Formation. Collection numbers correspond to those in Fig. 1.

from the same stratigraphic interval as collection 87SF-70, while collection 87SF-1 is from an isolated outcrop that correlates with collection 87SF-70.

Preservation of specimens within sandstone as opposed to shale presents a unique opportunity for study. In cases where specimens are preserved in shale, the graptolites are often preserved as black, carbon films within black shale. However, within the Vinini sandstone, the graptolites were preserved in three dimensions in a light colored lithology. As a result, morphology is unusually well shown and the morphometrics of these specimens are less likely to be altered by flattening during compaction and lithification (Rieke and Chilingarian, 1974; Chilingarian and Wolf, 1975, 1976). Although the specimens are not flattened, they are fragmented due to predepositional transport.

The Lower Member of the Vinini Formation, as a record of prograding and retrograding sequences of submarine fans, consists of turbidite deposits from which the graptolite specimens were collected. As such, the graptolites experienced considerable transport, after dying and settling to the seafloor. They include benthic dendroid graptolites, such as *Dendrograptus* and *Desmograptus*, as well as diverse species of planktonic graptoloids. The dendroids, consisting only of fragments, appear to have sustained considerable fragmentation, while the planktonic graptolites are less fragmented. These fragments of graptoloids are generally of a greater size, possibly due to a shorter distance of transport or due to being more robust. An anomaly, however, is *X. svalbardensis*. The specimens from two different sandstone collections (87SF-70 and 88BP-5) reach stipe lengths of 6.49-55.25 mm, whereas its shale counterparts only reach stipe lengths of 1.73-5.63 mm. If the shale represents background sedimentation in the

depositional basin (Finney and Perry, 1991), delicate species would be expected to be less fragmented than in turbidite deposits. The other species from the shale either do not show this differentiation or do not occur sandstone.

Finney and Ethington (1992) based their correlations of the Vinini graptolite collections on the Australian zonation. They concluded that collections 87SF-70 and 88BP-5 correlate with the middle Castlemainian (Ca1) of the Australian zonation, collection 87SF-1 with the base of the Darriwilian or the top of the Yapeenian, and collection 89BP-10 with the mid Castlemainian (Fig. 3).

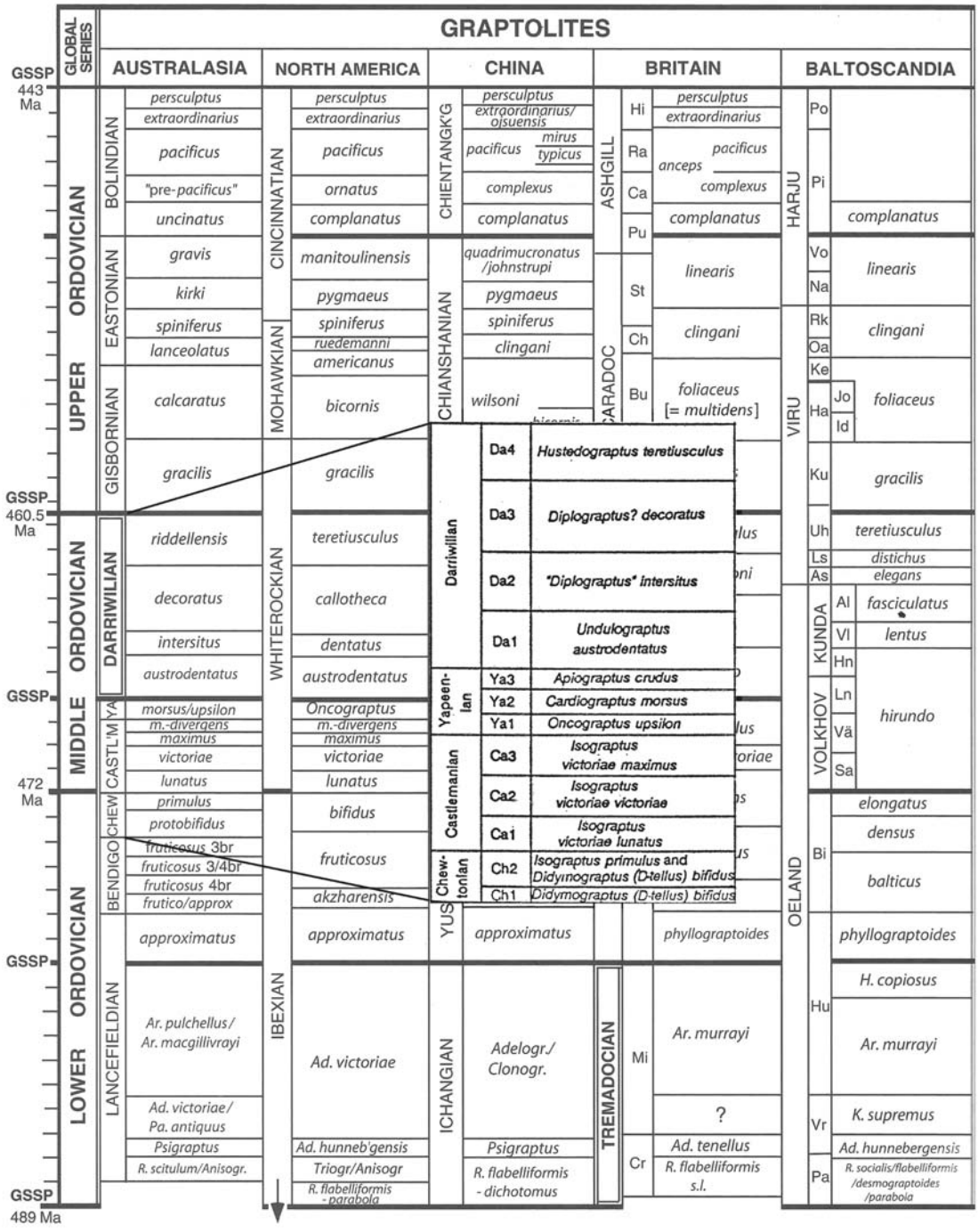



FIGURE 3. Ordovician time scale specifically showing the Australiasian (Australian) and North American zonation and correlation (Webby et al., 2004). The inset shows finer divisions of the Australian zonation (Webby and Nicoll, 1989).

# CHAPTER 4

## MODEL OF GRAPTOLITE PALEOECOLOGY

The Lower Member of the Vinini Formation has several beds containing Ordovician graptolites. In shale intervals, graptolites are restricted to thin intervals (Finney and Perry, 1991), and there are few specimens that represent few species (Finney and Berry, 1997). Within the sandstone interval, there are three productive quartz wacke beds, consisting of medium to coarse, well-rounded, well-sorted quartz grains in a calcareous or clay matrix. These beds yield abundant and diverse, well preserved specimens (Finney and Ethington, 1992). The turbiditic sandstones contain species that were restricted to shallow epicontinental seas (sessile, benthic dendroids and a few planktic graptoloids) mixed with a diverse assemblage of planktic graptoloids that were oceanic (the isograptids). Two hypotheses have been presented to explain the assemblage of Ordovician graptolites.

Cooper et al. (1991) argued that graptolites were divided within the water column into biotopes — epipelagic, deep water, and inshore — that stretched across ocean basins (Fig. 4). These graptolites were then further subdivided into provinces: truly pandemic species which were found globally, a Pacific province of Australia, North America, Siberia, Kazakhstan, North China, South China, and Argentina, as well as an Atlantic province of southern Britain, France, Czechoslovakia, Spain, northern Africa, and

Baltoscandia. Furthermore, Cooper et al. (1991) concluded that in upward deepening sections, the first graptolites encountered would be from the inshore or epipelagic biotope. However, this does not account for the assemblage encountered in the Lower Member of the Vinini Formation.

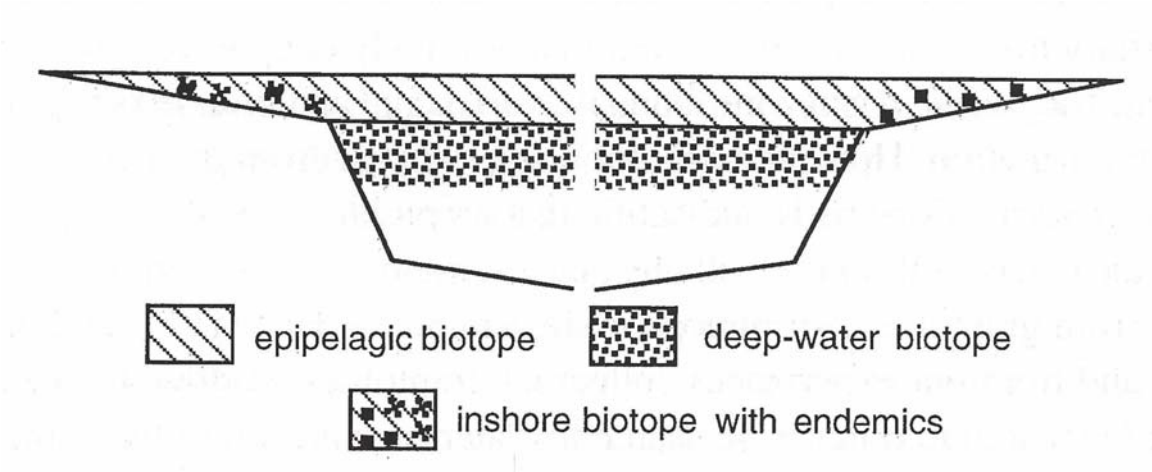



FIGURE 4. Cross section of ocean basin showing graptolite biotope model of Cooper et al. (1991). Graptolite faunas are depth stratified in the open ocean, extending onto the continental margins. The shallow water biotope extends onto the continental shelf where it mixes with local endemic species (Finney and Berry, 1997).

Finney and Berry (1997) alternatively proposed that Ordovician graptolites followed a similar pattern to modern zooplankton. Instead of spreading across ocean basins where resources are scarce, they argued that graptolites were actually concentrated in upwelling environments along continental margins where nutrients are more readily available. As a result the most prolific biotope would be zones of narrow upwelling with some oceanward spread from the shelf-slope break (Finney and Berry, 1997). This

biotope would be inhabited by abundant and diverse graptolites characterized as margin dwellers (Fig. 5). The post-mortem transport of the graptolites by turbidity currents from the shelf to the adjacent slope and rise would then explain the mixture of shallow-shelf and open ocean species seen in the Vinini Formation. Additionally, the occurrence of oxygen minimum zones below these upwelling zones would create the shales where most of the graptolites were preserved globally (Finney and Berry, 1997).

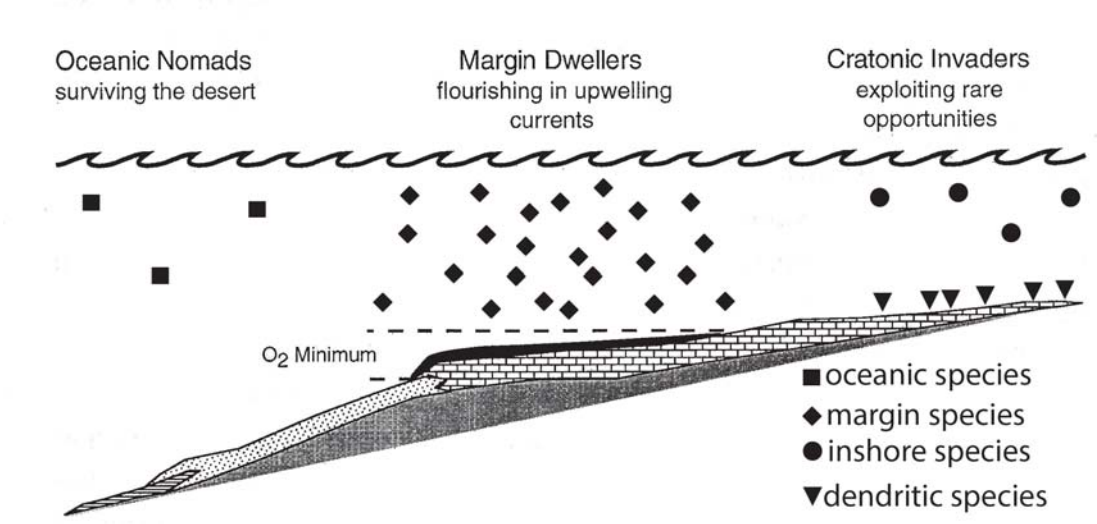



FIGURE 5. Graphic of a continental margin showing the Finney and Berry (1997) graptolite model. Symbols represent the different graptolite biotope species. According to the model, greatest diversity is in the zone of upwelling over the continental margin. Modified from Finney and Berry (1997, Fig. 2).

Further evidence for this model comes from the turbidite sandstone of the Lower Member. The occurrence of only fragmented dendritic graptolites in deep basinal deposits argues for transport off the shelf. Didymograptids, however, also lived within

this shelf habitat, but these graptolites are more robust, and are therefore less fragmented than the dendroids they were transported with. Offshore graptolites, the margin dwellers suggested by Finney and Berry (1997), did suffer some fragmentation, especially in instances where graptolites had particularly long stipes; however, the proximal ends in particular are not broken.

# CHAPTER 5

# METHODS

The use of general morphological characteristics such as the number and orientation of stipes and the thecal morphology are important for identifying graptolite genera. However, in order to identify species, more precise morphometrics are used. In general, measured features defined by Braithwaite (1976) are used here. However, measurements of additional features were helpful in this study (Cooper, 1973; Cooper and Ni, 1986). These measurements are defined as follows (Fig. 6).

*Sicular length* is the total length of the sicula.

*Supradorsal sicular length* is the length of the sicula that extends freely above proximal end.

*Stipe width* is the distance from the ventral lip of the thecal aperture to the dorsal side of the side of the stipe. However, stipe width is highly variable depending on where on the stipe the width is taken. For this study, stipe width was measured in multiple locations. For the sake of statistical analysis, each specimen was measured in the same place.

*Thecal length* is the total length of the theca from the lip of the thecal aperture along the angle of the theca to the dorsal side of the stipe. Thecal length can vary greatly

along the length of a specimen. As such, all thecal measurements between specimens were taken at the same thecae.

*Inclination of theca* is the angle of divergence of the theca from the axis of the stipe.

*Thecae in 10 mm* is often encountered in the literature, meaning the number of thecae occurring within a span of 10 mm, normally indicated if located proximally or distally on the rhabdosome. Additional terms include: *thecae in 5 mm*, *thecae in 3 mm*, or *two thecal distance* for instances when a specimen or species does not reach 10 mm in scale.

Additional terms are used solely for measuring *Pseudisograptus* specimens (Cooper and Ni, 1986). This genus possesses a manubrium which extends above the proximal end in much the same way as the supradorsal sicula. As such, there are additional measurements for manubrium length, width, and angle used solely for *Pseudisograptus* specimens.

Diagnostic measurements were taken on numerous specimens of each species as was permitted by the collection for the species. Within the collection, there are a total of 33 graptolite species, with each species represented by 1 to 20 specimens. Only photographed specimens were measured. In cases where many specimens were collected the specimens photographed and measured are the best preserved and best show the morphology of each species.

Each species was compared to described species from Cooper (1973, 1979), Braithwaite (1976), Cooper and Ni (1986), and Williams and Stevens (1988). In several

instances species showed smaller measurements than those reported due to the Nevada specimens being preserved in full relief instead of being flattened on shale. This mostly effected stipe width while not effecting other morphometrics.

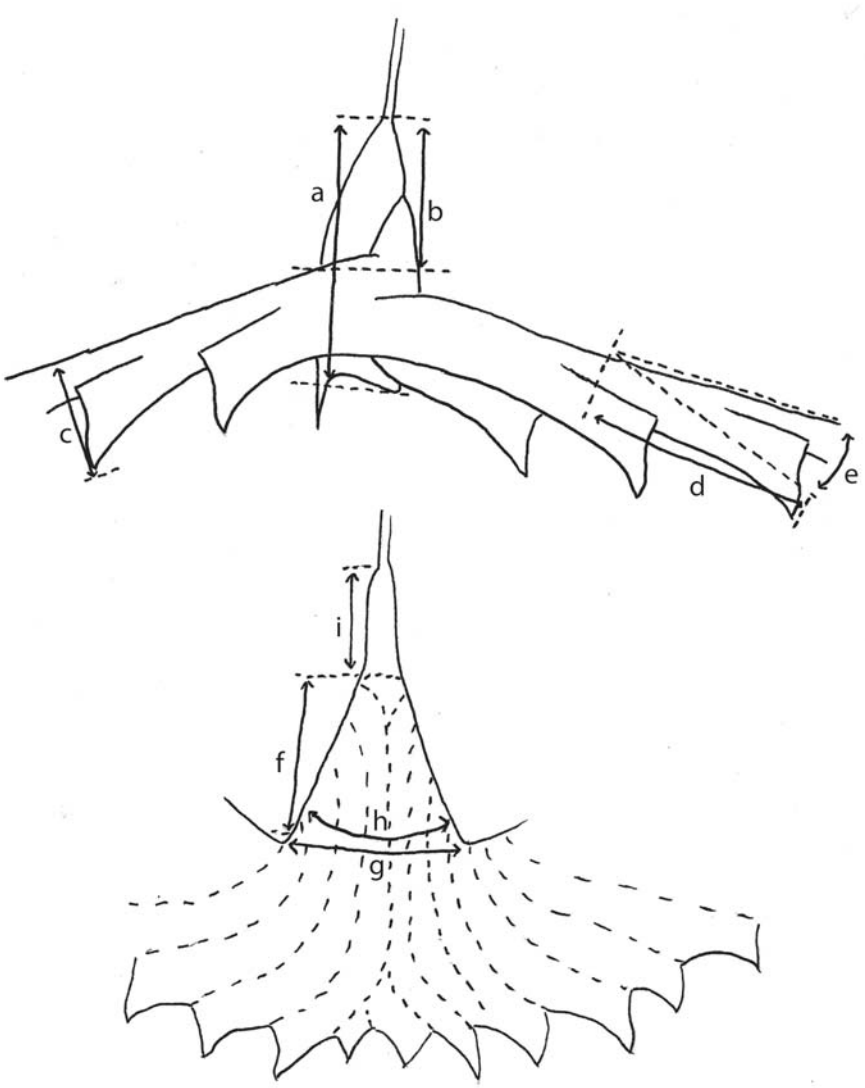



FIGURE 6. Morphometric measurements. (a) Sicular length (b) Supradorsal sicular length (c) Stipe width (d) Thecal length (e) Thecal inclination (f)Manubrium length (g) Manubrium width (h) Angle of manubrium (i) Free sicular length.

