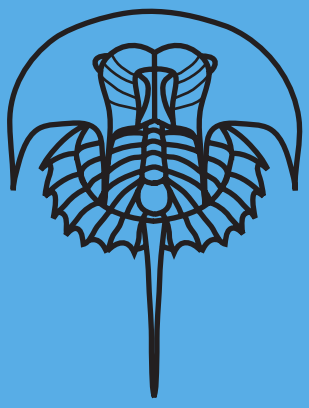

TREATISE ONLINE

Number 107

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Jörg Maletz, Yuandong Zhang,
and Alfons H. M. VandenBerg

2018

KU PALEONTOLOGICAL INSTITUTE
The University of Kansas

Lawrence, Kansas, USA
ISSN 2153-4012
paleo.ku.edu/treatiseonline

PART V, SECOND REVISION, CHAPTER 19: SUBORDER SINOGRAPTINA: INTRODUCTION, MORPHOLOGY, AND SYSTEMATIC DESCRIPTIONS

Jörg Maletz,[1] Yuandong Zhang,[2] and Alfons H. M. VandenBerg[3]

[1]Institut für Geologische Wissenschaften, Freie Universität Berlin, Malteser Str. 74–100, Berlin, Germany, yorge@zedat.fu-berlin.de; [2]Nanjing Institute of Geology & Palaeontology, Academia Sinica, Chi-Ming-Ssu, Nanjing, China, ydzhang@nigpas.ac.cn; [3]Geology, Museums Victoria, GPO Box 666, Melbourne, Vic 3001, Australia, lanceolatus@hotmail.com]

Suborder SINOGRAPTINA Mu, 1957

[Sinograptina MU, 1957, p. 387; *nom. transl.* Maletz, Zhang, & VandenBerg, herein; *ex* Sinograptidae Mu, 1957, p. 387] [=cohort Pan-Sinograpta Maletz, Carlucci, & Mitchell, 2009, p. 11]

Planktonic graptoloids with multiramous to single-stiped, horizontal to subhorizontal tubarium; sicula often nearly parallel sided and without rutellum, oriented perpendicular to stipes; proximal development isograptid, dextral or sinistral with distinct asymmetry of the crossing canals, lost in derived forms; artus-type development in derived taxa; origin of th1[1] in middle part of prosicula in early taxa, but generally in lower part of prosicula, rarely in metasicula; thecal style varies from simple dichograptid with gradually widening thecae to forms with distinctly differentiated pro- and metathecae; thecal elaborations such as prothecal folds, lateral apertural lappets, rutella or spines common; fusellum normal to strongly reduced and possibly lacking in some (Abrograptidae). *Lower Ordovician (upper Tremadocian,* Sagenograptus murrayi *Biozone)–Upper Ordovician (Sandbian,* Climacograptus bicornis *Biozone):* worldwide.

INTRODUCTION

The maeandrograptid proximal symmetry of the Graptodendroidina (Fig. 1.4) is retained in the Sinograptina, but the orientation of the sicula is changed from an oblique position to a vertical position (Fig. 1.1–1.2). The proximal development of the early members of the Sinograptina is characterized by very slender crossing canals and slender prothecal tubes with considerably widening metathecae. It shows some similarity to the features of the Graptodendroidina, with their typical asymmetrical development of the slender crossing canals, but lacks the typical bithecae of the Graptodendroidina. In all taxa, the first crossing canal diverges from the sicula at a point distinctly higher on the metasicula than the second crossing canal. The first crossing canal grows from its origin obliquely downwards and across the reverse side of the sicula. Its ventral side touches the dorsal side of the sicular aperture, where it often bends considerably to form the horizontal stipe (Fig. 1.1). The second crossing canal grows horizontally across the metatheca of th1[1] (Fig. 1.2). Both crossing canals are slender and the thecae widen only distally, towards the apertures in *Paradelograptus*.

Maletz, Carlucci, and Mitchell (2009, p. 11) defined the subcohort Pan-Sinograpta as the group comprising the common ancestor of *Nicholsonograptus fasciculatus* (Nicholson, 1869)—the first species with a slender sicula and parallel-sided prosicula—and all its descendants, based on the cladistic diagram provided in their paper. According to the authors, the cohort Pan-Sinograpta is a sister group to the cohort Pan-Reclinata, differing mainly in the development of the sicula and the shape and position of the crossing canals. The internal structure of the clade is not well resolved, but a number

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Maletz, Jörg, Yuandong Zhang, & A. H. M. VandenBerg. 2018. Part V, Second Revision, Chapter 19: Suborder Sinograptina: Introduction, morphology, and systematic descriptions. Treatise Online 107:1–23, 17 fig.

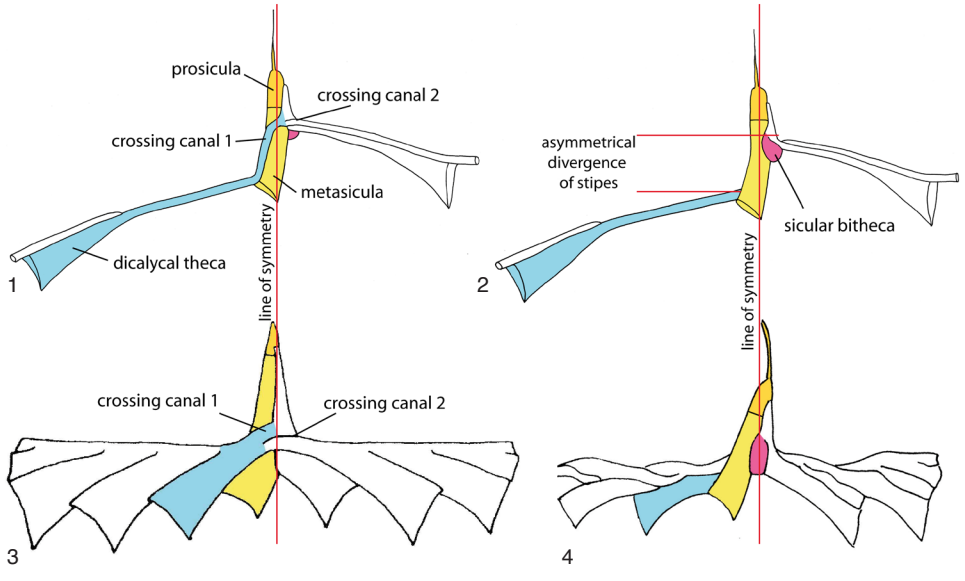

FIG. 1. Sinograptid (*1–2*) and dichograptid (*3–4*) proximal ends. *1–2*, *Paradelograptus onubensis* ERDTMANN, MALETZ, & GUTIERREZ-MARCO, 1987; *1,* reverse view, dextral; *2,* obverse view, sinistral, showing sicular bitheca; *3*, *Expansograptus holmi* (TÖRNQUIST, 1901), reverse view, dextral, showing inclination of sicula; *4*, *Kiaerograptus supremus* LINDHOLM, 1991, obverse view, sinistral, showing strong inclination of sicula (new).

of distinct groups are present (MALETZ, CARLUCCI, & MITCHELL, 2009). Derived forms are often strongly modified and may be difficult to classify. The Sinograptidae is the only group to show up as distinct in the cladistic analysis of MALETZ, CARLUCCI, and MITCHELL (2009), but it included the genus *Maeandrograptus*, here referred to the Sigmagraptidae (Fig. 2). The genus *Acrograptus*, which they included in the stem-reclinatids (suborder Dichograptina, herein) as a sister to *Didymograptellus* TZAJ, 1969, is now referred to the Sigmagraptidae, based on the proximal development. The genus *Perissograptus* with its four reclined stipes is considered to be a close relative to *Maeandrograptus.*

TAXONOMY OF THE SINOGRAPTINA

The differentiation of the Sinograptina into families, as proposed herein, is based mainly on proximal-end features. The older (upper Tremadocian to Darriwilian) Sigmagraptidae shows an asymmetrical proximal-end development with fairly simple thecal styles. The younger (largely Darriwilian) Sinograptidae possess a symmetrical development of the crossing canals and a more complex thecal style with prothecal folds, and some may even have metathecal folds. The Abrograptidae is differentiated by the reduction of the fusellum. However, whether it constitutes a monophyletic family is uncertain, as detailed tubarium structures are unknown for most members. The Thamnograptidae are referred to the Sinograptina as *incertae sedis,* as they share similarities in their thecal development. However, the proximal end of the Thamno-graptidae is known only from poorly preserved specimens of *Wuninograptus* NI, 1981.