# CHAPTER 6

# SYSTEMATIC PALEONTOLOGY

Class GRAPTOLITHINA Bronn, 1846

Order DENDROIDEA Nicholson, 1872

Family DENDROGRAPTIDAE Roemer, *in* French, 1897

Genus *Dendrograptus* Hall, 1858

*Diagnosis.* Members of this genus are characterized by stout dendritic branches that dichotomously branched irregularly from a basal attachment. Stipes are unconnected by anastomosis or transverse dissepiments (Braithwaite, 1976).

*Dendrograptus* sp.

Pl. 1, figs. 3-4, 11-13

*Material and occurrence.* Ten specimens from 87 SF-1 and 87 SF-70.

*Description.* The specimens of *Dendrograptus* are fragments with the largest fragment reaching 22.44 mm long and 11.56 mm wide. The stipes branch dichotomously at irregular intervals and are 0.30 mm wide throughout their length. Within a 10 mm width across the rhabdosome, there are 18-22 stipes (averaging 21 in 10 mm). The thecae were not visible in the fragments.

Genus *Desmograptus* Hopkinson, 1875

*Diagnosis.* Members of this genus are conical and rarely flagellate, with undulating stipes that fuse regularly to one another by anastomosis. Dissepiments are rare (Braithwaite, 1976).

*Desmograptus* sp.

Pl. 1, figs. 2, 5, 9

*Material and occurrence.* Five specimens from 87 SF-1.

*Description.* All the specimens of *Desmograptus* are preserved as fragments with the largest 23.46 mm long and 16.49 mm wide. The stipes regularly anastomose. The stipes are 0.23-0.3 mm wide (averaging 0.28 mm) throughout their length. The stipes number 12-16 in 10 mm (averaging 14 in 10 mm) across the width of the rhabdosome and have 8-12 instances of anastomosis in 10 mm (averaging 10 in 10 mm). The thecae were not visible in any of the fragments.

Genus *Dictyonema* Hall, 1851

*Diagnosis.* Rhabdosomes of this genus are conical and attached by a stem or rarely by a nema. Branching is dichotomous in parallel linear series of large numbers of stipes that are united by transverse dissepiments or rarely by anastomosis (Braithwaite, 1976).

*Dictyonema* sp.

Pl. 1, figs. 6, 8, 10

*Material and occurrence.* Four specimens from 87 SF-1, 88 BP-5.

*Description.* The rhabdosome is generally lace-like in appearance, however only fragments are preserved. The largest fragment is 40.97 mm long and 17.17 mm wide. The parallel stipes are connected by transverse dissepiments. The stipes are 0.23-0.38 mm wide (averaging 0.30 mm) and the dissepiments are 0.15-0.23 mm long (averaging 0.21 mm). Within a 10 mm width across the rhabdosome, the stipes number 14-24 (averaging 19 in 10 mm) and the dissepiments number 8-18 (averaging 14 in 10 mm). The thecae were not visible in any of the specimen fragments.

*Remarks.* Based on comparison with descriptions by Braithwaite (1976), the Nevada specimens most closely resemble *D. cordillerensis*, having similar dissepiment length and density.

Family DENDROIDEA incertae sedis

Genus *Cactograptus* Ruedemann, 1908

*Diagnosis.* This genus is though to be dendroid. It is characterized by broad biserial stipes (Braithwaite, 1976).

*Cactograptus* sp.

Pl. 1, figs. 1, 7

*Material and occurrence.* Two specimens from 87 SF-1.

*Description.* The specimens are fragments of the rhabdosome which consist of multiple branching biserial stipes. The longest stipe is 15.13 mm. Stipe width averages 0.93 mm. The thecae lack denticles and are generally straight tubes ending in a sharp angle between the ventral margin and the aperture. The thecae uniformly alternate along each stipe. The thecae average 0.50 mm long, and thecal density is 11 in 10 mm.

*Remarks.* The Nevada specimens agree well with the description of *C. pogonipensis* (Braithwaite, 1976). However, the thecal density of the Nevada specimens is much higher that than reported for the Utah specimens.

Order *GRAPTOLOIDEA Lapworth, 1875*

Family DICHOGRAPTIDAE Lapworth, 1873

Subfamily DICHOGRAPTINAE Lapworth, 1873

Genus *Dichograptus* Salter, 1863

*Diagnosis.* Rhabdosome consisting normally of eight stipes produced by two proximal, consecutive dichotomies. One or more dichotomies occasionally suppressed, resulting in fewer stipes. Third order stipes long and flexuous. Central membrane commonly present (Williams and Stevens, 1988).

*Dichograptus* sp.

Pl. 9, fig. 3

*Material and occurrence.* One specimen from 88 BP-5.

*Description.* The rhabdosome of the specimen is composed of eight third-order stipes produced by consecutive dichotomous branchings. The third-order stipes range in length from 2.03 mm to 5.18 mm (averaging 3.75 mm) and range in width from 0.36 mm to 0.56 mm (averaging 0.43 mm). The second-order stipes range in length from 1.20 mm to 1.58 mm (averaging 1.37 mm) and range in width from 0.24 mm to 0.44 mm (averaging 0.32 mm). The funicle is 1.80 mm long and 0.44 mm wide. Thecae are not visible on the specimen because the entire specimen is enclosed by the central disc.

*Remarks.* The central disc in the Nevada specimen, obscuring the thecae, prevents determination of species. However, the length of the funicle and branches are similar to those in specimens of *D. octobrachiatus* described by Braithwaite (1976).

Genus *Tetragraptus* Salter, 1863

*Diagnosis.* Members of this genus have biradial rhabdosome. Pendent to reclined stipes are present. Two primary stipes form a short funicle (Braithwaite, 1976).

*Tetragraptus serra serra* (Brongniart, 1828)

Pl. 2, figs. 4, 5, 6

*Material and occurrence.* Five specimens from 87 SF-1; 87 SF-70; 88 BP-5.

*Description.* The rhabdosome is composed of four reclined stipes resulting from dichotomous branching. The funicle is 0.83-1.35 mm (averaging 1.13 mm) long and 0.38-0.53 mm (averaging 0.45 mm) wide. The stipes average 3.78 mm in length, with the longest reaching 6 mm, and increase in width distally from 0.60-0.83 mm (averaging 0.69 mm) to 1.28-1.58 mm (averaging 1.48 mm). Thecal length is 0.68-1.80 mm (averaging 1.14 mm) proximally before increasing to 1.58-2.10 mm (averaging 1.84 mm) at the 5th theca. Thecal inclination is 50º proximally, declining to 35º distally. Thecae number 15 in 10 mm. Sicular length is 1.50-1.65 mm (averaging 1.58 mm).

*Remarks.* The Nevada specimens agree well with the juvenile form described by Williams and Stevens (1988) in most respects. However, the funicle of the Nevada specimens are significantly shorter at an average of 1.13 mm, as opposed to 2.4-3.0 mm long.

*Tetragraptus taraxacum* Ruedemann, 1904

Pl. 2, figs. 7-9

*Material and occurrence.* One specimen from 87 SF-1.

*Description.* The rhabdosome of the specimen is composed of four reclined second order stipes. The stipes average 5.08 mm long, with the longest reaching 5.40 mm. The stipes widen rapidly within 5 mm from 0.83-0.98 mm (averaging 0.88 mm) to 1.13-1.28 mm (averaging 1.18 mm) wide. Thecal length also increases distally from 1.28-1.58 mm (averaging 1.43 mm) to 1.80-2.85 mm (averaging 2.33 mm). The thecae maintain an average inclination of 45º to the stipe axis. Thecal density is 12 in 10 mm. Sicular length is 1.58 mm.

*Remarks.* The Nevada specimen has a larger sicula and longer thecae than described by Ruedemann (1947), however the stipes are narrower. The thecal density of the Nevada specimens agrees with Ruedemann's (1947) description.

*Tetragraptus bigsbyi* (J. Hall, 1865)

Pl. 3, figs. 1-16

*Material and occurrence.* Fourteen specimens from 87 SF-70; 88 BP-5.

*Description.* The rhabdosome is composed of four reclined stipes diverging at 60º and averaging 4.54 mm long, with the longest stipe reaching 19.89 mm. The stipes increase in width until about the 4th theca before narrowing distally. Proximal width is 0.53-2.10 mm (averaging 0.99 mm) with the maximum width reaching 1.35-2.93 mm (averaging 2.04 mm). The thecae also increase in length from 1.28-1.65 mm (averaging 1.47 mm) proximally to 1.80-3.08 mm (averaging 2.42 mm) at th4. The thecae number

about 14 in 10 mm. Thecal inclination averages 45º to the stipe axis before curving sharply to an average angle of 80º at the aperture. The sicular length is 1.20-2.78 mm (averaging 1.69 mm).

*Remarks.* The Nevada specimens agree well with the descriptions by Braithwaite (1976), Cooper (1979), and Williams and Stevens (1988) in most respects. However, the width of the Nevada specimens is slightly smaller.

*Tetragraptus quadribrachiatus* (J. Hall, 1858)

Pl. 2, figs. 1-4

*Material and occurrence.* Five specimens from 87 SF-1; 88 BP-5.

*Description.* The rhabdosome is composed of four horizontal stipes branching dichotomously from the funicle. The funicle is 1.53-2.04 mm (averaging 1.81 mm) long, and is 1.02-1.19 mm (averaging 1.11 mm) wide. The angle between the stipes is 85-105º (averaging 90º). The stipes are generally long and straight, averaging 9.83 mm long, with the longest reaching 16.15 mm. The stipes gradually increase in width from 0.68-1.02 mm (averaging 0.85 mm) to 1.36-1.87 mm (averaging 1.63 mm) wide. In the majority of the specimens, the thecae were not well preserved enough to measure thecal length, density, or inclination. Of the five specimens, the proximal end of three were enclosed by a central disc.

Genus *Phyllograptus* Hall, 1858

*Diagnosis.* This genus is quadriserial and is composed of four scandent, second-order stipes (Braithwaite, 1976).

*Phyllograptus anna*

Pl. 4, figs. 1-9

*Material and occurrence.* Eight specimens from 87 SF-1.

*Description.* The rhabdosome is generally small and oval in shape. The rhabdosomes range in length from 3.68 mm to 9.38 mm, averaging 5.60 mm. In a few specimens the rhabdosome is widest at the distal end, but the majority of specimens are narrower at both the most proximal and most distal ends, with the maximum width midway along the rhabdosome. The rhabdosome width is highly variable at 3.08-5.63 mm (averaging 4.03 mm). The most proximal thecae are 0.90-1.80 mm (averaging 1.28 mm) long, before increasing in length to 1.58-2.40 mm (averaging 2.16 mm) at the 7th theca. The thecae then decrease in length distally. The thecal density is highly variable, ranging between 11 and 22 in 10 mm, but averages 19 in 10 mm.

*Remarks.* While the Nevada specimens agree in thecal density with the specimens described by Braithwaite (1976), the Nevada specimens are considerably smaller than those described by Braithwaite (1976) and Williams and Stevens (1988). The Braithwaite (1976) and Williams and Stevens (1988) specimens average 8 mm in length and 5 mm in width, as opposed to the Nevada specimens, which average of 5.60 mm in length and 4.03 mm in width. These differences are attributed to the Utah and Canada specimens having grown to larger size.

Genus *Didymograptus* M'Coy, 1851

*Diagnosis.* Rhabdosomes are composed of one pair of stipes that are pendent to reclined (Braithwaite, 1976). Theca $1^1$ typically originates high on the sicula, an of

similar length to sicula. Theca $1^2$ dicaycal, with normal isograptid development (Williams and Stevens, 1988).

*Didymograptus bifidus* (J. Hall, 1858)

Pl. 5, figs. 1-12; Pl. 6, figs. 7-13

*Material and occurrence.* Eighteen specimens from 87 SF-10; 87 SF-69; 87 SF-70; 88 BP-5.

*Description.* The rhabdosome is composed of two pendent stipes that diverge at an angle of 15-30º. The stipes are straight with the longest stipe attaining 29.75 mm, although the average length is 11.27 mm. The stipes are narrowest proximally, with a width of 0.51-0.85 mm (averaging 0.61 mm) before widening to 0.68-1.53 mm (averaging 1.17 mm) more distally. Thecal density is 15 in 10 mm. The thecae maintain an average inclination of 19º to the stipe axis. The thecae increase in length distally from an average of 0.59 mm to an average of 1.21 mm. Sicular length is 1.02-1.70 mm (averaging 1.33 mm). The supradorsal sicula averages 0.73 mm long.

*Remarks.* The Nevada specimens agree well with the specimens described by Braithwaite (1976) and Williams and Stevens (1988) in most respects. However, the distal thecal length in the Nevada specimens is shorter, at 1.21 mm, than the specimens described by Braithwaite (1976), which average 1.82 mm long. The difference in length is attributed to the Utah specimens having grown to a greater size.

*Didymograptus extensus* (J. Hall, 1858)

Pl. 7, figs. 10-13

*Material and occurrence.* Seven flattened specimens from 89 BP-10.

*Description.* The rhabdosome is composed of two horizontal stipes. The stipes are generally long and straight, the longest of which is 11.73 mm. However the majority of specimens are smaller. Average stipe length is 4.30 mm. Stipe width increases very gradually from 0.38-0.72 mm (averaging 0.60 mm) to 0.64-0.80 mm (averaging 0.69 mm) distally. The thecae are long and straight and thecal length increases from 0.80-1.36 mm (averaging 1.03 mm) to 1.20-1.80 mm (averaging 1.54 mm) at the 5th thecal pair. Thecal inclination is 20º-25º to the stipe axis. Thecal density is about 15 in 10 mm proximally. The sicula curves slightly in some specimens, but generally appears straight.

*Remarks.* The Nevada specimens agree well with the specimens described by Braithwaite (1976) and Williams and Stevens (1988) in most respects. However the Nevada specimens have a thecal density of 15 in 10 mm, instead of 9-12 in 10 mm (Braithwaite, 1976) or 11-12 in 10 mm proximally (Williams and Stevens, 1988).

*Didymograptus paranidentus*

Pl. 6, figs. 1-6

*Material and occurrence.* Six specimens from 87 SF-1.

*Description.* The rhabdosome is composed of two pendent stipes with an angle that diverges at 15-30º. The stipes are straight after bending at the 2nd thecal pair. The longest stipe reaches 8.85 mm, with an average stipe length of 4.93 mm. The stipes are narrowest proximally, at 0.48-0.68 mm (averaging 0.56 mm), and quickly increase to 0.68-0.98 mm (averaging 0.83 mm) wide. The thecae are generally straight and increase in length from 0.60-1.05 mm (averaging 0.79 mm) to 0.80-1.20 mm (averaging 1.33 mm)

distally. Thecal density is 18 in 10 mm. The thecae maintain an average inclination of 40º to the stipe axis. Sicular length is 0.76-1.13 mm (averaging 0.92 mm).

*Remarks.* While the rhabdosome of *D. paranidentus* resembles *D. bifidus* in shape, *D. paranidentus* is considerably smaller. However, the thecae are longer in *D. paranidentus* than in *D. bifidus* and the thecal inclination to the stipe axis is much higher.

*Didymograptus v-deflexus*

Pl. 7, figs. 1-6, 8, 9

*Material and occurrence*. Eight specimens from 87 SF-70; 88 BP-5; 88 MM-4.

*Description.* The rhabdosome is deflexed to declined with two uniserial stipes. The angle between dorsal wall of the stipes is 100º-110º. The longest stipe is 8.70 mm long, average stipe length is 4.35 mm. The stipes widen distally from 0.45-0.83 mm (averaging 0.65 mm) to 0.83-0.98 mm (averaging 0.91 mm). The thecae are generally long and straight, lengthening from 0.30-0.90 mm (averaging 0.62 mm) proximally to 0.60-1.35 mm (averaging 1.04 mm) distally. Thecae are inclined at 20º-30º to the stipe axis. Thecal density is 7 in 5 mm. The sicular length is between 0.75 mm and 1.36 mm, averaging 1.00 mm. The supradorsal sicula is 0.44-1.02 mm (averaging 0.73 mm) long.

Genus *Xiphograptus* Cooper and Fortey, 1982

*Diagnosis.* Extensiform, horizontal to deflexed or slightly biramous dichograptid, with short sicula possessing a virgule on antirutellar margin (Williams and Stevens, 1988).

*Xiphograptus svalbardensis* (Archer and Fortey, 1974)

Pl. 8, figs. 1-12

*Material and occurrence.* Seven flattened specimens from 89 BP-10. Four specimens from 87 SF-70; 88 BP-5.

*Description.* The rhabdosome consists of two horizontal stipes, though some specimens are slightly deflexed, diverging at 140-180º. The longest stipe attains 55.25 mm, while the average length is 9.33 mm. The stipes gradually increase in width from 0.45-0.68 mm (averaging 0.57 mm), to 0.75-1.02 mm (averaging 0.92 mm) at 10 mm from the sicula. Thecal length increases from 0.60-1.35 mm (averaging 0.95 mm) to 1.43-1.95 mm (averaging 1.65 mm) in 10 mm. Thecal density is highly variable proximally. Distally thecae number 11 in 10 mm. The thecae are straight and inclined 20-40º to the stipe axis. Sicular length is 0.83-1.53 mm (averaging 1.04 mm).

*Remarks.* The Nevada specimens agree well with the specimens described by Williams and Stevens (1988) in most respects. However, some of the Nevada specimens have a higher proximal thecal density. In addition, there is greater variability in thecal inclination and stipe divergence.