Family SIGMAGRAPTIDAE Cooper & Fortey, 1982

[Sigmagraptidae COOPER & FORTEY, 1982, p. 259] [*nom. transl.* FORTEY & COOPER, 1986, p. 652; *ex* Sigmagraptinae COOPER & FORTEY, 1982, p. 259] [incl. Goniograptidae YU & FANG, 1979, p. 441; Azygograptinae MU, 1950, p. 176; Kinnegraptidae MU, 1974, p. 231; Prokinnegraptidae YU & FANG, 1979, p. 441]

Multiramous to one-stiped, reclined to horizontal and pendent tubaria; colony

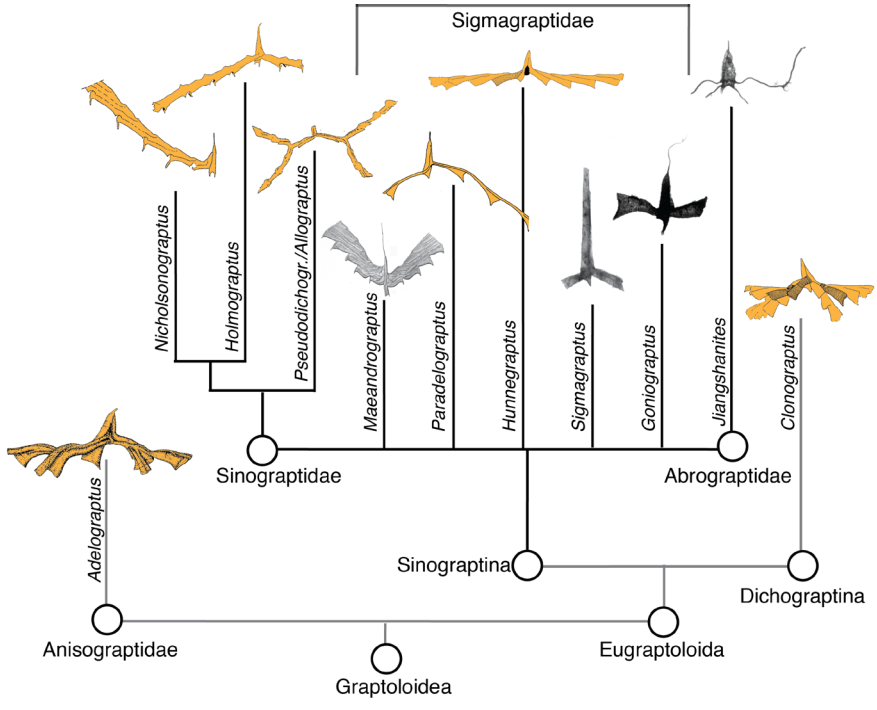

FIG. 2. The Sinograptina (new, based on diagram in MALETZ, CARLUCCI, & MITCHELL, 2009, fig. 2).

biradiate with asymmetrical placing of first-order stipes; sicula parallel sided or nearly parallel sided with parallel-sided prosicula; proximal development isograptid, dextral or sinistral, or of artus-type development in derived taxa; origin of first theca in median part of prosicula in early taxa, in lower part of prosicula in younger ones; crossing canals more slender than in Dichograptina; thecae simple or with complex and elaborate apertures, slender and sometimes elongated. *Lower Ordovician (upper Tremadocian,* Sagenograptus murrayi *Biozone)–Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* worldwide.

COOPER and FORTEY (1982) introduced the subfamily Sigmagraptinae for gracile dichograptid graptolites with an asymmetrical proximal end and a long and slender sicula. The earliest sigmagraptid in the current interpretation appears to be the genus *Paradelograptus* from the upper Tremadocian *Sagenograptus murrayi* Biozone, representing the first group of graptolites in which the thecae became differentiated into distinct pro- and metathecae. The Sigmagraptidae retain the asymmetrical divergence of the stipes from their ancestors, but change the orientation of the sicula. The widening cone of the sicula of the Graptodendroidina is modified and the metasicula in the Sigmagraptidae is more or less parallel sided with little widening from the aperture of the prosicula. Rutella are lacking in early Sigmagraptidae, but elaborate rutella can be found in some derived forms (i. e., *Kinnegraptus*).

MORPHOLOGY

The Sigmagraptidae includes taxa with a single stipe to taxa with numerous branching divisions. Branching appears highly irregular in early taxa, but the genera *Goniograptus* and *Sigmagraptus* possess very regular monoprogressive branching. In general, the colonies are subhorizontal to umbrella-shaped, but reclined taxa also occur, while pendent taxa are rare. All taxa with more than one stipe have th1[2] as the only proximal

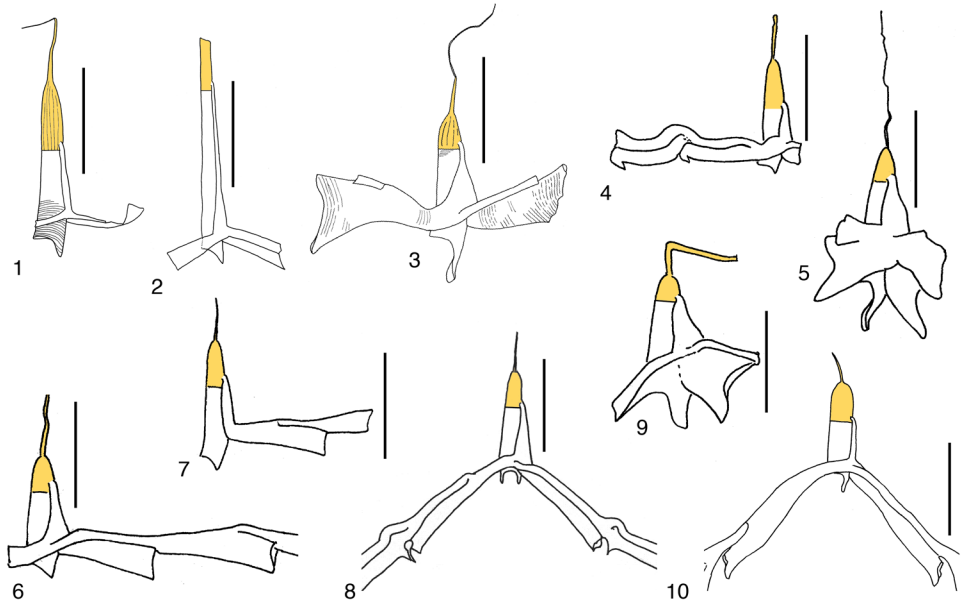

FIG. 3. Sicular and proximal development in the Sinograpta, prosicula shown in *color*. *1,* Sigmagraptine indet., GSC 81787a, showing long mitre-shaped prosicula with few longitudinal rods and isograptid, dextral development (new); *2, Sigmagraptus praecursor* RUEDEMANN, 1904, GSC 139255, CHN 11.4E, Cow Head Group, western Newfoundland (new); *3, Goniograptus thureaui* (M'COY, 1876), GSC 125786, proximal end with typical rutellate sicula and small prosicula (new); *4, Maeandrograptus sinuosus* MALETZ, 2004, holotype, GSC 125764, Sigmagraptidae (MALETZ, 2004, fig. 5I); *5, ?Eotetragraptus* sp. cf. *E. spinosus* (SPJELDNAES, 1953), GSC 125752, Sigmagraptidae (MALETZ, 2004, fig. 2V); *6,* GSC 125806, sigmagraptine p. indet. (MALETZ, 2004, fig. 6K); *7,* GSC 125810, sigmagraptine sp. with one single stipe (Maletz, 2004, fig. 6P); *8, Holmograptus* sp., Sinograptidae, reconstruction (new); *9, Keblograptus geminus* MALETZ, 2004, GSC 125778, Sigmagraptidae (Maletz, 2004: fig. 4C); *10, Anomalograptus reliquus* (CLARK, 1924), Sinograptidae, reconstruction (new). All scale bars, 1 mm.

dicalycal theca or lack proximal dicalycal thecae. The position of later dicalycal thecae is adventitious and irregular in many species, and the position of a dicalycal theca cannot be taken as a character of higher taxonomic value.