*Xiphograptus cypselo* (Archer and Fortey, 1974)

Pl. 8, figs. 13-18

*Material and occurrence.* Two specimens from 87 SF-1.

*Description.* The rhabdosome is composed of two horizontal stipes, diverging at 180º. The stipes are generally very long, reaching 54.23 mm. The stipes widen from 1.05-1.13 mm (averaging 1.09 mm) to 1.43-1.50 mm (averaging 1.46 mm) within 10 mm,

and reach a maximum width of 2.63 mm. The thecae are generally long and curved. The proximal thecae are 1.65-1.80 mm (averaging 1.73 mm) long and reach 1.95-2.25 mm (averaging 2.10 mm) within 10 mm. Metathecal inclination changes from about 30º at the proximal end to 50-55º distally. Thecae number 10-11 in 10 mm proximally and decrease to number 9 in 10 mm distally. The sicular length is 1.05-1.13 mm (averaging 1.09 mm).

*Remarks.* With the exception of sicular length, the Nevada specimens are slightly larger than the specimens described by Archer and Fortey (1974). The Spitsbergen specimens are initially 0.70 mm wide, reaching 1.0 mm wide within 6 mm with a maximum width of 2.00 mm. The Nevada specimens are initially about 1.09 mm wide, increasing to about 1.46 mm within 10 mm and reaching a maximum of about 2.21 mm. However, the average sicular length of the Spitsbergen specimens is 1.40 mm, as opposed to 1.09 mm observed in the Nevada specimens. Finally, Archer and Fortey (1974) do not report a decrease in thecal density as measured in the Nevada specimens.

Genus *Pseudotrigonograptus* Mu and Lee, 1958

*Diagnosis.* Quadriserial, scadent rhabdosome with four stipes united along their dorsal margins; median septa separating adjacent thecal series cruciform, imperforate; proximal development isograptid, dextral; initial thecae declined or horizontal, sicula lacks virgule (Williams and Stevens, 1988).

*Pseudotrigonograptus ensiformis* (J. Hall, 1865)

Pl. 19, figs. 9-13

*Material and occurrence.* Five specimens from 87 SF-1; 87 SF-70.

*Description.* The rhabdosome is composed of three scandent stipes, and is preserved either with a smooth, fusiform outline or showing the ventral apertural process. The rhabdosome is generally very long, reaching a maximum of 25.50 mm (averaging 21.62 mm) long. The rhabdosome widens from 1.02-3.74 mm (averaging 1.98 mm) proximally to 2.89-4.76 mm (averaging 3.43 mm) at its widest, before narrowing to 1.19-1.87 mm (averaging 1.53 mm). The thecal length follows a similar pattern, lengthening from 0.85-1.53 mm (averaging 0.85 mm) to 2.21-2.55 mm (averaging 2.41 mm) at the 21st thecal pair, then decreasing in length to 1.36-2.21 mm (averaging 1.76 mm). In rhabdosomes with a smooth outline, the thecae are straight, however in rhabdosomes showing the ventral apertural process the thecae have a slight curve near the aperture. Thecal angle rotates from about 50º proximally, to about 45º at the widest point of the rhabdosome, then to about 55º distally. Thecal density is 11 in 10 mm proximally and 10 in 10 mm distally.

*Remarks.* The Nevada specimens agree well with the specimens described by Williams and Stevens (1988) in most respects. However, the Nevada specimens have a lower thecal density proximally at 11 in 10 mm as opposed to 15 in 10 mm observed by Williams and Stevens (1988).

Genus *Cardiograptus* Harris and Keble, 1916

*Diagnosis.* Biserial, elongate-ovate, emarinate distally resembling an *Oncograptus* in which distal uniserial stipes have failed to develop (Bulman, 1970).

*Cardiograptus morsus*

Pl. 9, figs. 1-2, 4-9

*Material and occurrence.* Eight specimens from 87 SF-1.

*Description.* The rhabdosome is biserial, scandent, and generally elongate. The longest rhabdosome reaches 20.23 mm in length, averaging 13.15 mm. The rhabdosome width at the 2nd thecal pair is variable at 1.53-5.27 mm (averaging 3.02 mm) and widens to 4.08-6.97 mm (averaging 5.67 mm) at the 16th thecal pair. Thecal length increases distally from 0.68-2.38 mm long (averaging 1.62 mm) to 2.04-4.76 mm (averaging 3.08 mm). The thecae are inclined at 40º from the axis of the rhabdosome. Thecal density is 11-13 in 10 mm proximally.

*Remarks.* The Nevada specimens agree well with the specimens of *C. morsus* described by Cooper (1979).

Genus *Oncograptus T. S. Hall, 1914*

*Diagnosis*. Initially scandent biserial, later diverging; thecae long, slender, with high inclination and considerable overlap; development dichograptid, th1[1] dicalycal, first thecae short, downwardly directed increasing in length and changing direction distally (Bulman, 1970).

*Oncograptus upsilon biangulatus* Harris and Keble, 1916

Pl. 10, figs. 1-10

*Material and occurrence.* Fourteen specimens from 87 SF-1; 87 SF-70.

*Description.* The rhabdosome is composed of a scadent biserial proximal end followed by diverging uniserial stipes. The proximal end of the rhabdosome is 10 mm

long. The uniserial stipes diverge at an average angle of 55°. The uniserial stipes are straight and the longest measures 20.4 mm. The proximal end of the rhabdosome is widest just before stipes diverge. The proximal end widens from 1.87-6.12 mm (averaging 3.38 mm) at th2 to 5.87-11.22 mm (averaging 8.56 mm) at th13. The stipes are widest just after the rhabdosome diverges, narrowing from 3.06-6.12 mm (averaging 4.02 mm) wide to 2.38-3.57 mm (averaging 2.92 mm) wide. The thecae are long and slender, and show a slight distal convex curvature back toward the proximal end. The thecae increase in length from the proximal end through the length of the scadent rhabdosome, then decrease in length after the stipes diverge. The proximal thecae are 1.19-2.89 mm (averaging 1.64 mm) long. The most distal thecae within the scandent rhabdosome are 3.4-7.14 mm (averaging 5.07 mm) long. After the stipes diverge, the thecae are 3.91-4.42 mm (averaging 4.14 mm) long. Within the scadent biserial portion of the rhabdosome, the thecal density is 13 in 10 mm. After the stipes diverge, thecal density drops to 9 in 10 mm. The thecae show a progressive rotation from an inclination of about 90° from the axis at th2 to an inclination of 25° in more distal thecae. In two of the specimens, it is possible to see that th1[1] is a dicalycal theca and is about 3 mm long. All other specimens show the reverse side, where th2 overlays the dicalycal theca.

Family ISOGRAPTIDAE Harris, 1933

Subfamily ISOGRAPTINAE Harris, 1933

Genus *Isograptus* Moberg, 1892

*Diagnosis*. Sicula and proximal thecae relatively long; development of isograptid type, dextral or rarely sinistral, sicula and th1[1] symmetrically developed (isograptid

symmetry); single dichotomy produces two reclined to scandent stipes, united (biserial) in some scandent forms; thecal inclination initially low or high, generally high (Williams and Stevens, 1988).

*Isograptus victoriae* Harris, 1933

*Isograptus victoriae lunatus* Harris, 1933

Pl. 11, figs. 10, 11

*Material and occurrence.* Two specimens from 92 SF-16.

*Description.* Of the two specimens measured, the rhabdosome is generally u-shaped, and the stipes diverge 45-50°. The stipes have a slight convex curvature. The longest stipe is 3.23 mm and the average length across all specimens is 2.55 mm. The stipes are narrowest at the proximal end, 0.68-1.04 mm (averaging 0.86 mm) wide, widen slightly to 0.72-1.2 mm (averaging 0.91 mm) where the stipes bend, and are widest at the distal ends, averaging 1.05 mm. There are 2 pairs of pendent thecae, 0.64-0.68 mm (averaging 0.66 mm) long. Adjacent proximal thecae are 0.83-0.92 mm (averaging 0.87 mm) long, and distal thecae are 0.75-0.98 mm (averaging 0.86 mm) long. Thecal density is 17 in 10 mm. The sicular length is 2.00-2.18 mm (averaging 2.09 mm) and the supradorsal sicular length is 0.96-1.35 mm (averaging 1.16 mm).

*Remarks.* The Nevada specimens are, on a whole, smaller in sicular length, stipe length, and stipe width than the specimens described by Cooper (1973, 1979) and Williams and Stevens (1988). The exception to this is the thecal density, which is 17 in 10 mm as opposed to 12-15 in 10 mm (Williams and Stevens, 1988).

*Isograptus victoriae victoriae* Harris, 1933

Pl. 11, figs. 3-9; Pl. 12, figs. 1-10; Pl. 13, figs 1-3

*Material and occurrence.* Eighteen specimens from 88 MM-4; 92 SF-11; 92 SF-13. One flattened specimen from 92 SF-11.

*Description.* The rhabdosome is generally v-shaped, though some specimens are more u-shaped, and the stipes diverge 30-50°. The stipes are generally straight, some having a slight convex curvature leading to the u-shape of some of the specimens. The longest stipes are 21.25 mm with an average length of 10.71 mm. The stipes are widest at the distal ends, at 1.70-2.38 mm (averaging 1.92 mm), are thinnest just after the stipes bend, at 1.36-2.21 mm (averaging 1.72 mm) wide, and are 1.53-2.04 mm (averaging 1.87 mm) wide at the proximal end. The thecae have a concave curvature throughout their length leading to an inclination of about 90° at the aperture. The pendent thecae are 1.02-1.87 mm (averaging 1.33 mm) long, proximal thecae are 1.19-2.04 mm (averaging 1.64 mm) long, and the distal thecae are 1.70-2.55 mm (averaging 2.06 mm) long. The distal thecae have an average inclination of 20° to the stipe axis. The number of pairs of pendent thecae range from 2 to 4, with an average of 3 pairs of pendent thecae. Thecal density is 10-14 in 10 mm. The nema ranges from 0.85 mm to 6.46 mm (averaging 3.06 mm) long. Sicular length ranges from 1.87 mm to 3.40 mm (averaging 2.72 mm). The supradorsal sicula ranges from 0.34 mm to 1.53 mm (averaging 0.91 mm) long.

*Remarks.* The Nevada specimens agree well with the specimens described by Cooper (1973) and Williams and Stevens (1988) in most respects, except in rhabdosome shape and stipe widths. The Nevada specimens appear to be more v-shaped, with straight

stipes, a few of the specimens have u-shaped rhabdosomes with slightly more convex curvature to the stipes as described by both Cooper (1973) and Williams and Stevens (1988). Furthermore, the stipe widths vary little throughout their length, as described by Cooper (1973); however the widths are 1.72 mm to 1.92 mm in the Nevada specimens as opposed to the widths of between 2.1 and 2.3 mm in the Cooper (1973) specimens. There is no drastic decrease in width after the bend in the stipes as described in Williams and Stevens (1988).

*Isograptus victoriae maximus* Harris, 1933

Pl. 14, figs. 1-10

*Material and occurrence.* Eleven specimens from 87 SF-70; 88 BP-5.

*Description.* The rhabdosome is generally v-shaped and the stipes diverge 30-60°. The stipes are straight with an average length of 10.46 mm; the longest stipe is 22.8 mm. The stipes are narrower near the proximal end, 1.87-2.55 mm (averaging 2.18 mm) wide. The stipes widen slightly to 2.38-2.89 mm (averaging 2.54 mm) at the 10th theca. Thecal length gradually increases with stipe length. The pendent thecae are 1.19-1.87 mm (averaging 1.53 mm) long, proximal thecae are 1.53-3.23 mm (averaging 2.01 mm) long, and the distal thecae are 1.19-3.74 mm (averaging 2.41 mm) long. The proximal thecal density is 10-12 in 10 mm. There are 2-3 pairs of pendent thecae. The distal thecae are inclined at 20° to the stipe axis. The sicular length is 3.23-3.74 mm (averaging 3.52 mm). The supradorsal sicula is 1.02-2.04 mm (averaging 1.40 mm) long.

*Remarks.* The Nevada specimens agree well with the specimens of Cooper (1973), Cooper (1979), and Williams and Stevens (1988) except the sicular length and the

width of the stipes. The sicula is slightly shorter, at an average length of 3.52 mm, than the described specimens measuring at 4.25 mm long. Additionally the stipes are not as wide, averaging 2.5 mm wide distally, as the specimens in Cooper (1973, 1979), and Williams and Stevens (1988), which range between 3.4 mm and 4.5 mm wide distally.

*Isograptus victoriae divergens* Harris, 1933

Pl. 17, figs. 10-15

*Material and occurrence.* Six specimens from 87 SF-1.

*Description.* The rhabdosmes are generally large and v-shaped with stipes diverging at 35-40°. The maximum stipe length is 37.23 mm, in most specimens the average length is 14.88 mm. Stipe width increases from 1.36-1.87 mm (averaging 1.57 mm) near the sicula to 1.70-2.38 mm (averaging 2.10 mm) distally. Thecal length increases from 1.19-1.53 mm (averaging 1.26 mm) for the pendent thecae to 1.43-2.72 mm (averaging 2.03 mm) distally. Thecal density is 11-13 in 10 mm, with between 3 and 4 pairs of pendent thecae. Sicular length ranges from 2.55 mm to 3.40 mm (averaging 3.09 mm). The supradorsal sicula ranges from 1.02 mm to 1.87 mm (averaging 1.47 mm) long. The maximum length of the nema is 2.38 mm.

*Remarks.* The Nevada specimens are similar to specimens described by Cooper (1973) and Williams and Stevens (1988) in all features except sicular length, stipe width, and thecal density. In the Nevada specimens the sicula ranges from 2.55 mm to 3.40 mm, averaging 3.09 mm whereas the sicular lengths of the specimens of Cooper (1973) are 3.5-4.0 mm long, and those of Williams and Stevens (1988) are about 4.5 mm long. The specimens described by Cooper (1973) and Williams and Stevens (1988) have stipe

widths that gradually increase from about 2 mm to 4.5 mm. However, the Nevada specimens widen from an average of 1.57 mm to an average of 2.10 mm. Thecal density is 11-13 in 10 mm in the Nevada specimens versus 9 in 10 mm (Cooper, 73) or 9-12 in 10 mm (Williams and Stevens 88). The most significant difference is the narrower stipes in the Nevada specimens.

*Isograptus victoriae* sp.

Pl. 11, figs. 1, 2

*Material and occurrence.* Three flattened specimens on shale from 89 BP-10.

*Description.* The specimens consist of only a proximal end and are early growth stages. The stipes adjacent to the sicula are 1.50-2.25 mm wide (averaging 1.95 mm). The pendent thecae are 0.84-1.40 mm long (averaging 1.13 mm). The 2 thecal distance of the pendent thecae is 0.88-1.40 mm (averaging 1.17 mm). There are 2-3 pairs of pendent thecae. The sicular length is 2.70-3.08 mm (averaging 2.90 mm).

*Remarks.* While the Nevada specimens consist of only the proximal end, the measurements match well with descriptions of *I. v. victoriae* from Cooper (1973) and Williams and Stevens (1988). Compared to the Nevada specimens of *I. v. victoriae*, the specimens of *I. victoriae* sp. are slightly larger in respect to sicular length and stipe width and the thecal density, estimated from the 2 thecal distance, is much higher. However the pendent thecae are shorter in *I. victoriae* sp. than in the Nevada specimens for *I. v. victoriae.*

*Isograptus caduceus* (Salter, 1853)

*Isograputs caduceus australis* Cooper, 1973

Pl. 15, figs. 1-12; Pl. 16, figs. 1-7

*Material and occurrence.* Nineteen specimens from 87 SF-1; 87 SF-70; 88 BP-5.

*Description.* The rhabdosome is generally v-shaped and the stipes diverge 20-30°. The stipes are straight and the longest reaches 18.2 mm, although average length is 9.15 mm. The stipes are widest near the sicula, 1.70-2.38 mm (averaging 1.98 mm) wide, decreasing to 1.19-1.87 mm (averaging 1.51 mm). The stipes remain parallel sided, with only a difference of 0.10 mm between proximal and distal width. Thecal length increases from 0.75-1.36 mm (averaging 1.10 mm) in pendent thecae, to 0.85-1.73 mm (averaging 1.24 mm) in proximal thecae, and to 0.75-2.21 mm (averaging 1.41 mm) in distal thecae. Thecal inclination gradually changes from the pendent thecae to distal thecae which are 20-30° to the stipe axis. Thecal density is 13-14 in 10 mm. The nema ranges from 1.28 mm to 5.61 mm long (averaging 3.89 mm). Sicular length ranges from 2.21 mm to 4.76 mm (averaging 3.01 mm). The supradorsal sicula averages 1.05 mm long. There are 3-4 pairs of pendent thecae.

*Remarks.* The Nevada specimens are virtually identical to specimens described by Cooper (1973) and Williams and Stevens (1988) in all features except thecal density and widening of the stipes. Thecal density ranges from 13-14 in 10 mm in the Nevada specimens versus 11-12 in 12 mm in Williams and Stevens (1988). The stipes of the specimens described by Cooper (1973) and Williams and Stevens (1988) narrow slightly distally whereas, in the Nevada specimens the stipes remain parallel-sided.

*Isograptus subtilis* Williams and Stevens, 1988

Pl. 17, fig. 5

*Material and occurrence.* One specimen from 87 SF-1.

*Description.* The single specimen has parallel stipes, with a maximum length of 5.95 mm. Stipe width near the sicula is 2.30 mm and gradually decreases to 1.36 mm distally. The sicula is 2.89 mm long, the supradorsal sicular length is 0.68 mm, and the nema is 2.72 mm long. Thecal density is 5-6 in 5 mm. There are 3 pairs of pendent thecae. Thecal length increases from 0.94 mm long proximally to a length of 1.31 mm distally.

*Remarks.* The single Nevada specimen falls within the ranges of the measurements of the specimens in Williams and Stevens (1988). The only exception is the sicula, which is slightly shorter.