The sicula is highly variable in the Sigmagraptidae (Fig. 3), but species with a parallel-sided pro- and metasicula prevail (Fig. 3.1). In some genera, the prosicula is relatively large, often forming more than half of the length of the sicula. Strongly elongated siculae are present in some *Maeandrograptus* species and in *Sigmagraptus*. *Perissograptus* is a strongly derived genus sharing numerous tubarium characters with *Maeandrograptus*, but developing a reclined, four-stiped colony with an aperturally isolated, parallel-sided sicula. Siculae with strongly widening, triangular shapes develop in a number of genera (*Keblograptus*, *Kinnegraptus*, abrograptids) (Fig. 3.9). The prosicula has numerous longitudinal rods in many taxa, but the exact development in others is unknown. WILLIAMS and CLARKE (1999) illustrated prosiculae of *Goniograptus* sp. with few (~8–10) longitudinal ridges. There is no information on the differentiation of the conus and cauda in the prosicula of the Sigmagraptidae. The helical line is distinctive in chemically isolated specimens and in relief specimens of *Paradelograptus*, where the prosicular fusellar band is wider than the subsequent metasicular fusellar half rings (see *Adelograptus filiformis* WILLIAMS & STEVENS, 1991).

The proximal development type is isograptid, dextral in most forms (Fig. 3–4), but a sinistral development has been recognized in *Paradelograptus* (see ERDTMANN,

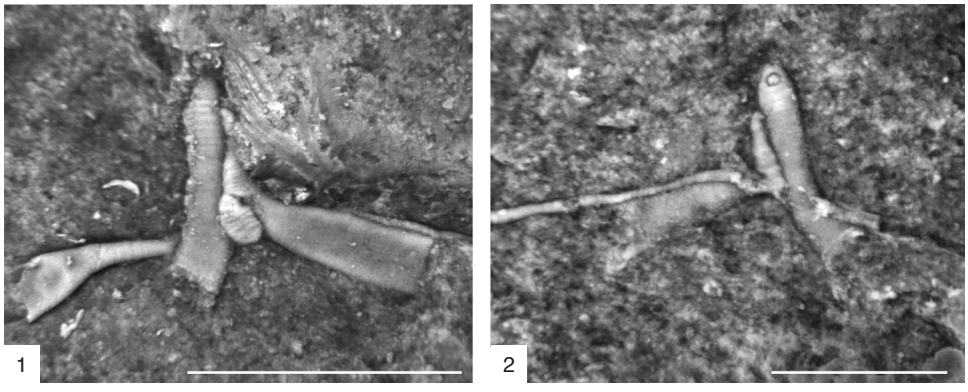

FIG. 4. Proximal development in *Paradelograptus*. *1*, specimen on slab with GSC 118739, obverse view showing sicular bitheca, sinistral development (*Adelograptus antiquus* T. S. HALL, 1899 in Jackson & Lenz, 2000, fig. 7A); *2*, GSC 118750, reverse view, sinistral development, crossing canal of th1[1] broken off (*Paradelograptus onubensis* in Jackson & Lenz, 2000, fig. 11A); specimens from Road River Formation, Yukon, Canada; scale bars, 1 mm (new).

MALETZ, & GUTIERREZ-MARCO, 1987) (Fig. 4.1). SKOGLUND (1961) described chemically isolated material of the genus *Kinnegraptus* from the Dapingian of Sweden with an artus-type development and a metasicular origin of th1[1]. The proximal development is uncertain in many slender sigmagraptines so that the taxonomic interpretation is often questionable. The development in *Acrograptus affinis* (NICHOLSON, 1869) can be interpreted as of artus-type, based on a possible topotype specimen illustrated by RUSHTON (2000a). It has a distal origin of th2[2] on th2[1], thus the dicalycal theca must be th1[1].

The origin of th1[1] is in the middle part of the prosicula in some *Paradelograptus* specimens known from relief material (Fig. 4). In most taxa, however, the origin of th1[1] is in the lower part of the prosicula (WILLIAMS & STEVENS, 1988; MALETZ, 2004). SKOGLUND (1961, fig. 5B) described and illustrated a high prosicular origin of th1[1] in *Prokinnegraptus multiramosus*, but this is based on fragmentary material and additional specimens are not available. This feature might indicate a secondarily derived condition.

The presence of bithecae is very difficult to verify in early members of the Sigmagraptidae, as the stipes are extremely slender and thecal details are difficult to see. A sicular bitheca is present in some early species of the genus *Paradelograptus* (Fig. 1, Fig. 4.1), but not in derived taxa of the genus. The sicular bitheca is short and wide and opens in the crotch between the sicula and th1[1] with the aperture directed towards the reverse side of the colony. Thecal bithecae have not been recognized in *Paradelograptus* and are unlikely to be present due to the dorsal origins of the very slender prothecae.

The Sigmagraptidae are characterized by the ability to generate a variety of thecal elaborations. The thecal length may vary considerably along the stipes in a number of taxa. As the thecae generally show a low overlap and inclination, lengthening of thecae and increase of thecal overlap provides a means of stability and rigidity for the stipes. A cross section of a distal stipe can cut through five or six thecae in mature specimens of *Maeandrograptus*. In *M. leptograptoides*, thecal overlap increases distally and stipes show considerable widening whereas in the robust *M. schmalenseei*, thecal length remains constant, with overlap remaining at three thecae. The changes seen in *M. leptograptoides* occur independently in the sinograptid genera *Holmograptus* and *Nicholsonograptus*, in which thecal overlap is low in the proximal portion of the stipe but very high in the extremely robust distal portion. The thecal apertures can be simple as in *Paradelograptus*, but considerable elborations are present in some younger forms.

Branching in the Sigmagraptidae is either progressive with regular or irregular dichotomous branching (*Paradelograptus*, *Anomalograptus*, *Allograptus*) or monoprogressive as exemplified by the genera *Goniograptus* and *Sigmagraptus*. Dichotomous lateral branching was reported in *Trichograptus* but no cladial branching has been observed.

The genus *Azygograptus* lost all capacity for branching and bears a single, usually curved, slender stipe. MALETZ (2004) described an unusual sigmagraptine taxon without a proximal dichotomy as sigmagraptine sp. 3. The species shows a typical slender sigmagraptine sicula with low prosicular origin of th1[1]. The first dichotomy is formed as a distal dichotomy only after two successive monocalycal thecae have developed from th1[1].

The Sigmagraptidae are here differentiated into a number of informal groups, but only for easier reference; no taxonomic implications are intended and a taxonomic differentiation of subgroups has to be left to the future when better material is known.

The following are multiramous to single-stiped genera with simple thecae.

Catenagraptus VANDENBERG, 2018, p. 4 [**C. communalis;* OD]. Assemblages of pseudotubaria resembling those of *Azygograptus* but linked by thread-like structures (aulons) of variable length that join fallosiculae to adjacent pseudotubaria. *Lower Ordovician (Floian,* Tshallograptus fruticosus *Biozone):* Australia.——FIG. 5,*6. *C. communalis,* holotype, NMV-P318828, Victoria, Australia, scale bar 1 mm (VandenBerg, 2018, fig. 2D).

Etagraptus RUEDEMANN, 1904, p. 644 [**Tetragraptus (Etagraptus) lentus;* M]. Four-stiped to multiramous horizontal sigmagraptines with simple thecae and low thecal inclination; proximal development isograptid, dextral; branching regular. *Lower Ordovician (Floian,* Didymograptellus bifidus *Biozone)–Middle Ordovician (Dapingian,* Isograptus maximodivergens *Biozone):* Australia, New Zealand, Norway, Sweden, China, Canada, USA.——FIG. 5,*2a. *E. lentus,* syntype, NYSM 6064, scale bar, 1 mm (new).——FIG. 5,*2b–c. E. tenuissimus* (HARRIS & THOMAS, 1942), holotype, NMVP 32110, along with detail of thecal style (*c*), Chewtonian 2 (Lower Ordovician) Campbelltown, Allotment 41B, Victoria, Australia; scale bars, 1 mm (VandenBerg, 2008a). Specimen was subsequently prepared and has much longer distal stipes.