Subfamily PSEUDISOGRAPTINAE Cooper and Ni, 1986

Genus *Pseudisograptus* Beavis, 1972

*Diagnosis*. Stipes reclined to scandent, initially monoserial or monoserial throughout; proximal structure pseudopreicalycal; thecae of advanced manubriate form (Cooper and Ni, 1986)

*Pseudisograptus gracilis* (Ruedemann, 1947)

Pl. 17, figs. 6-9

*Material and occurrence.* Two flattened specimens from 89 BP-10. Three specimens from 87 SF-1.

*Description.* The rhabdosome is V-shaped with short stipes that diverge at 50-75°. The stipes are generally straight and average 3.17 mm in length, with the longest stipe measuring 3.92 mm. The stipes are 0.8-1.8 mm (averaging 0.97 mm) wide. The thecal density is 5-6 in 3 mm. The sicular length is 3.48-3.88 mm (averaging 3.68 mm), the supradorsal sicular length is 2.36-2.76 mm (averaging 2.56 mm), and the free sicular length is 1.28-1.76 mm (averaging 1.52 mm). The manubrium is 0.96-1.80 mm (averaging 1.23 mm) long, 1.00-1.76 mm (averaging 1.29 mm) wide, and the manubrium angle is 50-55°.

*Remarks.* The Nevada specimens agree well with the specimens described by Cooper and Ni (1986) and Williams and Stevens (1988) in most respects, excluding stipe length. The Nevada specimens have on average shorter stipes than the described specimens.

*Pseudisograptus dumosus* (Harris, 1933)

Pl. 17, figs. 1-4

*Material and occurrence.* Four specimens from 87 SF-1; 87 SF-70.

*Description.* The rhabdosomes are generally small and U-shaped with stipes diverging at 300º-330º. The rhabdosome is primarily composed of the manubrium and short stipes that average 3.85 mm long, the longest measuring 4.73 mm. The rhabdosome at the manubrium is 3.08-4.28 mm (averaging 3.88 mm) wide. The stipes are 0.60-1.35 mm (averaging 1.03 mm) wide. Thecae number 16 in 10 mm and the thecae are inclined 20º-30º to the stipe axis. Sicular length ranges from 3.45 mm to 4.13 mm (averaging 3.66 mm). The supradorsal sicula ranges from 0.90 mm to 1.88 mm (averaging 1.28 mm)

long. The free sicula length ranges from 0.45 mm to 1.05 mm (averaging 0.68 mm). The manubrium is 0.38-0.83 mm (averaging 0.62 mm) long and 1.58-2.33 mm (averaging 2.03 mm) wide. The manubrium angle averages 70º.

*Remarks.* There is some discrepancy in the measurements of the specimens described by Cooper and Ni (1986) and Williams and Stevens (1988). In sicular length and rhabdosome width, the Nevada specimens agree well with the Form A described by Cooper and Ni (1986), but the sicular length is significantly greater than the Form A specimens described by Williams and Stevens (1988). The manubrium width agrees with the Form A specimens from Williams and Stevens (1988). However, the supradorsal sicula, the manubrium length, and stipe width of the Nevada specimens are much smaller than in the other described specimens.

*Pseudisograptus manubriatus* (T. S. Hall, 1914)

*Pseudisograptus manubriatus koi* Cooper and Ni, 1986

Pl. 18, figs. 1-12

*Material and occurrence.* Twelve specimens from 87 SF-70; 88 BP-5.

*Description.* The rhabdosome is generally short and U-shaped and the angle of divergence between the stipes varies between 260º and 330º, with an average angle of 300º. The U-shape of the rhabdosome is a result of the shape of the stipes. The majority of the stipes are slightly convex, however the stipes range from strongly curved to nearly straight. The longest stipe is 14.11 mm, with an average length of 7.82 mm. The stipes are nearly parallel sided, widening from 1.05-1.70 mm (averaging 1.46 mm) proximally to 1.20-1.87 mm (averaging 1.53 mm) distally. Thecal length increases with stipe length,

increasing from 2.04-3.23 mm (averaging 2.64 mm) proximally to 1.73-4.76 mm (averaging 3.21 mm) distally. Thecal density is 6 in 5 mm. Thecal angle rotates from about 15º proximally to about 30º more distally. The sicular length ranges between 4.42 mm and 6.12 mm (averaging 5.33 mm). The free sicular length is 0.83-2.55 mm (averaging 1.52 mm). The supradorsal sicular length is 2.63-4.42 mm (averaging 3.37 mm). The manubrium is 1.35-2.55 mm (averaging 1.96 mm) long, 1.35-2.21 mm (averaging 1.72 mm) wide, and the manubrium angle is an average of 47º.

*Remarks*. The Nevada specimens agree well with the specimens described by Cooper and Ni (1986), with the exception of the manubrium measurements. The manubrium in the Nevada specimens is on average of 1.96 mm long and an average of 1.72 mm wide, whereas the Cooper and Ni (1986) specimens are 1.6 mm long and 1.5 mm wide.

Family SINOGRAPTIDAE Mu, 1957

Subfamily SIGMAGRAPTINAE Cooper and Fortey, 1982

Genus *Holmograptus* Kozlowski, 1954

*Diagnosis.* Rhabdosome of two declined stipes; thecae with prothecal folds accentuated by dorsal "notches" and introverted apertures with mesial spine and lateral lappets; an "apertural plate" on the succeeding metatheca further constricts the aperture (Bulman, 1970).

*Holmograptus* sp.

Pl. 7, fig. 7

*Material and occurrence.* One specimen from 87 SF-1.

*Description.* The specimen is a fragment 13.26 mm long and 0.28 mm wide, reaching a maximum width of 0.4 mm. Thecal length is 1.88 mm. The thecae number 10 in 10 mm.

*Remarks.* It is unclear which species the Nevada specimen corresponds to when compared to descriptions from Williams and Stevens (1988). The fragment is much longer and wider than the measured stipes of *H. leptograptoides, H.* sp. A (Williams and Stevens, 1988), and *H. bovis*. The thecal density, 10 in 10 mm, matches the lower range of *H. leptograptoides*; however, thecal density decreases distally in *Holmograptus* sp. A and could reach a density of 10 in 10 mm if the stipe grew long enough.

Family DIPLOGRAPTIDAE Lapworth, 1873

Genus *Undulograptus* Boucek, 1973

*Diagnosis.* Scandent, biserial graptolite with streptoblastic development and dicalycal th2[1]. Thecae strongly overlapping, not geniculate, sinuously shaped. The S-shaped interthecal septa originate at a level below each previous thecal pasture. Median septum strongly undulose. Rhabdosome typically squat and blunt proximally

*Undulograptus autrodentatus americanus* (Bulman, 1963)

Pl. 19, figs. 2-8

*Material and occurrence.* Eight specimens from 87 SF-1.

*Description.* The rhabdosome is biserial and essentially parallel sided. The longest rhabdosome is 12.93 mm; the average length is 7.51 mm. The rhabdosome is 1.13-1.43 mm (averaging 1.28 mm) wide at the first thecal pair and widens to 1.43-1.80 mm (averaging 1.63 mm) within 5 mm, maintaining that width through the rest of the

rhabdosome. Thecal length increases from 0.53-0.90 mm (averaging 0.69 mm) at th1 to 1.13-1.35 mm (averaging 1.28 mm) at th7. Thecal density is 7-8 in 5 mm proximally and thecal inclination varies between 20º and 50º, averaging 35º.

*Remarks.* The Nevada specimens are not as wide and have a greater thecal density than the specimens described by Berry (1980).

*Undulograptus* sp.

Pl. 19, fig. 1

*Material and occurrence.* One specimen from 87 SF-1.

*Description.* The specimen consists of the proximal end of the rhabdosome, reaching the fourth thecal pair. The rhabdosome is 2.18 mm long, and is parallel sided maintaining a width of 1.13 mm. Thecal length increases slightly from 0.53 mm to 0.68 mm. Thecal inclination increases from 35º to 50º to the stipe axis. The thecae number 11 in 5 mm.

*Remarks.* Based on comparison to descriptions by Williams and Stevens (1988), it is possible that this specimen is *U. a. austrodentatus*, however the thecal density of this specimen is much higher than 13-15 in 10 mm.

Family GLOSSOGRAPTIDAE Lapworth, 1873

Subfamily GLOSSOGRAPTINAE Lapworth, 1873

Genus *Glossograptus* Emmons, 1855

*Diagnosis.* Rhabdosome with apertural, “dorsal” and lateral spines (Bulman, 1970).

*Glossograptus acanthus* Elles and Wood, 1908

Pl. 20, figs. 1-12

*Material and occurrence.* Twelve specimens from 87 SF-1; 87 SF-10; 87 SF-69.

*Description.* The rhabdosome is scandent and elongate to ovular. The rhabdosome averages 7.13 mm long, with a few specimens reaching as much as 12.58 mm in length. The rhabdosome generally increases abruptly in width to 1.65-3.75 mm (averaging 2.91 mm) at the 8th thecal pair and maintains that width distally. The thecae bear prominent spines that arise from the ventral margin of the thecal aperture and are straight before curving sharply. The 2nd pair of thecae range in length from 0.45 mm to 0.75 mm (averaging 0.62 mm). Distally thecal length increases to 1.20-1.35 mm (averaging 1.26 mm) by the 7th thecal pair. The thecae number 9-11 in 5 mm.

# APPENDIX

# PLATES

## Plate 1

**Fig. 1.** *Cactograptus* sp., 87SF-1, x10.

**Fig. 2.** *Desmograptus* sp., 87SF-1, x2.5.

**Figs. 3, 4.** *Dendrograptus* sp., x5.

3. 87SF-70.

4. 87SF-1.

**Fig. 5.** *Desmograptus* sp., 87SF-1, x5.

**Fig. 6.** *Dictyonema* sp., 87SF-1, x2.5.

**Fig. 7.** *Cactograptus* sp., 87SF-1, x5.

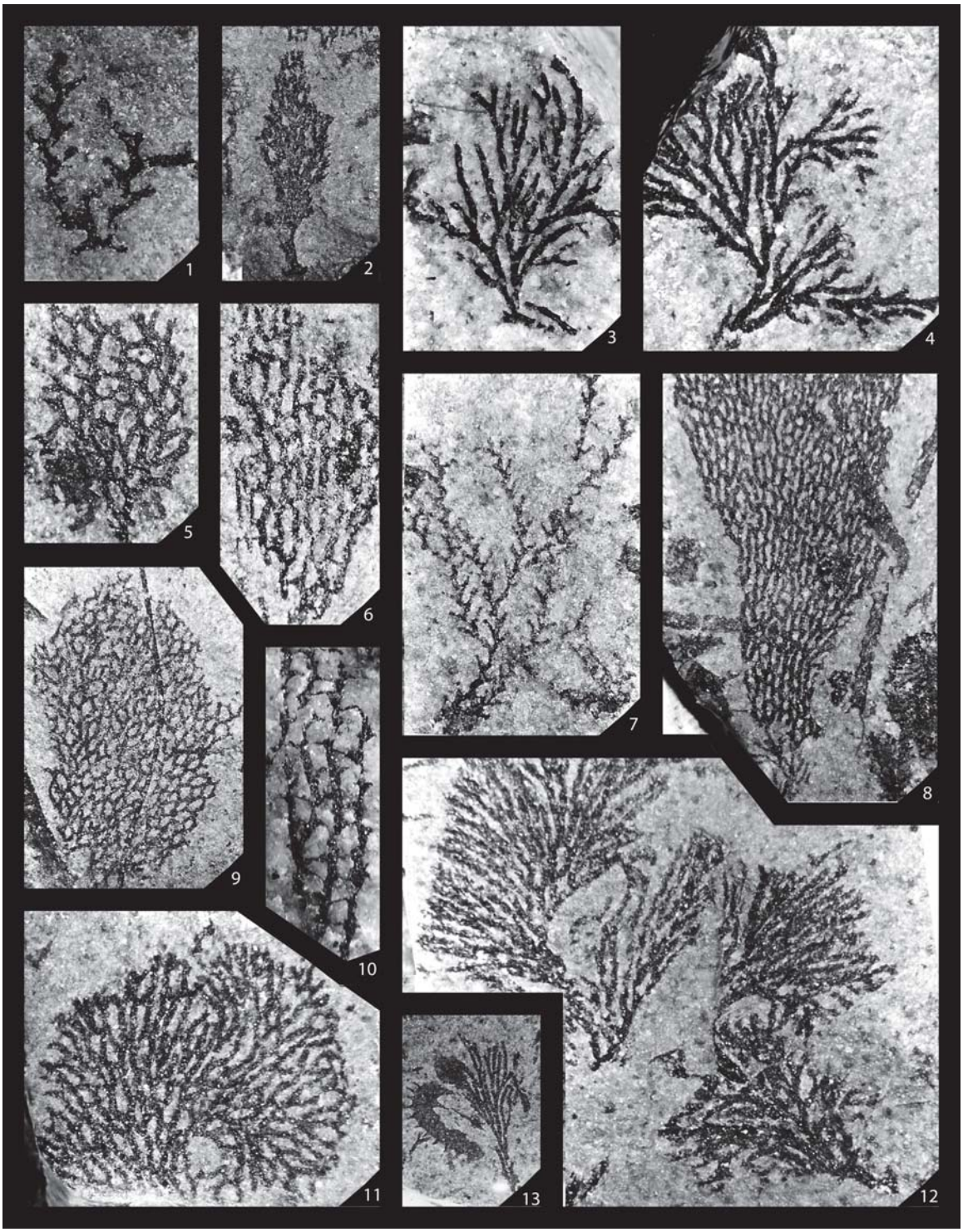
**Fig. 8.** *Dictyonema* sp., 88BP-5, x5.

**Fig. 9.** *Desmograptus* sp., 87SF-1, x2.5.

**Fig. 10.** *Dictyonema* sp., 87SF-1, x5.

**Figs 11, 12.** *Dendrograptus* sp., 87SF-1, x5.

**Fig. 13.** *Dendrograptus* sp., 87SF-1, x2.5.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## Plate 2

**Figs. 1-4.** *Tetragraptus quadribrachiatus* (J. Hall, 1858)

1. Showing proximal membrane. 87SF-70, x5.

2. Showing proximal membrane. 88BP-5, x2.5.

3, 4. 87SF-1, in association with *T. s. serra*, x5.

**Figs. 4-6.** *Tetragraptus serra serra* (Brongniart, 1828), 87SF-1, x5.

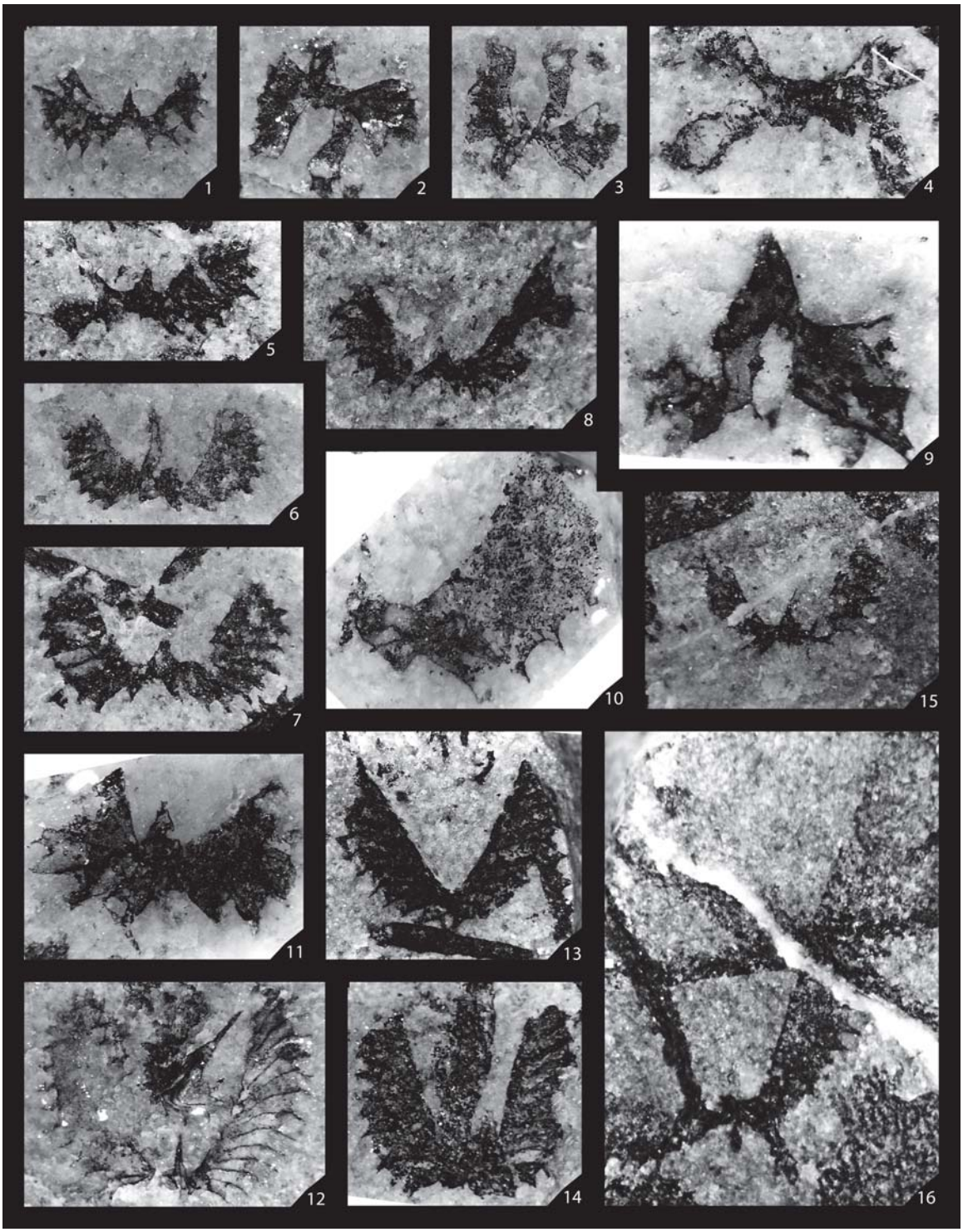
4. 87SF-1, in association with *T. quardribrachiatus*, x5.