Jiangnanograptus XIAO & CHEN, 1990, p. 99 [**J. undulatus;* OD]. Multiramous sigmagraptines with two declined to reclined first-order stipes and short first and second branching divisions; third- to fifth-order stipes long and slender; branching appears to be triple due to elongated metathecae; proximal development unknown. *Middle Ordovician (lower Dapingian,* Azygograptus suecicus *Biozone):* China (Jiangnan Region).——FIG. 5,*1. *J. undulatus*, Yc77-333 (repository of material unknown), Yushan, China, scale bar, 1 mm (Xiao & Chen, 1990, fig. 9).

Laxograptus COOPER & FORTEY, 1982, p. 269 [**Zygograptus irregularis* HARRIS & THOMAS, 1941, p. 310; OD]. Sigmagraptines with stipes of two or more orders in which dichotomies after the first dichotomy are delayed and placed irregularly; progressive branching; thecae simple with low overlap; indistinct rutella in some species. *Lower Ordovician (Lower Floian,* Paratetragraptus approximatus *Biozone*)*–?Middle Ordovician (Dapingian,* Isograptus maximodivergens *Biozone):* worldwide.——FIG. 5,*3a–b. *L. irregularis* (HARRIS & THOMAS), holotype, NMVP 32124; *3a,* full specimen; *3b,* close-up showing proximal end of holotype; Scotts Gully, Castlemaine, Victoria, Australia; scale bars, 1 mm (Rickards & Chapman, 1991, fig. 73 and 61, respectively).

Sigmagraptus RUEDEMANN, 1904, p. 701 [**S. praecursor;* OD] [=*Hemigoniograptus* JIN & WANG, 1977, p. 81 (type, *H. declinatus,* OD), see MU & others, 2002, p. 329]. Sigmagraptines with single order of progressive branching followed by monoprogressive branching, forming two main zigzag shaped stipes and numerous lateral stipes; proximal end isograptid, dextral, with long and slender sicula; thecae simple with low thecal overlap and without apertural elaborations. *Lower Ordovician (Floian,* Tshallograptus fruticosus *Biozone*–Didymograptellus bifidus *Biozone):* Australia, New Zealand, China, Canada, USA, Norway.——Fig. 5,*4a–c. *S. praecursor; 4a,* lectotype, NYSM 16006, Deep Kill, New York, USA (Cooper & Fortey, 1982, fig. 60c); *4b,* holotype of *Hemigoniograptus declinatus* JIN & WANG, 1977, IV75045 (repository unknown), Qiaotingzhe Formation, central Hunan, China (Jin & Wang, 1977, fig. 7,*1*); *4c*, GSC 79889, mature specimen, Cow Head Group, western Newfoundland, Canada (Williams & Stevens, 1988, fig. 75H). All scale bars, 1 mm.

Trichograptus NICHOLSON, 1876, p. 248 [**Dichograptus fragilis* NICHOLSON, 1869, p. 232; OD]. Horizontal to subhorizontal sigmagraptine with two curved main stipes; lateral second-order stipes originating on one side of main stipes through normal dichograptid, but lateral branching; proximal development isograptid, dextral, with distinct asymmetry of crossing canals; thecae simple dichograptid, low overlaping tubes. *Lower Ordovician (Floian,* Baltograptus vacillans *Biozone)–Middle Ordovician (Darriwilian,* Didymograptus artus *Biozone):* Australia, UK, Ireland, Norway, Argentina.——FIG. 5,*5a. *T. fragilis* (NICHOLSON), holotype, NHMUK PI Q.1, Tarn Moor Formation, Thornship Beck, Shap, Cumbria, UK, scale bar, 1 mm (Rushton, 2000b).——FIG. 5,*5b–c*.

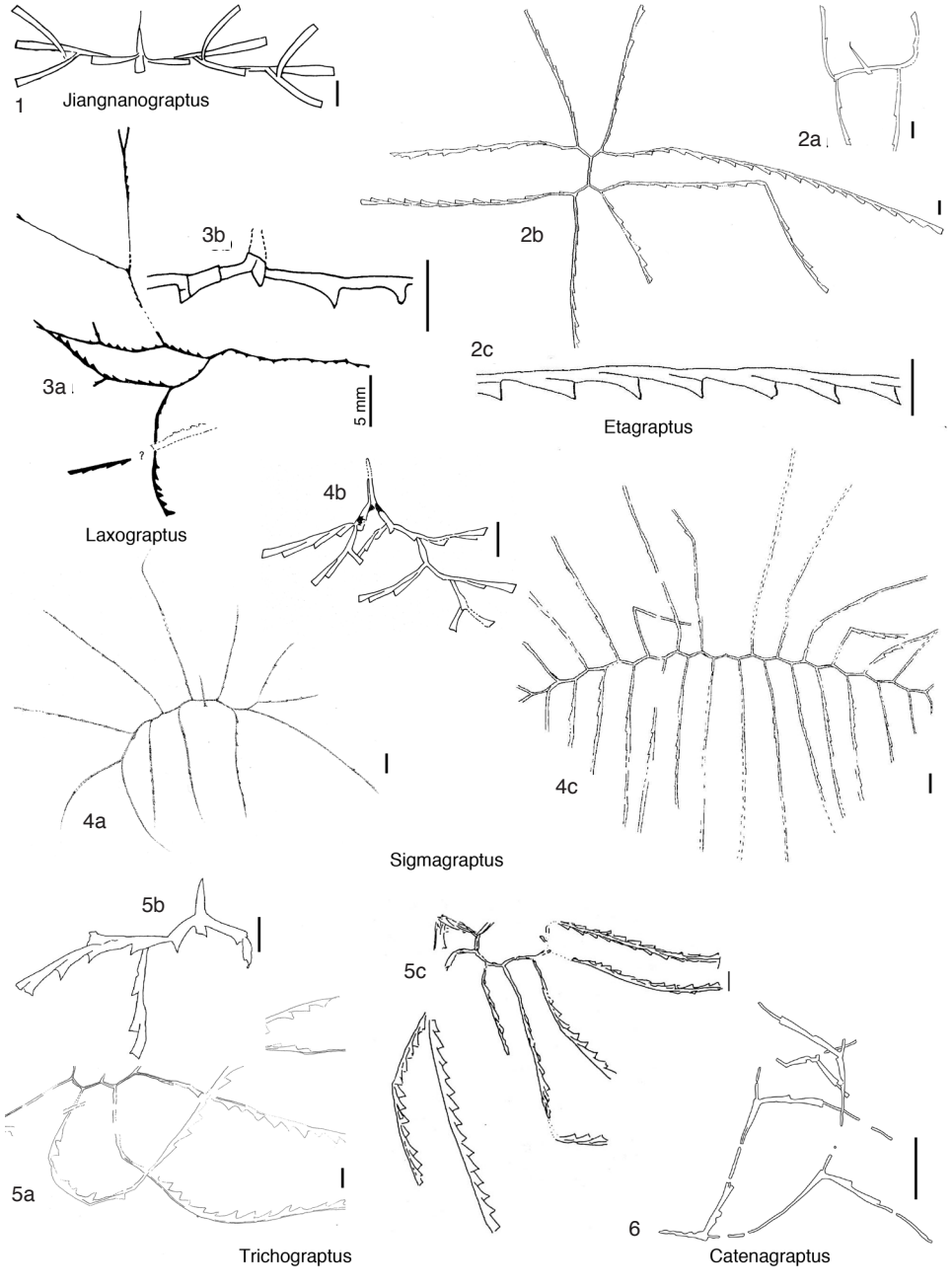

FIG. 5. Sigmagraptidae (p. 6–7).

T. dilaceratus (HERRMANN, 1885), Diabasbrottet, Hunneberg, Sweden; *5b,* MB.G. DI 894/1301-2, small specimen showing sicular shape; *5c*, MB.G. DI 894/1291-1, large specimen showing lateral branching of curved main stipes; scale bars, 1 mm (new).

Yushanograptus CHEN, SUN, & HAN, 1964, p. 236 [**Y. separatus;* OD] [=*Pendeosalicograptus* JIAO, 1981, p. 65 (type, *P. zhejiangensis,* OD), herein]. Multiramous sigmagraptines with long first-order stipes and monoprogressive distal branching; thecal style simple, dichograptid with low thecal overlap.

Middle Ordovician (Dapingian, Didymograptus abnormis *Biozone):* China.——Fig. 6,*1a–d*. **Y. separatus; 1a,* paratype, NIGP 14515; *1b,* holotype, NIGP 14514; *1c,* paratype, NIGP 14516; *1d*, NIGP 168219, AEP 27, proximal end in obverse view, scale bar 1 mm (*1a–1c,* Chen, Sun, & Han, 1964, fig. 1; *1d,* new).

Acrograptus Tzaj 1969, p. 142 [**Didymograptus affinis* Nicholson, 1869, p. 240; OD]. Slender sigmagraptine with two horizontal to declined stipes; sicula small, triangular; proximal development artus type; thecae slender and with low thecal overlap or with distally increasing overlap. *Middle Ordovician (Darriwilian,* ?Levisograptus dentatus *Biozone)–Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* worldwide.——Fig. 6,*4a–b*. **A. affinis* (Nicholson); *4a,* lectotype (selected by Elles & Wood, 1901, p. 24), NHMUK PI Q.3108; *4b,* possible topotype, NHMUK PI Q.5858a, low relief showing th2[1] originating on distal end of th1[1] (*arrow*), indicating artus-type development; Llanvirn (Darriwilian), Tarn Moor Formation, Aik Beck, east of Ullswater, Cumbria, UK, scale bars, 1 mm (Rushton, 2000a).

Paraulograptus Bouček, 1973, p. 74 [**P. expectatus;* OD]. Two-stiped horizontal sigmagraptines with low-inclined, geniculate thecae and high thecal overlap distally. *Middle Ordovician (Darriwilian,* Corymbograptus retroflexus *Biozone,* Expansograptus ferrugineus *horizon):* Czech Republic.——Fig. 6,*3*. **P. expectatus,* holotype, UUG-BB 85, proximal end, Šarka Formation, Krušná hora, Czech Republic, scale bar, 1 mm (adapted from Bouček, 1973, fig. 23).

Azygograptus Nicholson & Lapworth in Nicholson, 1875, p. 269 [**A. lapworthi;* OD] [=*A.* (*Eoazygograptus*) Obut & Sennikov, 1984, p. 100 (type, *A. coelebs* Lapworth, 1880, p. 159, OD, see Beckly & Maletz, 1991, p. 896); =*A.* (*Metazygograptus*) Obut & Sennikov, 1984, p. 101 (type, *A. suecicus* Moberg, 1892, p. 342, OD, see Beckly & Maletz, 1991, p. 896)]. Single-stiped tubarium; th1[1] originating from metasicula, growing downwards first or immediately outwards from lower part of metasicula; stipe either straight or dorsally curved; sicula straight to slightly curved, moderate widening towards aperture; thecae simple, elongate, and inclined at low angle to the dorsal margin and with low thecal overlap; prothecal folds in one species. [The type material of *A. lapworthi*, from Hodgson How Quarry (1 km west of Keswick, UK), has not yet been identified]. *Lower Ordovician (upper Floian,* Tetragraptus phyllograptoides *Biozone)–Middle Ordovician (lower Darriwilian,* Levisograptus austrodentatus *Biozone):* China, Czech Republic, UK, Germany, Norway, Spain, Sweden, Canada, Argentina, Bolivia.——Fig. 6,*2a–b*. **A. suecicus; 2a,* lectotype, SGU 5247; *2b,* paratype, SGU 5248; Killeröd, Scania, Sweden, scale bars, 1 mm (Moberg, 1892, pl. 8,*1* and 8,*2,* respectively).——Fig. 6,*2c*. **A. lapworthi*, NIGP 32222, southwest China, scale bar, 1 mm (on slab with Mu & others, 1979, pl. 38,*11*).

The following are multiramous to two-stiped genera with simple thecae, differentiated rutellum on sicula and often with lateral lobes.

Praegoniograptus Rickards & Chapman, 1991, p. 91 [**Goniograptus thureaui clonograptoides* Harris & Thomas, 1939, p. 55; OD]. Multiramous sigmagraptines with several orders of progressive branching followed by monoprogressive branching; thecae simple with low overlap. *Lower Ordovician (Floian,* Tshallograptus fruticosus *Biozone):* Australia (Victoria), Canada (Newfoundland).——Fig. 7,*2*. **P. clonograptoides* (Harris & Thomas), holotype, NMVP 32169, Campbelltown, Victoria, Australia (new).

Goniograptus M'Coy, 1876, p. 129 [**Didymograpsus thureaui;* M]. Sigmagraptines with two orders of progressive branching, followed by unlimited monoprogressive branching forming four zigzag main stipes; proximal end isograptid, dextral; extended rutellum on sicula; thecae dichograptid with short rutella; moderate to high thecal overlap; thecal shape variable, from low inclined and considerably widening to high overlap and strong curvature towards aperture. *Lower Ordovician (upper Floian,* Tshallograptus fruticosus *Biozone)–Middle Ordovician (Darriwilian,* Levisograptus austrodentatus *Biozone):* Australia, New Zealand, China, Norway, Sweden, Canada, USA, Argentina.——Fig. 7,*1a–b*. **G. thureaui; 1a*, holotype, NMVP 12215; *1b*, GSC 125786, proximal end; scale bars, 1 mm (new).

Eotetragraptus Bouček & Přibyl, 1952, p. 7 [**Graptolithus quadribrachiatus* Hall, 1858, p. 125; OD]. Four-stiped sigmagraptines with simple, rutellate, often considerably curved thecae; stipes pendent to reclined and reflexed, rarely with dorsal spines; short and wide sicula with distinct rutellum and lateral apertural lobes; proximal development isograptid, dextral, with symmetrically placed slender crossing canals; thecal style simple, widening tubes with rutellate apertures, often with slight lateral lobes. *Middle Ordovician (Darriwilian,* Levisograptus austrodentatus–Pterograptus elegans *Biozones):* worldwide.——Fig. 7,*4a–b*. **E. quadribrachiatus* (Hall); *4a,* syntype, GSC 928b, specimen shows the distinct rutellum on the sicula, Lévis, Quebec, Canada, scale bar, 1 mm (new); *4b,* GSC 132327, obverse view of flattened proximal end, Bay Cove, western Newfoundland, Canada (new).——Fig. 7,*4c*. **E. acanthonotus* (Gurley, 1896) (new, reconstruction based on Maletz, 1997, fig. 7N).

Keblograptus Riva, 1992, p. 316 [**Didymograptus bidens* Keble, 1927, p. 157; OD]. Sigmagraptines with two slender, declined to pendent stipes; sicula short and triangular; sicular aperture with strong rutellum and often with lateral lobes; thecae curved, distinctly widening aperturally and with gentle prothecal folds in some species. *Lower Ordovician* (uppermost *Floian,* Didymograptellus bifidus *Biozone)–Middle Ordovician (lower Dapingian,*

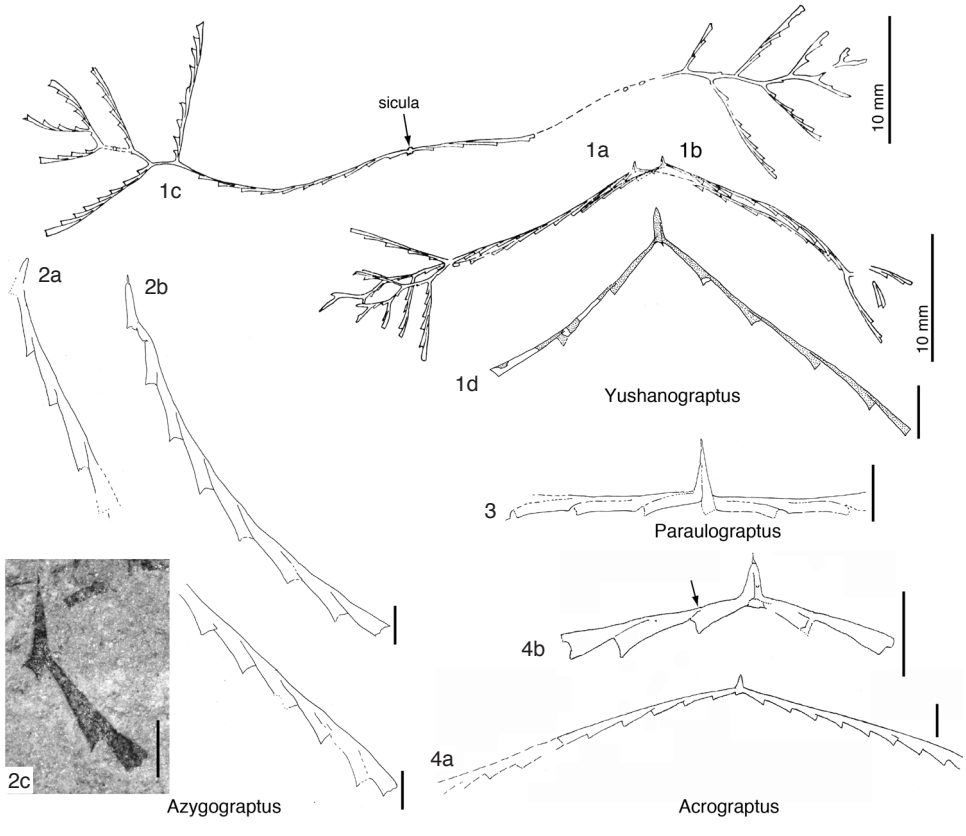

FIG. 6. Sigmagraptidae (p. 7–8).