**Figs. 7-9.** *Tetragraptus taraxacum* Ruedemann, 1904, 87SF-1.

7. x5.

8. x10.

9. x5.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## Plate 3

**Figs. 1-16.** *Tetragraptus bigsbyi* (J. Hall, 1865)

1-3. 88BP-5, x5.

4. 87SF-70, x10.

5, 6. 87SF-70, x5.

7, 8. 88BP-5, x5.

9, 10. 87SF-70, x10.

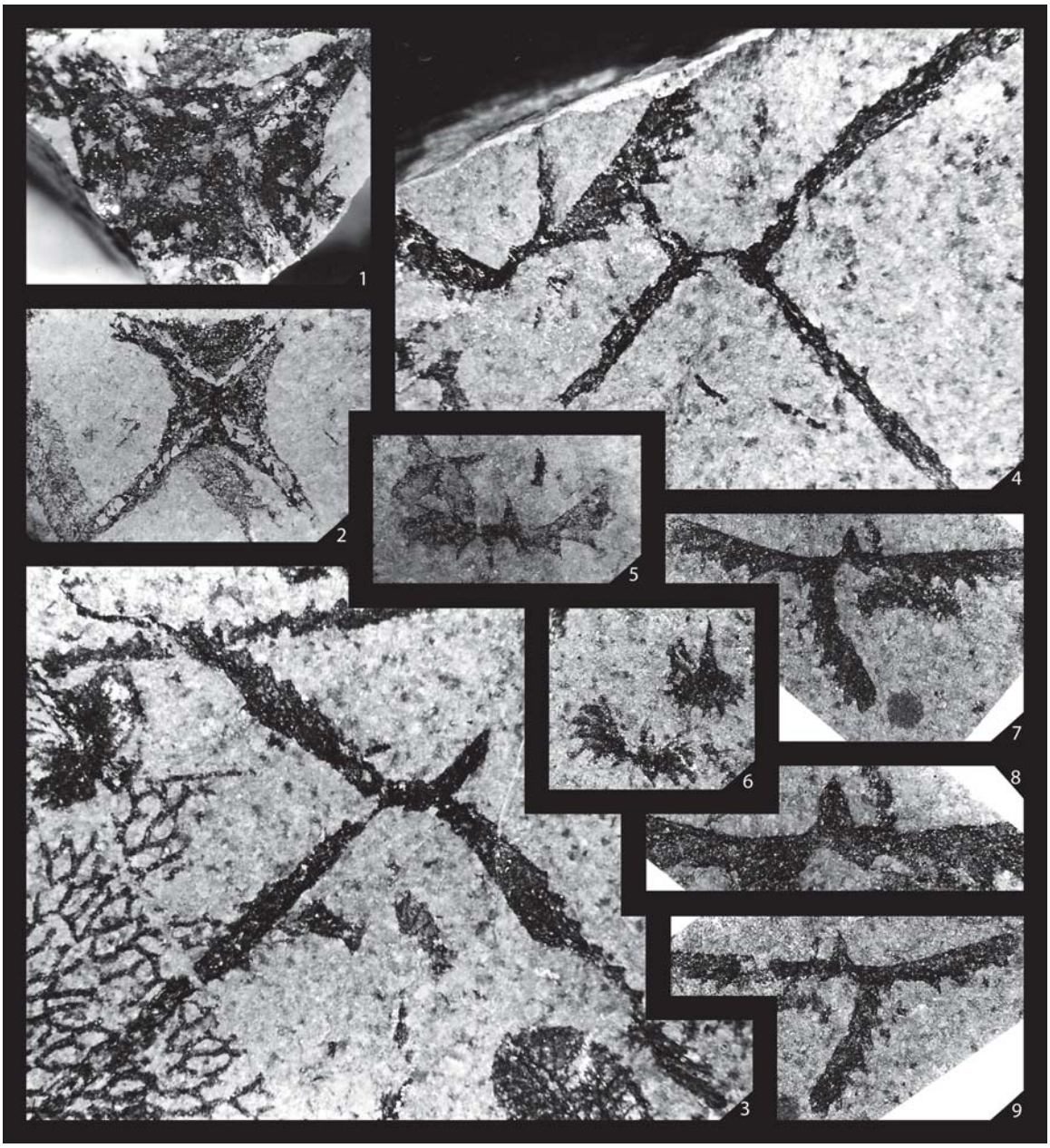
11. 87SF-10, x5.

12. 88BP-5, x5.

13. 87SF-70, x5.

14. 87SF-70, x10.

15, 16. 88BP-5, x5.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## Plate 4

**Figs. 1-9.** *Phyllograptus anna* Hall, 1858, 87SF-1.

1-3. x5.

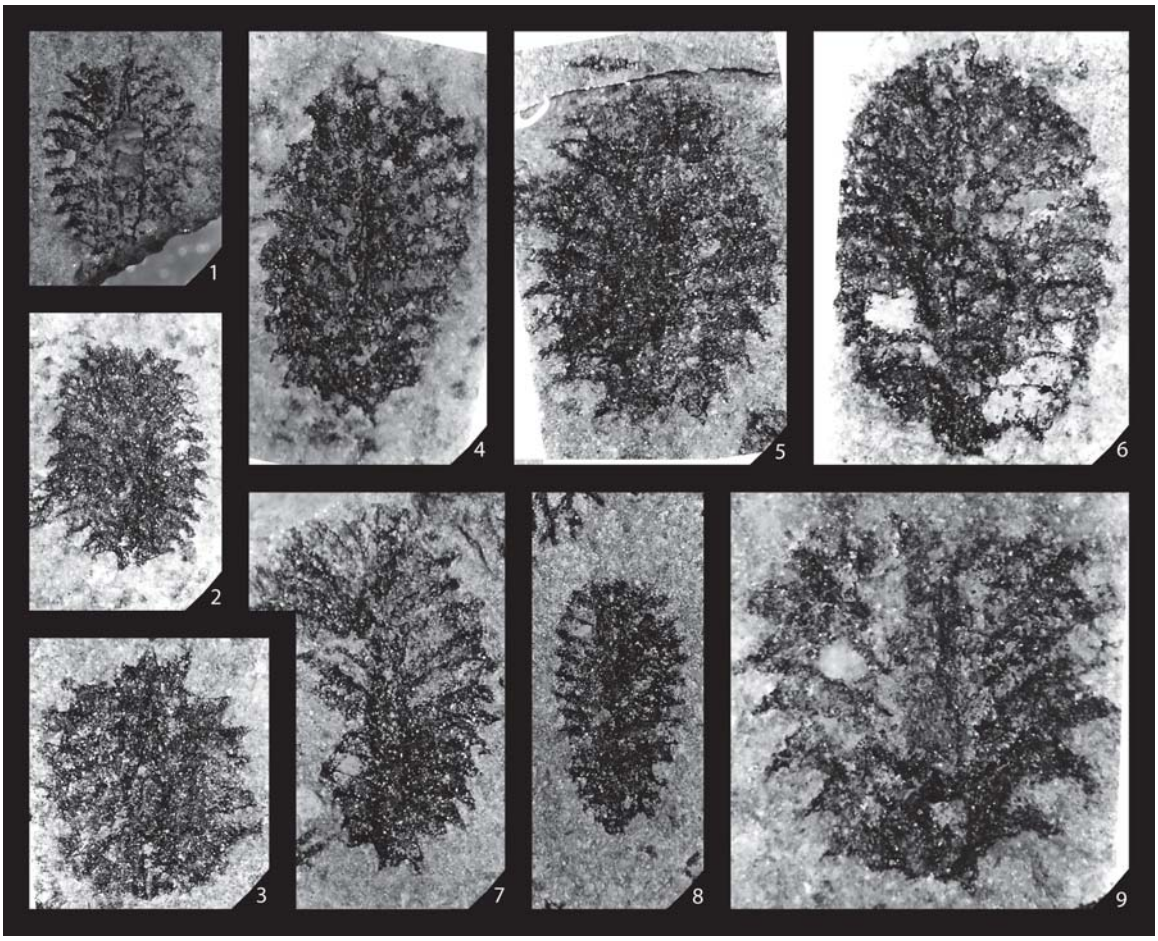
4. x10.

5. x5.

6. x10.

7, 8. x5.

9. x15.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## Plate 5

**Figs. 1-12.** *Didymograptus bifidus* (J. Hall, 1858), 87SF-10, 87SF-69, 87SF-70, 88BP-5.

1, 2. 88BP-5, x5.

3. 87SF-69, x2.5.

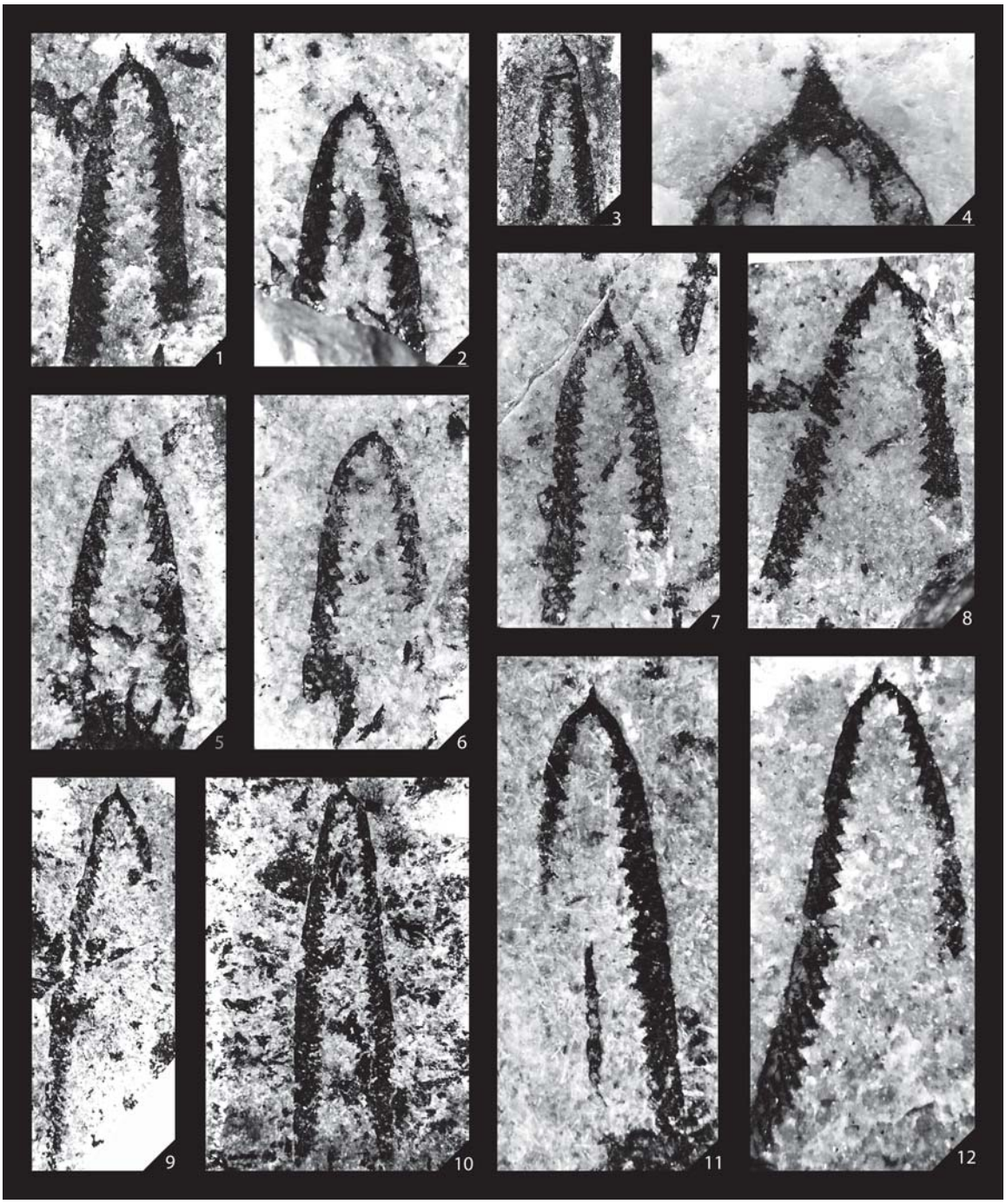
4. 88BP-5, x10.

5, 6. 87SF-10, x5.

7, 8. 88BP-5, x5.

9-10. 87SF-10, x2.5.

11, 12. 88BP-5, x5.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## Plate 6

**Figs. 1-6.** *Didymograptus paranidentus*, 87SF-1.

1. x10.

2-4. x5.

5. x10.

6. x5.

**Figs. 7-13.** *Didymograptus bifidus* (J. Hall, 1858), 87SF-10, 87SF-69, 87SF-70, 88BP-5.

7. 87SF-70, x10.

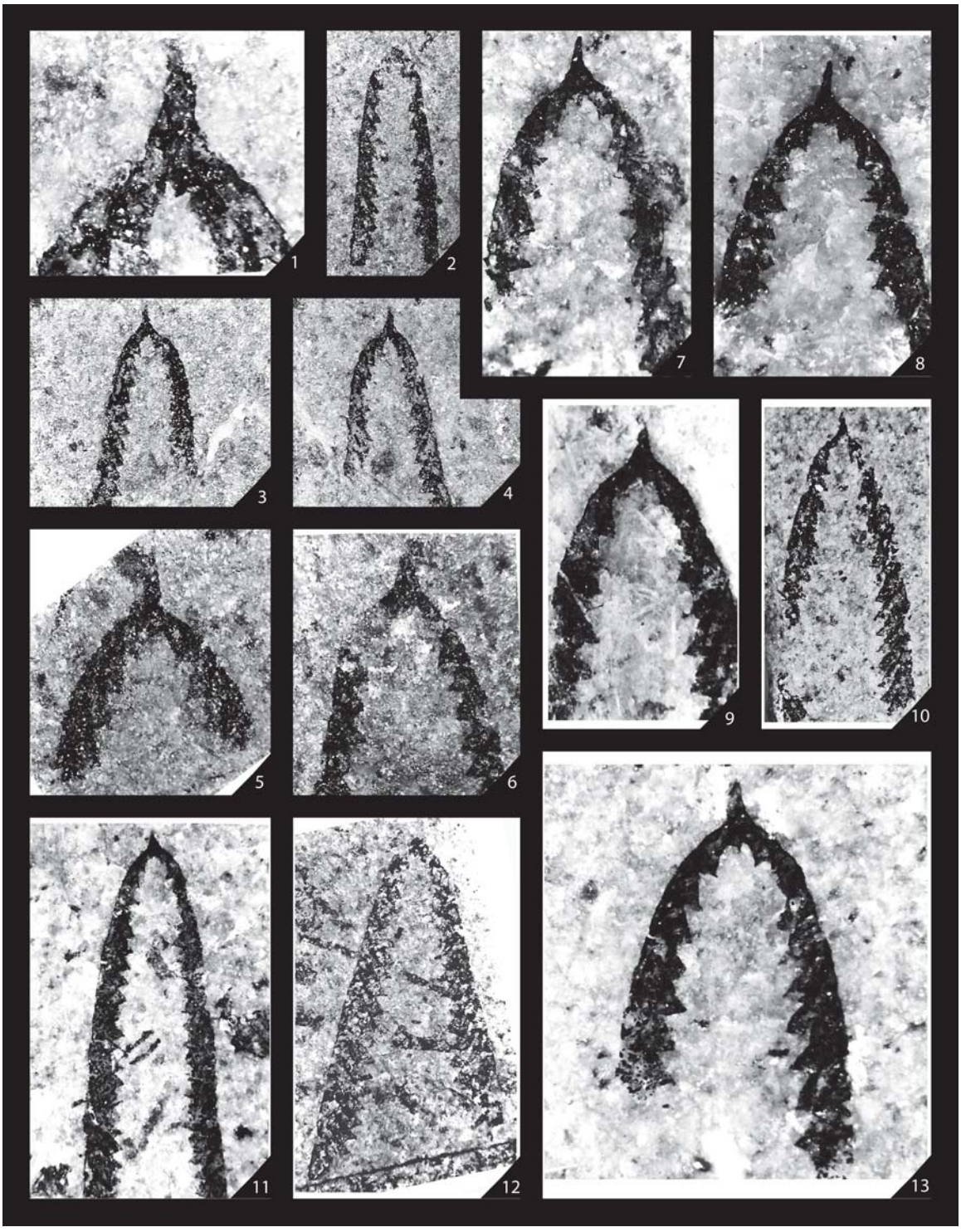
8, 9. 88BP-5, x10.

10. 87SF-70, x5.

11. 88BP-5, x5.

12. 87SF-70, x5.

13. 87SF-70, x10.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## Plate 7

**Figs. 1-6.** *Didymograptus v-deflexus*

1-3. 88MM-4, x10.

4-5. 88MM-4, x 20.

6. 87SF-70, x10.