Isograptus lunatus *Biozone):* Australia, New Zealand, China, Norway, Canada, USA.——FIG. 7,*3a*. **K. bidens* (KEBLE), holotype, OU 2512, Cape Providence, Chalky Inlet, Southland, New Zealand, scale bar, 1 mm (Riva, 1992, fig. 2A).——FIG. 7,*3b*. *K. mendicus* (KEBLE & HARRIS, 1934), GSC 81778, proximal end, western Newfoundland, Canada, scale bar, 1 mm (new).——FIG. 7,*3c*. *K. geminus* MALETZ, 2004, holotype, GSC 125734, Martin Point south, western Newfoundland, Canada, scale bar, 1 mm (Maletz, 2004, fig. 5E).

The following are genera with long thecal overlap and differentiated apertures, often increasing overlap distally.

Oslograptus JAANUSSON, 1965, p. 427 [**O. peculiaris;* M]. Sigmagraptines with a subhorizontal to pendent tubarium; thecal apertures positioned in distinct excavations formed by thecal folding. *Lower Ordovician (upper Floian,* Didymograptellus bifidus *Biozone):* Norway, Canada.——FIG. 8,*1*. **O. peculiaris,* holotype, PMO 73669, drawing of latex cast, Old Quarry, Slemmestad, Norway, scale bar, 1 mm (new).

Perissograptus WILLIAMS & STEVENS, 1988, p. 88 [**Tetragraptus pygmaeus* RUEDEMANN, 1904, p. 664; M]. Sigmagraptine with four reclined stipes; proximal end with stipes diverging high on sicula, leaving apertural part of sicula free pending; thecae with distinct rutella. *Lower Ordovician (upper Floian,* Didymograptellus bifidus *Biozone):* Australia, ?China, Canada, USA.——FIG. 8,*2a–c*. **P. pygmaeus* (RUEDEMANN); *2a,* lectotype (designated by WILLIAMS & STEVENS, 1988, p. 89), NYSM 6073, Deep Kill, New York, USA (Ruedemann, 1904, pl. 12,*14*); *2b–c,* GSC 82059, obverse (*b*) and reverse (*c*) views of isolated specimen (infra-red photos, new).

Maeandrograptus MOBERG, 1892, p. 344 [**M. schmalenseei;* M]. Horizontal to subhorizontal and reclined sigmagraptines with two stipes; stipes often showing increased thecal overlap distally; thecae long and slender; sicula with long and parallel-sided prosicula and often long metasicula; aperture of metasicula often but not necessarily isolated; thecae with rutella and sometimes lateral lappets; prothecal folds and undulating thecae in some species. *Lower Ordovician (upper Floian,* Tshallograptus fruticosus *Biozone)–Middle Ordovician*

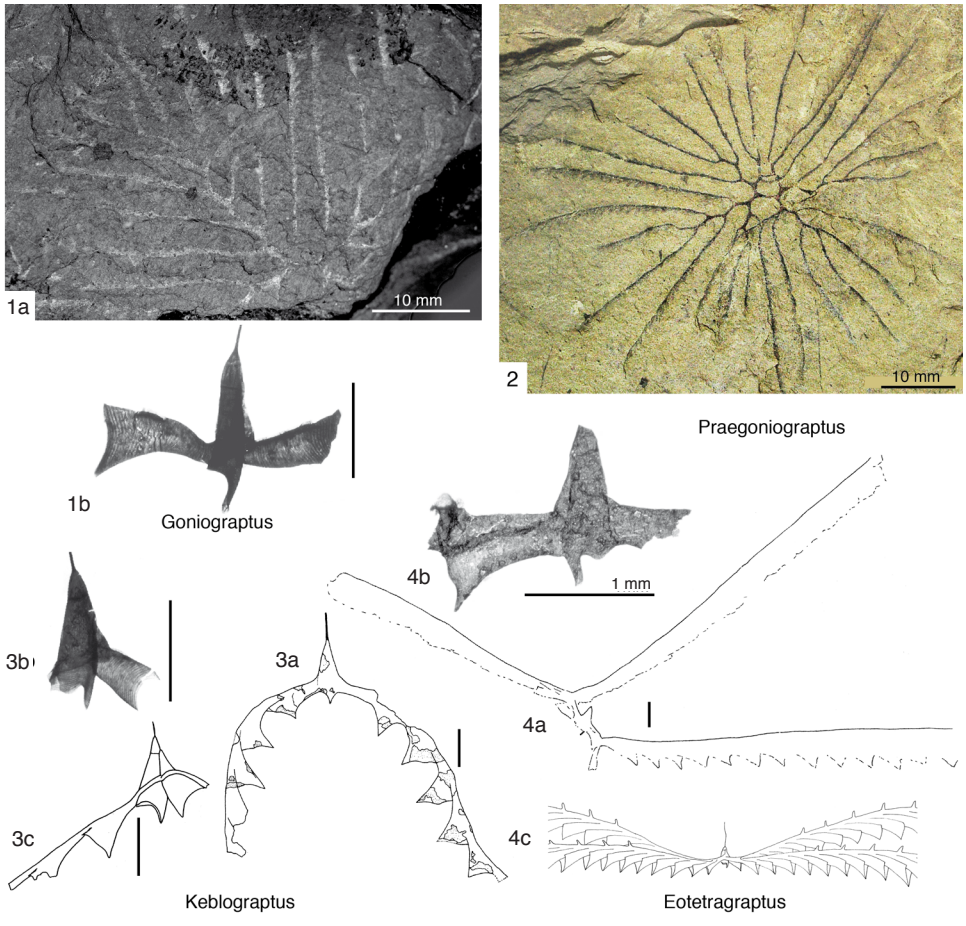

FIG. 7. Sigmagraptidae (p. 8–9).

(lower Dapingian, Isograptus maximus *Biozone):* China, Norway, Sweden, Canada.——FIG. *8,3a. M. mobergi* (TÖRNQUIST, 1901), holotype, LO 1642T, reverse view, drawing of latex cast, Killeröd, Scania, Sweden, scale bar, 1 mm (new).——FIG. 8,*3b–c.* **M. schmalenseei; 3b,* lectotype, SGU 5255, reverse view; *3c,* paratype, SGU 5257, obverse view, showing long sicula; Killeröd, Scania, Sweden, scale bars, 1 mm (Bulman, 1932, pl. 9).——FIG. 8,*3d. M. leptograptoides* (MONSEN, 1937), PMU 23165/2, reverse view, drawing of latex cast, Nipan, Jemtland, Sweden, scale bar, 1 mm (new).

Jishougraptus GE, 1988, p. 208 [**J. mui;* OD]. Sigmagraptines with a single deflexed stipe; dorsal stipe margin somewhat undulate but without pronounced prothecal folds; sicula long and slender with th1[1] origin in middle part of metasicula or close to sicular aperture; thecae long and slender with high overlap and increasing overlap distally; apertural elaborations indistinct; thecae may be geniculate. *Lower Ordovician (Floian,* Tshallograptus fruticosus *Biozone)–Middle Ordovician (lower Dapingian,* Azygograptus suecicus *Biozone or* Baltograptus minutus *Biozone):* China, Norway, Sweden.——FIG. 8,*4a–b.* **J. mui; 4a,* juvenile, showing sicula shape; *4b,* holotype, NIGP 104481, fragment showing thecal style; scale bars, 1 mm (new).——FIG. 8,*4c. J. novus* BECKLY & MALETZ, 1991, paratype, PMO 118593, latex cast, Tøyen Shale, Oslo, Norway, scale bar, 1 mm (Beckly & Maletz, 1991, pl. 1,*9*).