**Fig. 7.** *Holmograptus* sp., 87SF-1, x5.

**Figs. 8, 9.** *Didymograptus v-deflexus*

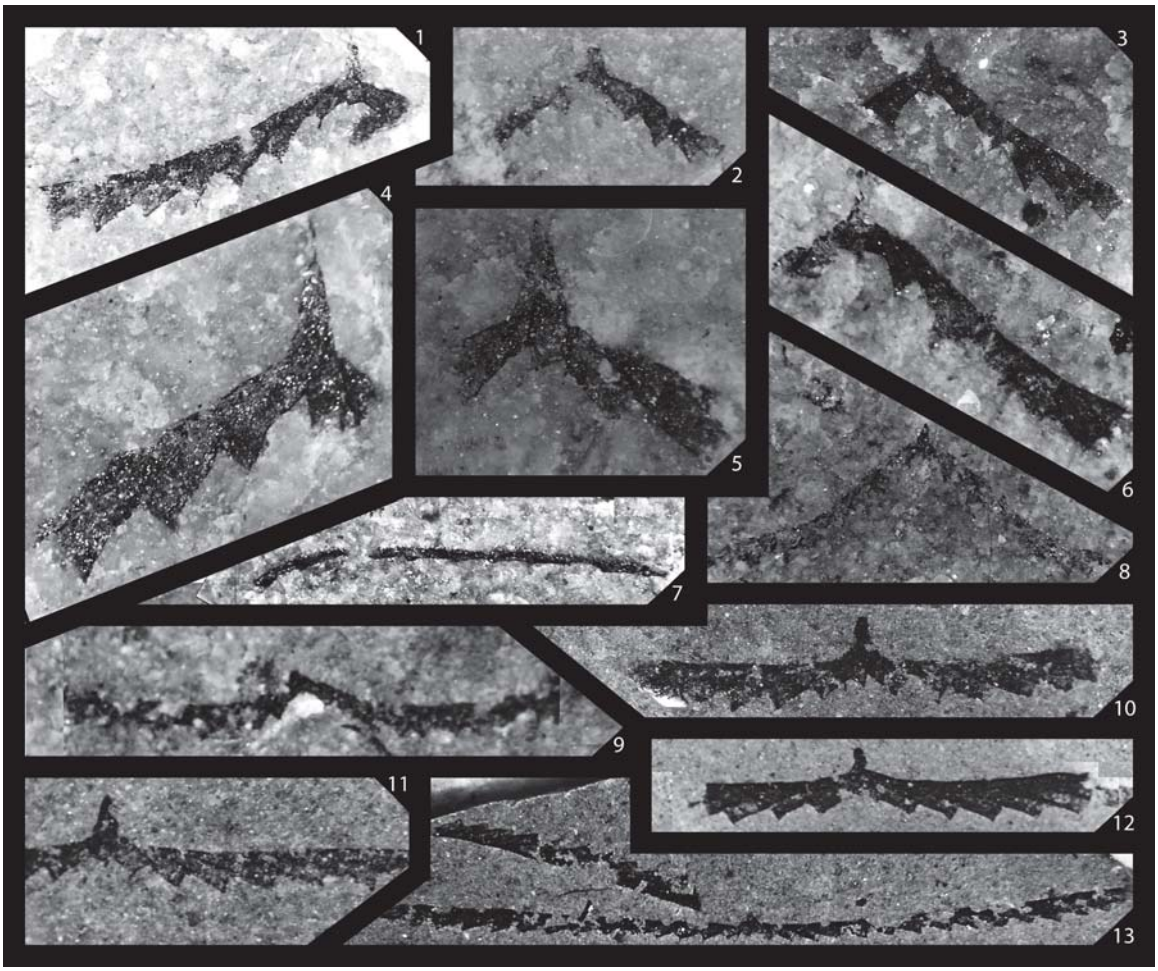
8. 88BP-5, x5.

9. 88MM-4, x5.

**Figs. 10-13.** *Didymograptus extensus* (J. Hall, 1858), 89BP-10.

10-12. x10.

13. x5.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## Plate 8

**Figs. 1-12.** *Xiphograptus svalbardensis* (Archer and Fortey, 1974).

1. 89BP-10, x20.

2. 87SF-70, x10.

3. 89BP-10, x15.

4. 88BP-5, x2.5.

5. 87SF-70, x5.

6. 88BP-5, x2.5.

7, 8. 89BP-10, x5.

9. 88BP-5, x5.

10. 89BP-10, x5.

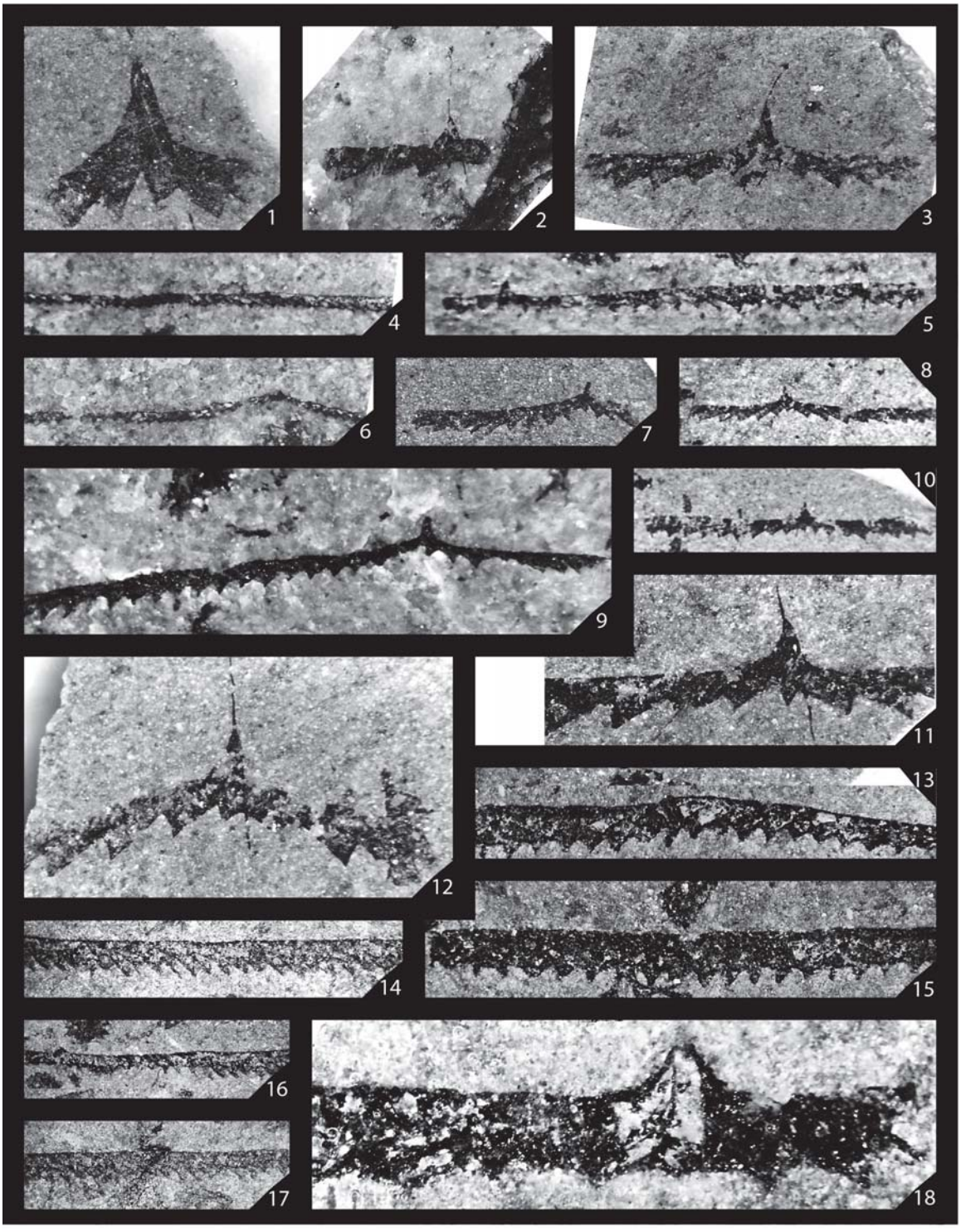
11, 12. 89BP-10, x10.

**Figs. 13-18.** *Xiphograptus cypselo* (Archer and Fortey, 1974), 87SF-1.

13, 14. x5.

15-17. x2.5.

18. x10.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## Plate 9

**Figs. 1, 2.** *Cardiograptus* sp., 87SF-1, x2.5.

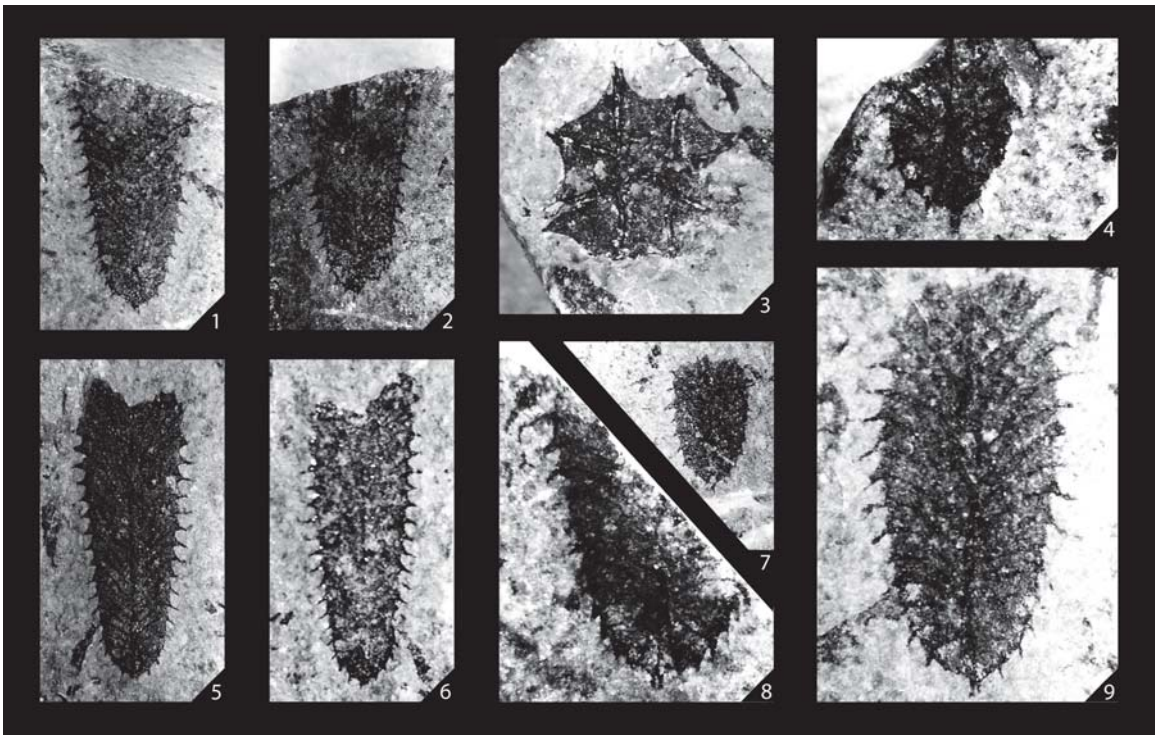
**Fig. 3.** *Dichograptus* sp., 88BP-5 47, x2.5.

**Fig. 4-9.** *Cardiograptus* sp., 87SF-1.

4. x5.

5-7. x2.5.

8, 9. x5.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## Plate 10

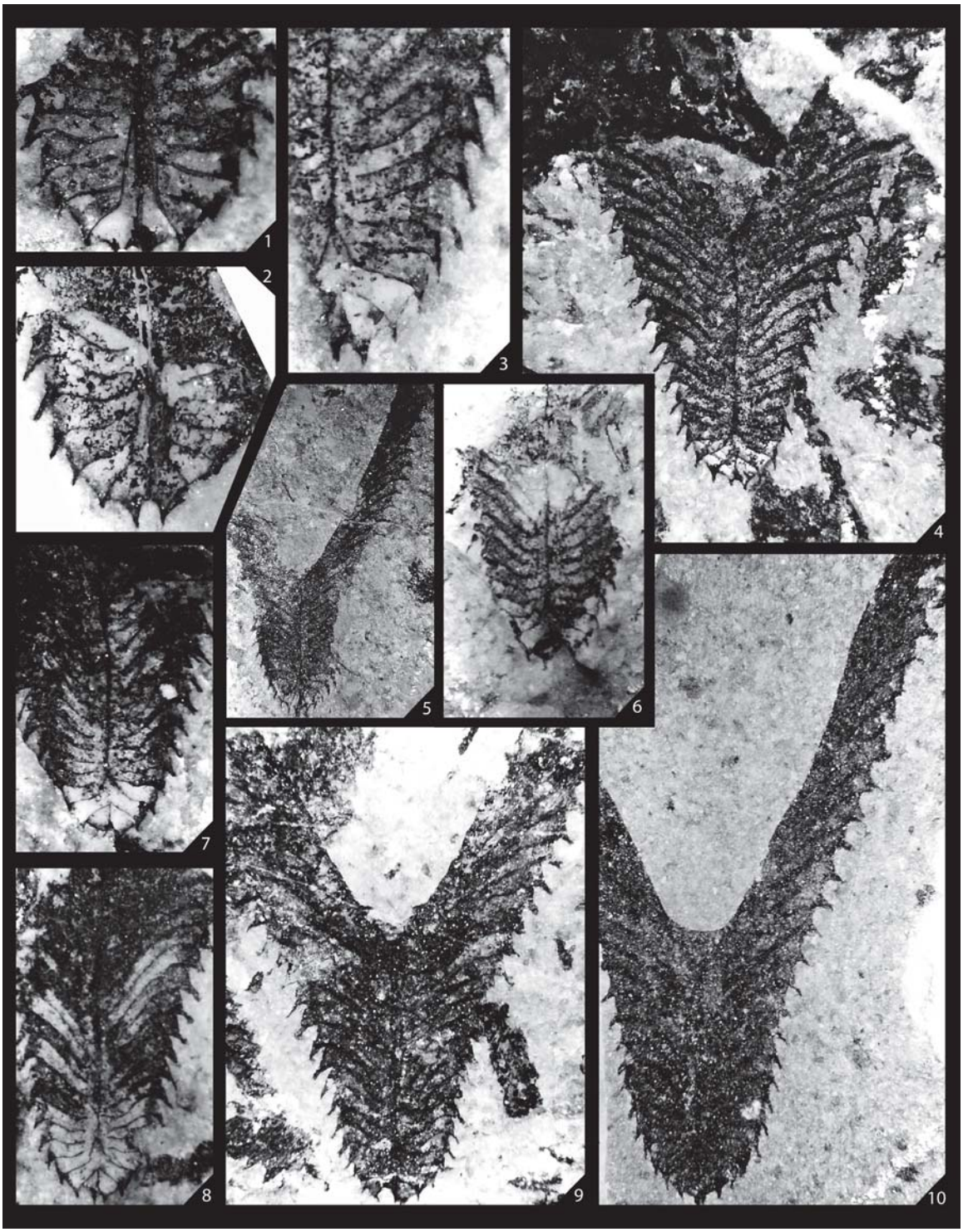
**Figs. 1-10.** *Oncograptus upsilon biangulatus* Harris and Keble, 1916.

1-3. 87SF-70, x10.

4. 87SF-1, x5.

5-9. 87SF-70, x5.

10. 87SF-1, x5.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## Plate 11

**Figs. 1, 2.** *Isograptus victoriae* sp., 89BP-10

1. x10.

2. x5.

**Figs. 3-9.** *Isograptus victoriae victoriae* Harris, 1933

3. 92SF-11, x5.

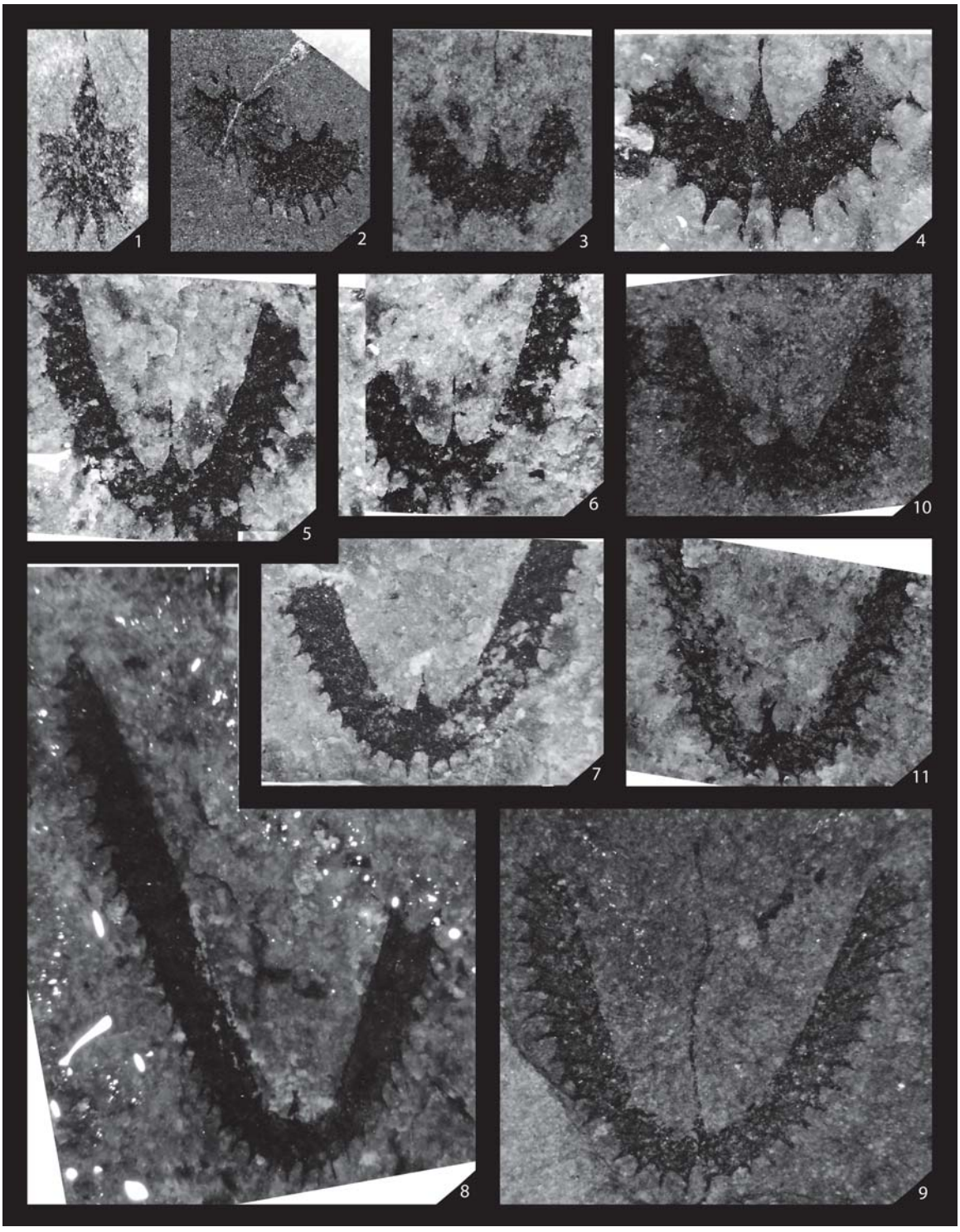
4. 92SF-11, x10.

5. 92SF-11, x5.

6. 88MM-4, x5.

7-9. 92SF-11, x5.

**Figs. 10, 11.** *Isograptus victoriae lunatus* Harris, 1933, 92SF-16, x10.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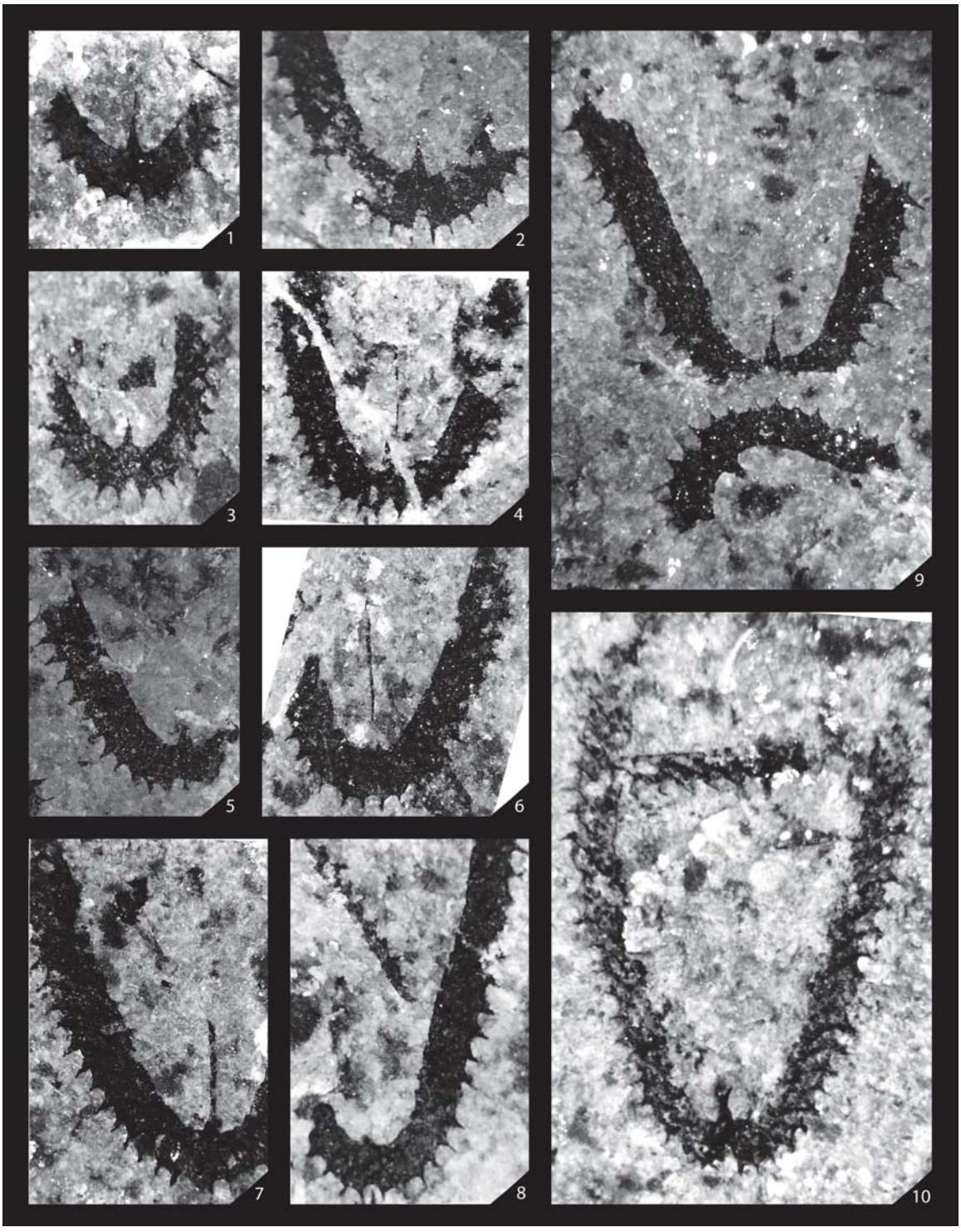
## Plate 12

**Figs. 1-10.** *Isograptus victoriae victoriae* Harris, 1933, x5.

1. 92SF-11.

2. 88MM-4.

3-10. 92SF-11.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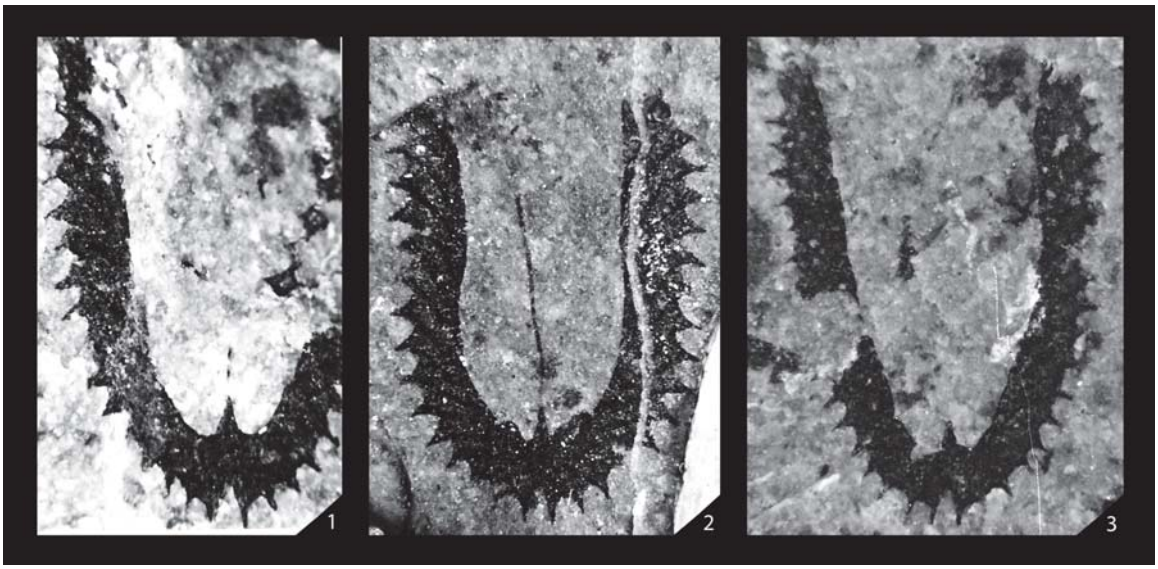
## Plate 13

**Figs. 1-3.** *Isograptus victoriae victoriae* Harris, 1933, x5.

1. 92SF-11.

2. 88MM-4.

3. 92SF-11.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## Plate 14

**Figs. 1-10.** *Isograptus victoriae maximus* Harris, 1933

1. 88BP-5, x5.

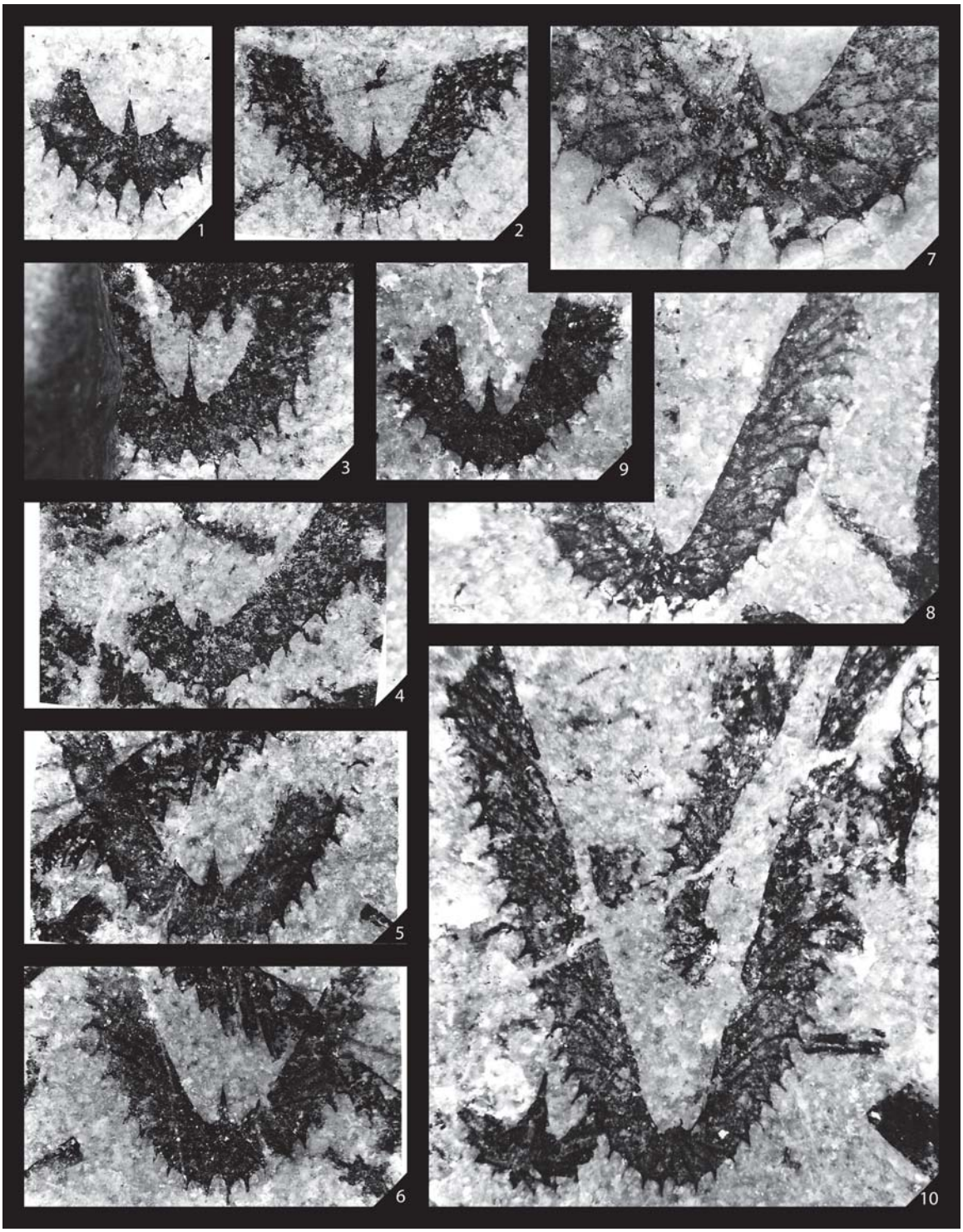
2-6. 87SF-70, x5.

7, 8. 88BP-5.

7. Proximal detail, x10.

8. Complete specimen, x5.

9, 10. 88BP-5, x5.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## Plate 15

**Figs. 1-12.** *Isograptus caduceus australis* Cooper, 1973.

1. 87SF-1, x5.

2. 87SF-70, x5.

3, 4. 87SF-1, x5.

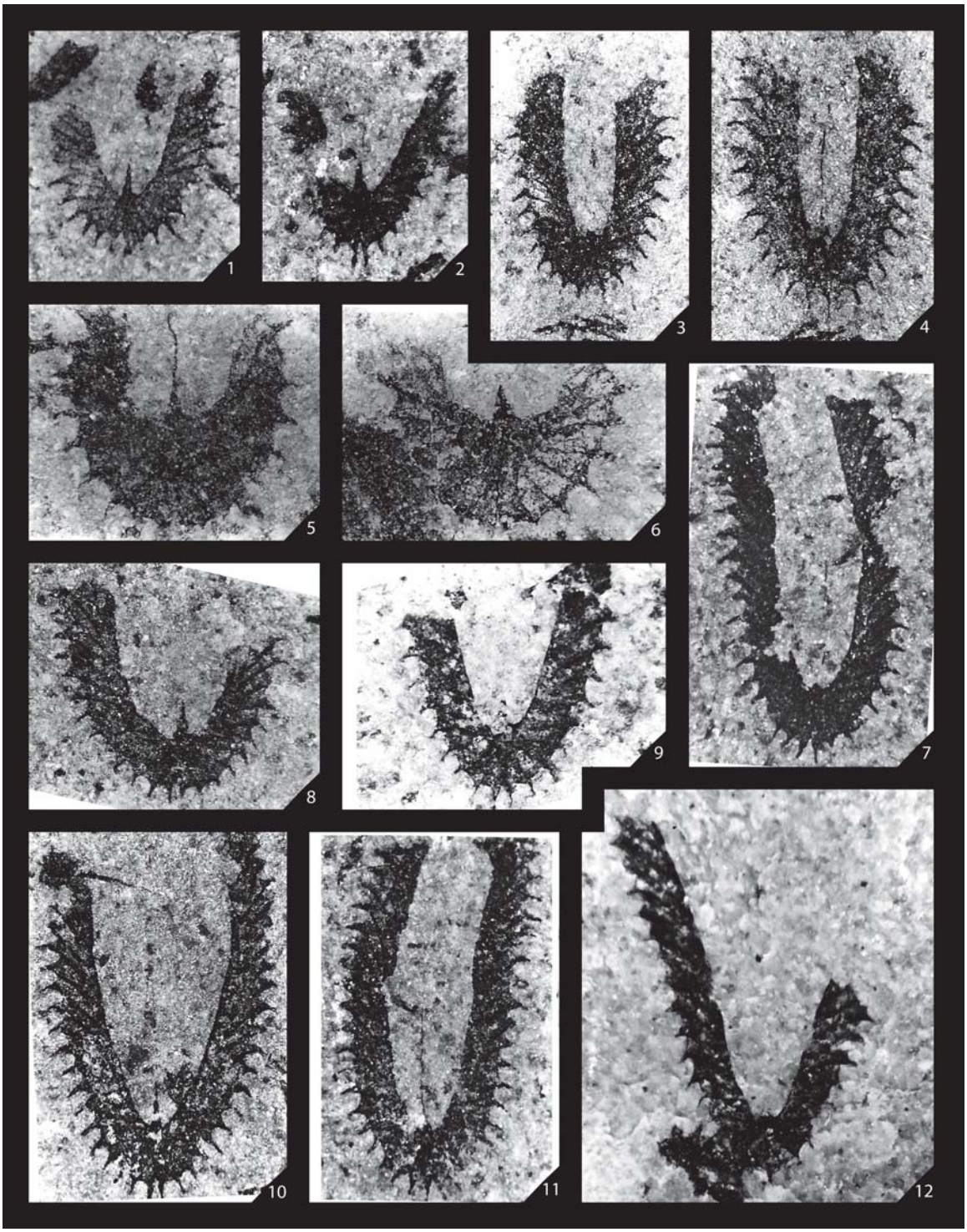
5, 6. 87SF-1, x10.

7, 8. 87SF-1, x5.

9. 87SF-70, x5.

10, 11. 87SF-1, x5.

12. 88BP-5, x5.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## Plate 16

**Figs. 1-7.** *Isograputs caduceus australis* Cooper, 1973.

1. 88BP-5, x5.

2. 87SF-1, x5.

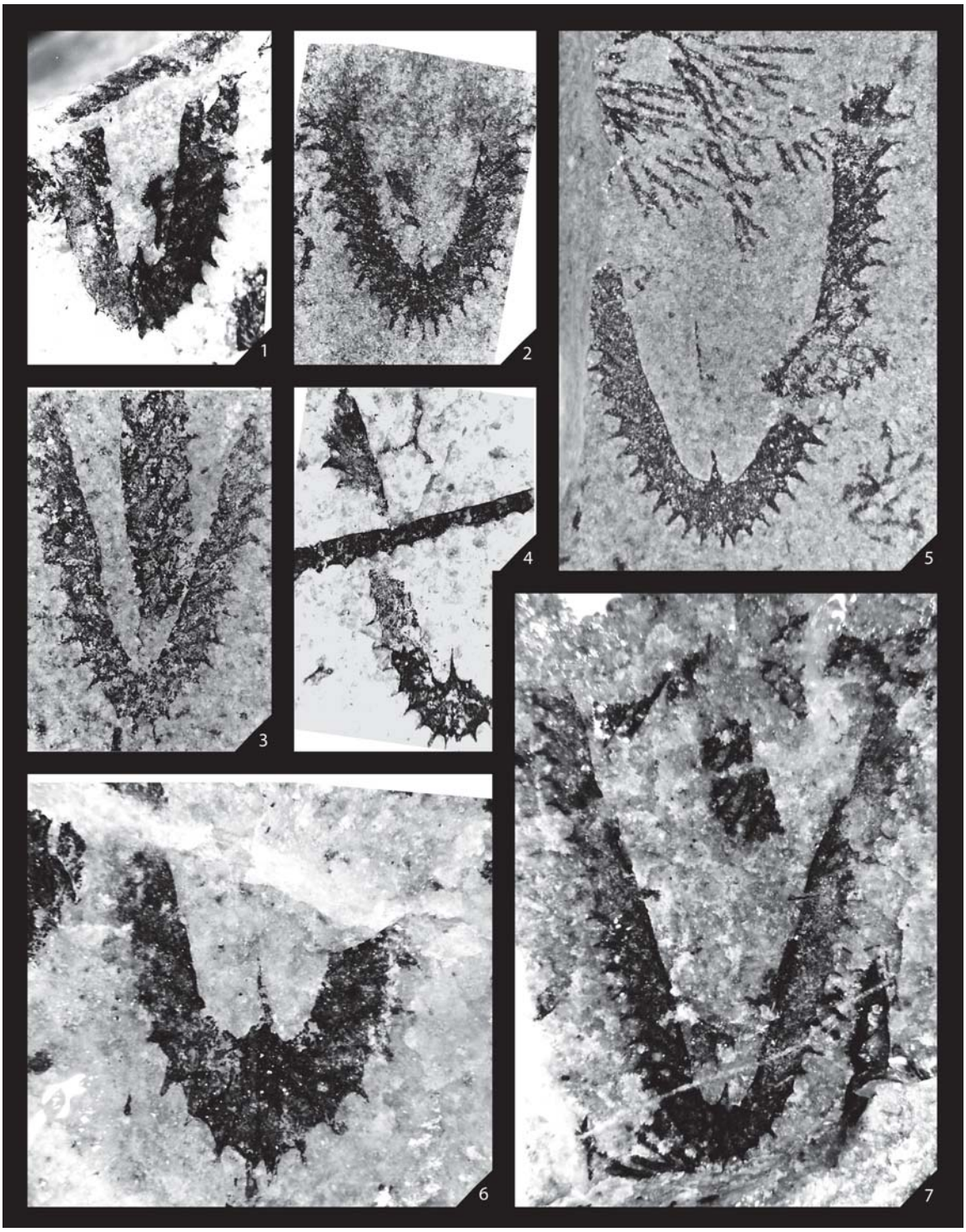
3. 87SF-70, x5.