The following are multiramous to two-stiped genera with distinctly differentiated pro- and metathecae, often with apertural elaborations (Kinnegraptidae of MU, 1974):

Paradelograptus ERDTMANN, MALETZ, & GUTIERREZ-MARCO, 1987, p. 114 [**P. onubensis;* OD]. Multiramous to biramous, horizontal to subhorizontal sigmagraptines with distinct differentiation of thecae; prothecae very slender, metathecae considerably widening; thecal apertures simple and straight to bearing moderate rutellum; bithecae

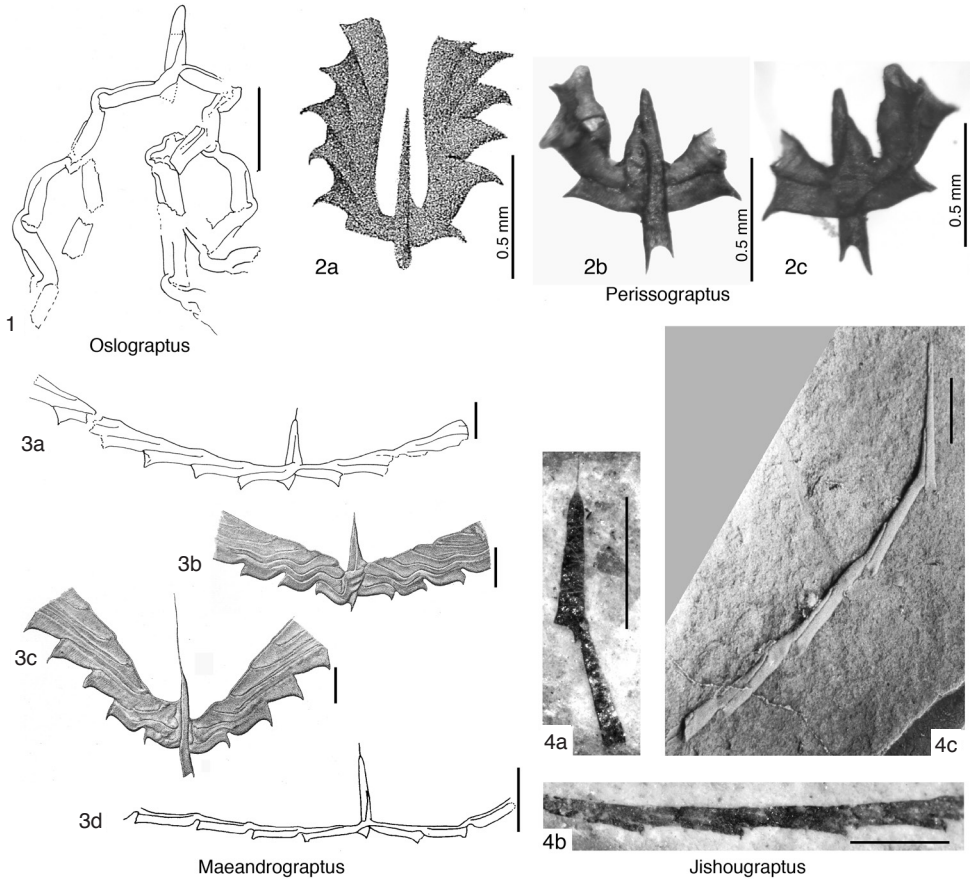

FIG. 8. Sigmagraptidae (p. 9–10).

present in earlier species, at least on sicula. *Lower Ordovician (upper Tremadocian,* Hunnegraptus copiosus *Biozone–Floian,* Tshallograptus fruticosus *Biozone):* Australia, New Zealand, China, Sweden, Norway, Scotland, Spain, Canada, USA, Argentina, Bolivia.——FIG. 9,*1a–b. *P. onubensis; 1a,* holotype, DPM 4107, scale bar, 1 mm; *1b,* paratype, DPM 4001, large specimen (Erdtmann, Maletz, & Gutierrez-Marco, 1987, fig 7C).——FIG. 9,*1c. P. mosseboensis* ERDTMANN, MALETZ, & GUTIERREZ-MARCO, 1987, holotype, MB.G. Di 614/119, scale bar, 1 mm (Erdtmann, Maletz, & Gutierrez-Marco, 1987, fig 1).——FIG. 9,*1d. P. smithi* (HARRIS & THOMAS, 1938) MB.G. Mo 400/225 (Erdtmann, Maletz, & Gutierrez-Marco, 1987, fig 8B).

Kinnegraptus SKOGLUND, 1961, p. 391 [**K. kinnekullensis;* OD]. Multiramous to two-stiped sigmagraptines with horizontal to subhorizontal tubarium; proximal end isograptid or artus type, with dextral or sinistral development; origin of th1[1] in prosicula or metasicula; thecae with very slender prothecae and distinctly widening metathecae; strong rutella on all thecae. *Middle Ordovician (lower Dapingian,* Isograptus victoriae lunatus *Biozone):* Norway, Sweden, Canada, Argentina.——FIG. 9,*2a–c. *K. kinnekullensis; 2a,* PMU 23633; *2b,* PMU 23634; *2c,* holotype PMU 23635; Hällekis, Västergötland, Sweden, scale bars, 0.5 mm (Skoglund, 1961, fig. 1B, 1D, and 2A, respectively).

Prokinnegraptus MU, 1974, p. 233 [**Kinnegraptus multiramosus* SKOGLUND, 1961, p. 397; OD]. Multiramous sigmagraptines with horizontal to subhorizontal tubarium; proximal end isograptid type, with dextral or sinistral development; origin of th1[1] high in prosicula; thecae with very low thecal overlap, very slender prothecae and distinctly widening metathecae; strong rutella on all thecae. *Middle Ordovician (lower Dapingian,* Isograptus victoriae lunatus *Biozone):* Norway, Sweden.——FIG. 9,*3a–c. *P. multiramosus* (SKOGLUND), Norra Skagen drill core near Hällekis, Västergötland, Sweden; *3a,* PMU 23639, Norra Skagen at 61.10 m; *3b,* PMU 23641, Norra Skagen at 62.16 m; *3c,* PMU 23642, Norra Skagen at 62.72 m; scale

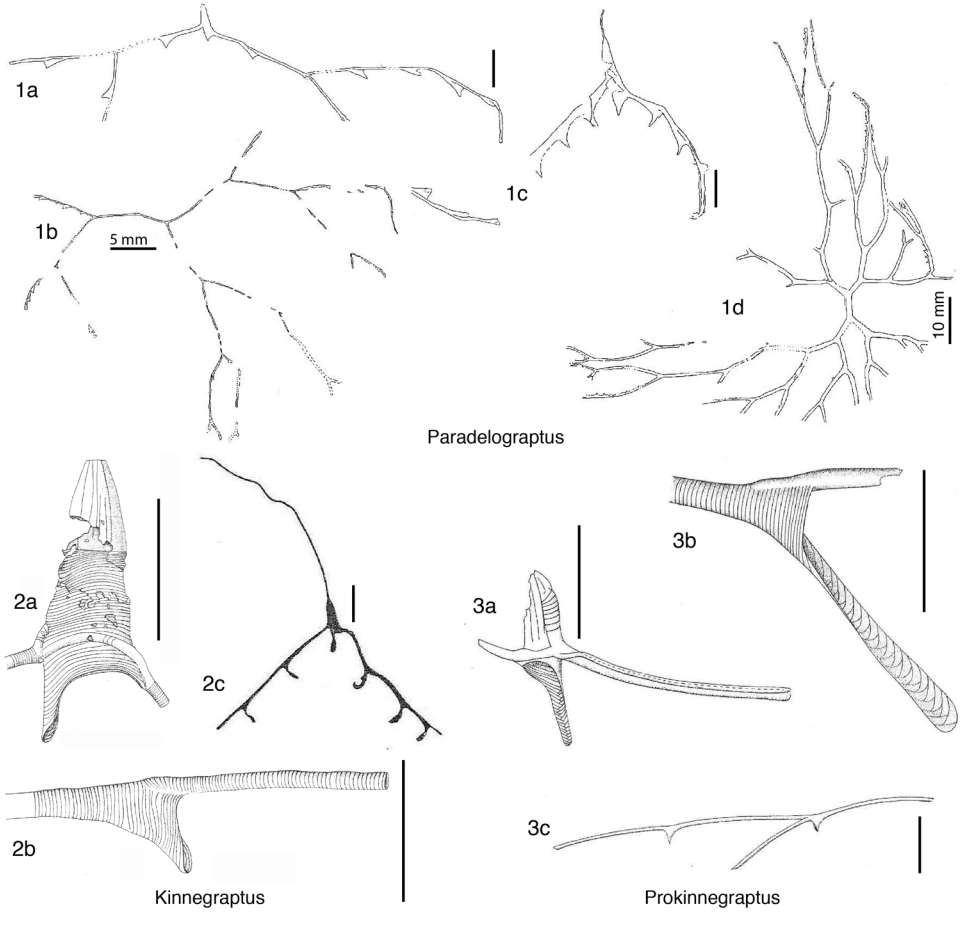

FIG. 9. Sigmagraptidae (p. 10–12).