4. 88BP-5, x5.

5. 87SF-1, x5.

6. 87SF-70, x10.

7. 88BP-5, x5.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## Plate 17

**Figs. 1-4.** *Pseudisograptus dumosus* (Harris, 1933), x5.

1. 87SF-1.

2-4. 87SF-70.

**Fig. 5.** *Isograptus subtilis* Williams and Stevens, 1988, 87SF-1, x5.

**Figs. 6-9.** *Pseudisograptus gracilis* (Ruedemann, 1947).

6. 87SF-1, x5.

7. 87SF-1, x10.

8, 9. 89BP-10, x15.

**Figs. 10-15.** *Isograptus victoriae divergens* Harris, 1933, 87SF-1.

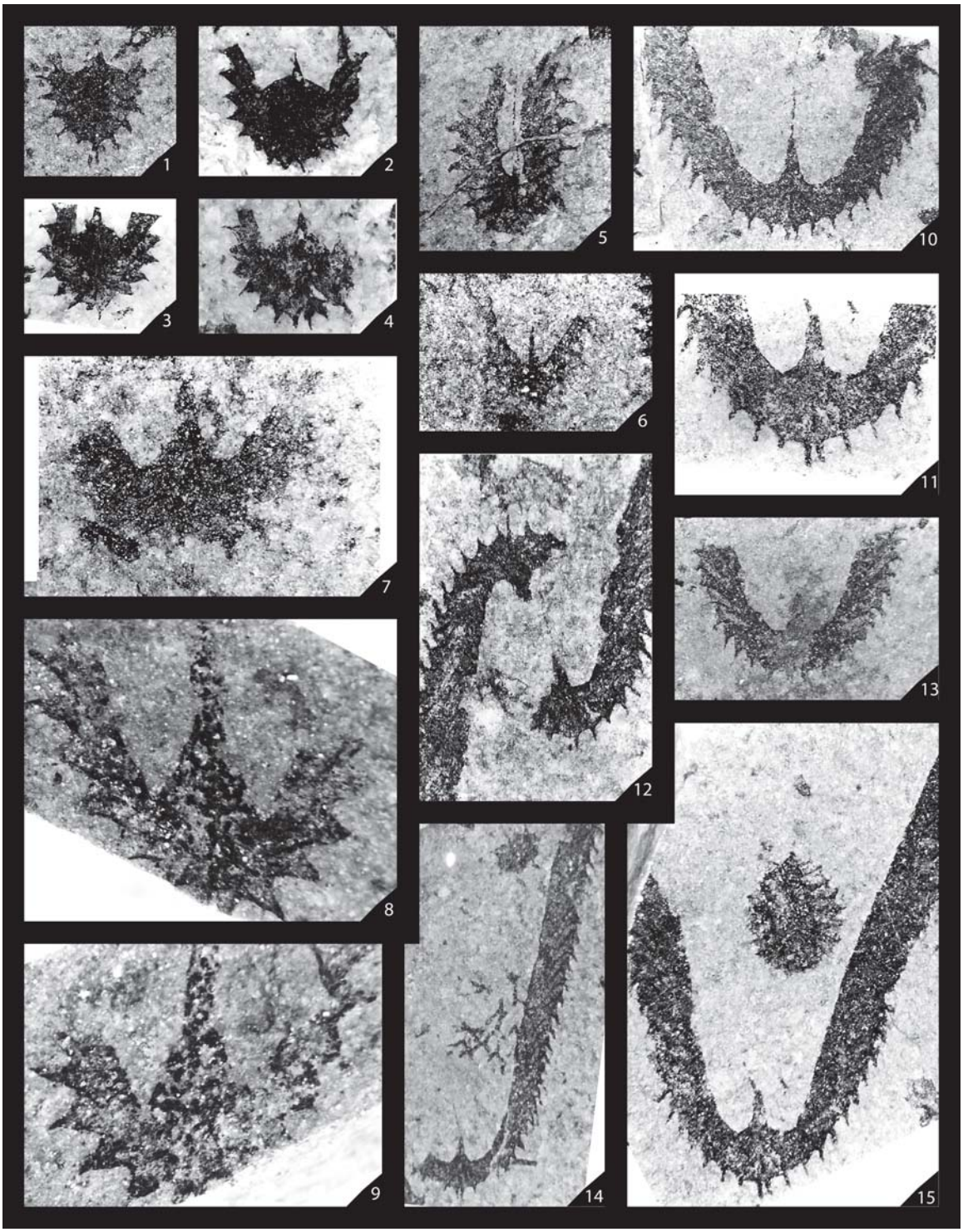
10. x5.

11. x10.

12, 13. x5.

14. x3.

15. x5.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## Plate 18

**Figs. 1-12.** *Pseudisograptus manubriatus koi* Cooper and Ni, 1986.

1. 87SF-70, x10.

2. 87SF-70, x5.

3, 4. 88BP-5.

3. Proximal detail, x10.

4. Complete specimen, x5.

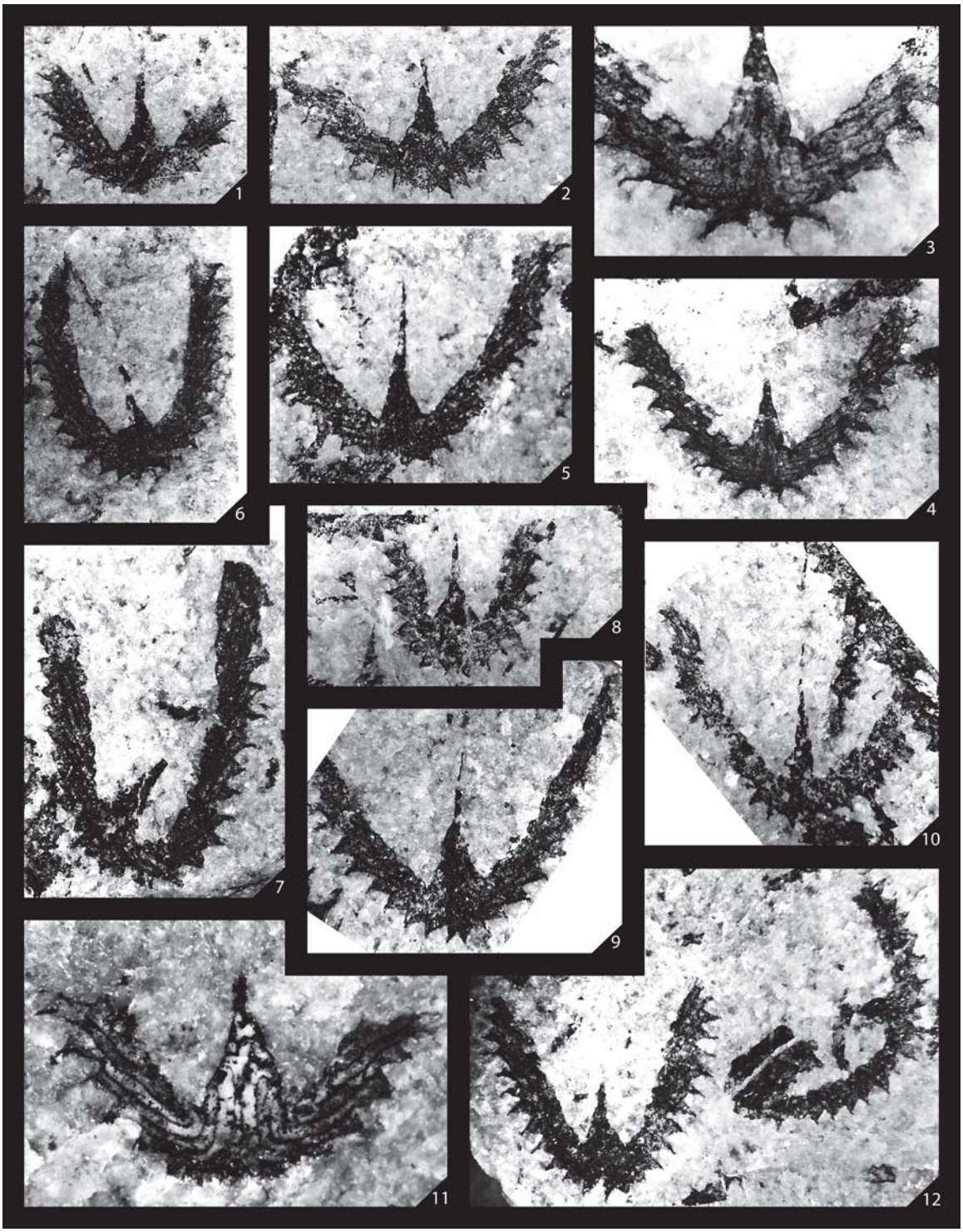
5. 87SF-70, x5.

6. 87SF-70, x10.

7-10. 87SF-70, x5.

11. 88BP-5, x10.

12. 88BP-5, x5.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## Plate 19

**Fig. 1.** *Undulograptus* sp., 87SF-1, x5.

**Figs. 2-8.** *Undulograptus astrodentatus americanus* (Bulman, 1963), 87SF-1.

2-5. x5.

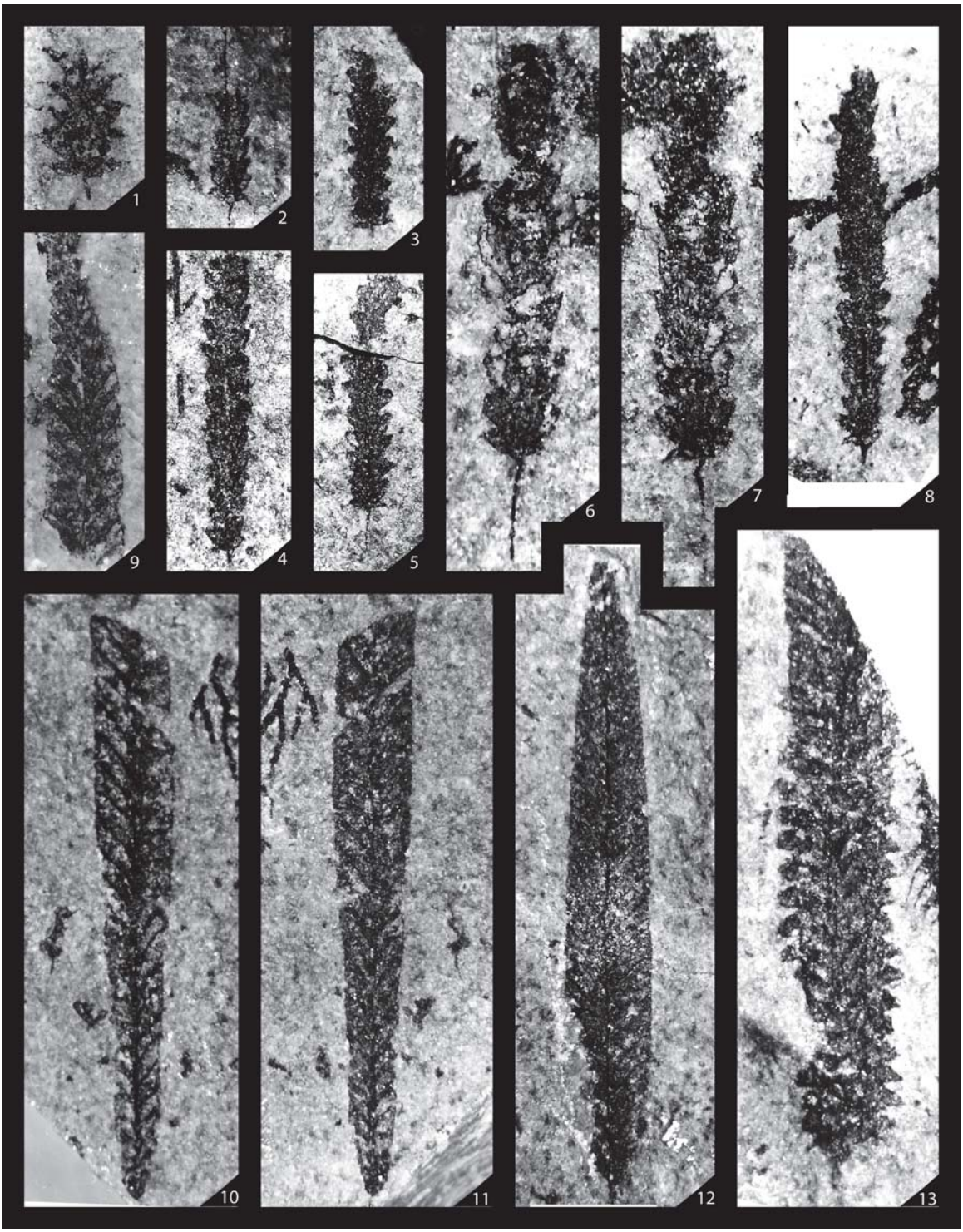
6, 7. x10.

8. x5.

**Figs. 9-13.** *Pseudotrigonograptus ensiformis* (J. Hall, 1865), x5.

9. 87SF-70.

10-13. 87SF-1.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## Plate 20

**Figs. 1-12.** *Glossograptus acanthus* Elles and Wood, 1908.

1. 87SF-10, x5.

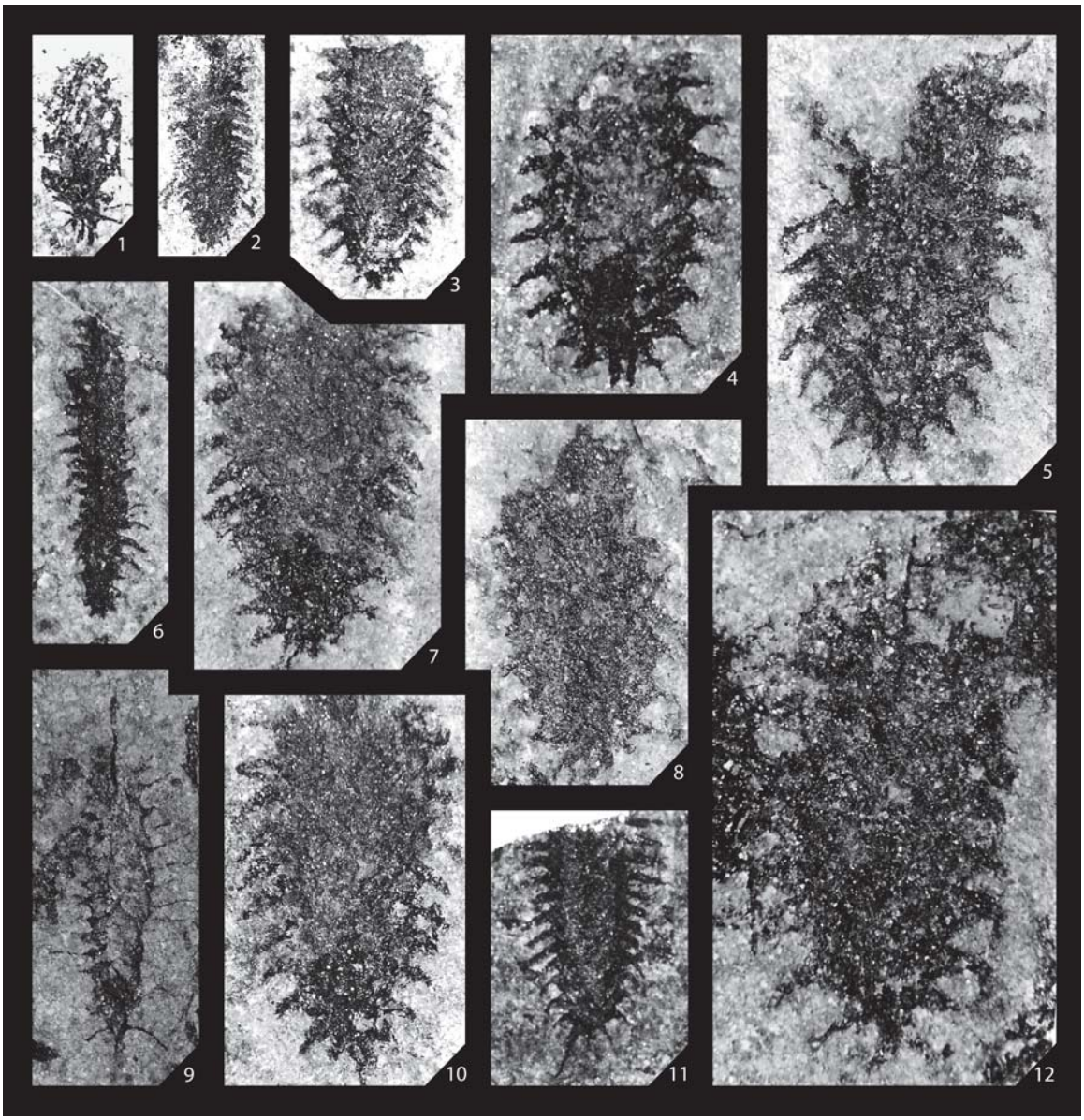
2. 87SF-69, x2.5.

3. 87SF-1, x10.

4-10. 87SF-1, x5.

11. 87SF-69, x5.

12. 87SF-1, x2.5.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