bars, 0.5 mm (Skoglund, 1961, fig. 5B, 6B, and 7, respectively).

Family SINOGRAPTIDAE Mu, 1957

[Sinograptidae MU, 1957, p. 387] [incl. Paradidymograptidae WANG, 1975, p. 8; Atopograptidae HARRIS, 1926, p. 59; Pseudodichograptinae HSÜ & CHAO, 1976, p. 126; Pseudotetragraptinae HSÜ & CHAO, 1976, p. 129; Holmograptinae HSÜ & CHAO, 1976, p. 132]

Planktic, graptoloid graptolites with multiramous to single-stiped, horizontal to subhorizontal tubaria; sicula parallel-sided with straight aperture, perpendicular to the stipes; sicular aperture with ventral rutellum or dorsal and ventral rutellate extensions; proximal development isograptid, dextral, with symmetrically placed crossing canals close to the aperture of the sicula; origin of th1[1] in the lower part of the prosicula; thecal style often complex with distinctly differentiated pro- and metathecae; thecal elaborations such as prothecal folds, lateral apertural lappets, rutella, or spines common. *Middle Ordovician (Darriwilian,* Levisograptus austrodentatus–Nicholsonograptus fasciculatus *Biozones):* worldwide.

The Sinograptidae includes a group of closely related sinograptid graptolites with a symmetrical proximal development and distinctly elaborated thecal apertures (Fig. 10). The members of the family show the most elaborate thecal structure known from Lower to Middle Ordovician multiramous graptolites. The thecae are fairly simple in early members, with low thecal inclination. Derived taxa may show considerable prothecal and metathecal

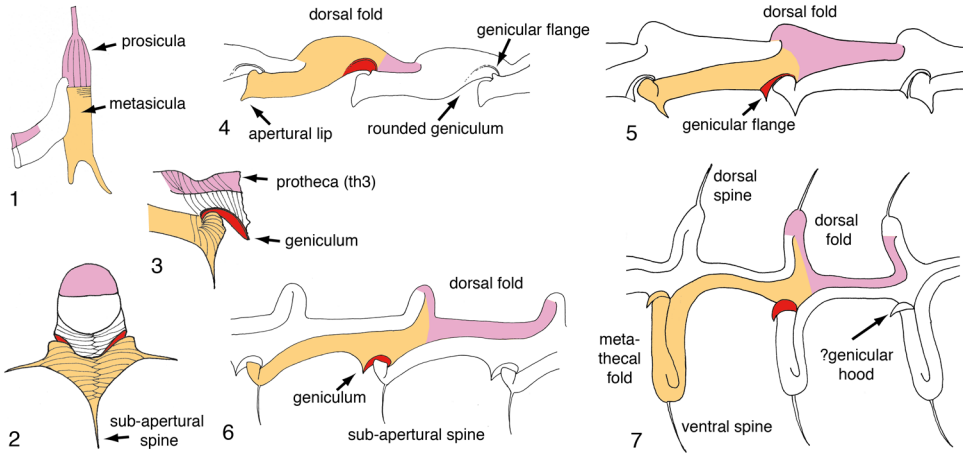

FIG. 10. Thecal development in *Holmograptus* KOZŁOWSKI, 1954 and *Sinograptus* MU, 1957. *1*, *Nicholsonograptus fasciculatus* (NICHOLSON, 1869), sicula and first theca (based on GSC 132333); *2, Holmograptus* sp., reconstruction, apertural view, showing lateral and subapertural thecal spines; *3*, *Holmograptus* sp., lateral view to show geniculum and apertural elaborations, note the lack of lateral spines; *4*, *Anomalograptus reliquus* (CLARK 1924), simple theca with median position of dorsal fold; *5*, *N. fasciculatus* with dorsal fold prior to origin of next theca and elaborated geniculum; *6*, *Holmograptus* sp. with strong dorsal fold and subapertural spine; *7*, *Sinograptus typicalis* MU, 1957 with dorsal and metathecal folds, dorsal and ventral spines (new, based in part on Kozłowski, 1954; Zhang & Fortey, 2001).

folding, forming strongly elongated thecae. The thecal apertures are often complexly formed with introverted apertures and lateral lobes (see KOZŁOWSKI, 1954, fig. 6). Subapertural ventral spines and even paired lateral spines may be present. Dorsal spines are developed on the top of the prothecal folds in some *Holmograptus* species (MALETZ, 2009, fig. 5L–N, fig. 6H) and especially in *Sinograptus* (Fig. 10.7). The details of the thecal constructions are unknown, as fuselli are rarely seen even in isolated material. Therefore, the construction of the prothecal and metathecal folds is unclear. The material of KOZŁOWSKI (1954) may indicate a considerable widening of the prothecae before the insertion of a new theca (see Fig. 10.3). In this case, the dorsal prothecal folding may actually represent this widening, and the initial protheca of the succeeding theca is only part of the fold.

Anomalograptus CLARK, 1924, p. 63 [**A. reliquus;* OD] [=*Brachiograptus* HARRIS & KEBLE, 1932, p. 43 (type, *B. etaformis,* OD), herein; =*Pseudologanograptus* HSÜ & CHAO, 1976, p. 126 (type, *P. geniculatus*), herein]. Multiramous, horizontal to subhorizontal sinograptids; first distal dichotomies usually at th3[1] and th3[2]; branching crowded proximally with two to four progressive dichotomies; no distal branching; thecae with variably developed prothecal folding, sometimes possessing geniculum and apertural elaborations. *Middle Ordovician (lower Darriwilian,* Levisograptus austrodentatus *Biozone*–Levisograptus dentatus *Biozone):* Australia, New Zealand, China, Canada, USA, Argentina, Bolivia, UK.——FIG. 11,*1a, c–d. *A. reliquus; 1a*, holotype, MCZ 101403, near Victoria Hotel, Lévis, Quebec, Canada (Clark, 1924, pl. 5,*4*); *1c,* GSC 140007, stipe fragment; *1d,* GSC 139257, isolated proximal end, *Levisograptus dentatus* Biozone, Western Brook Pond, bed 52, Cow Head Group, western Newfoundland, Canada; scale bars, 1 mm unless stated otherwise (new).——FIG. 11.*1b. A. etaformis* (HARRIS & KEBLE, 1932), paratype, NMVP 24109, (VandenBerg, 2008d).

Zygograptus HARRIS & THOMAS, 1941, p. 308 [**Graptolithus abnormis* HALL, 1858, p. 117; OD]. Multiramous sinograptids with strongly elongated funicle, followed by number of progressive dichotomies at close intervals of 1–3 thecae; thecae low inclined, slightly undulating, with slight apertural elaborations. *Middle Ordovician (Darriwilian,* Levisograptus austrodentatus *Biozone*–Levisograptus dentatus *Biozone):* ?China, Canada.——FIG. 11,*2. *Z. abnormis* (HALL), holotype, GSC 941, Darriwilian, Lévis, Quebec (new).

Allograptus MU, 1957, p. 388 [**A. mirus;* OD] [=*Pseudodichograptus* CHU, 1965, p. 97 (type, *P. confertus,* OD), herein; =*Pseudojanograptus* HSÜ &

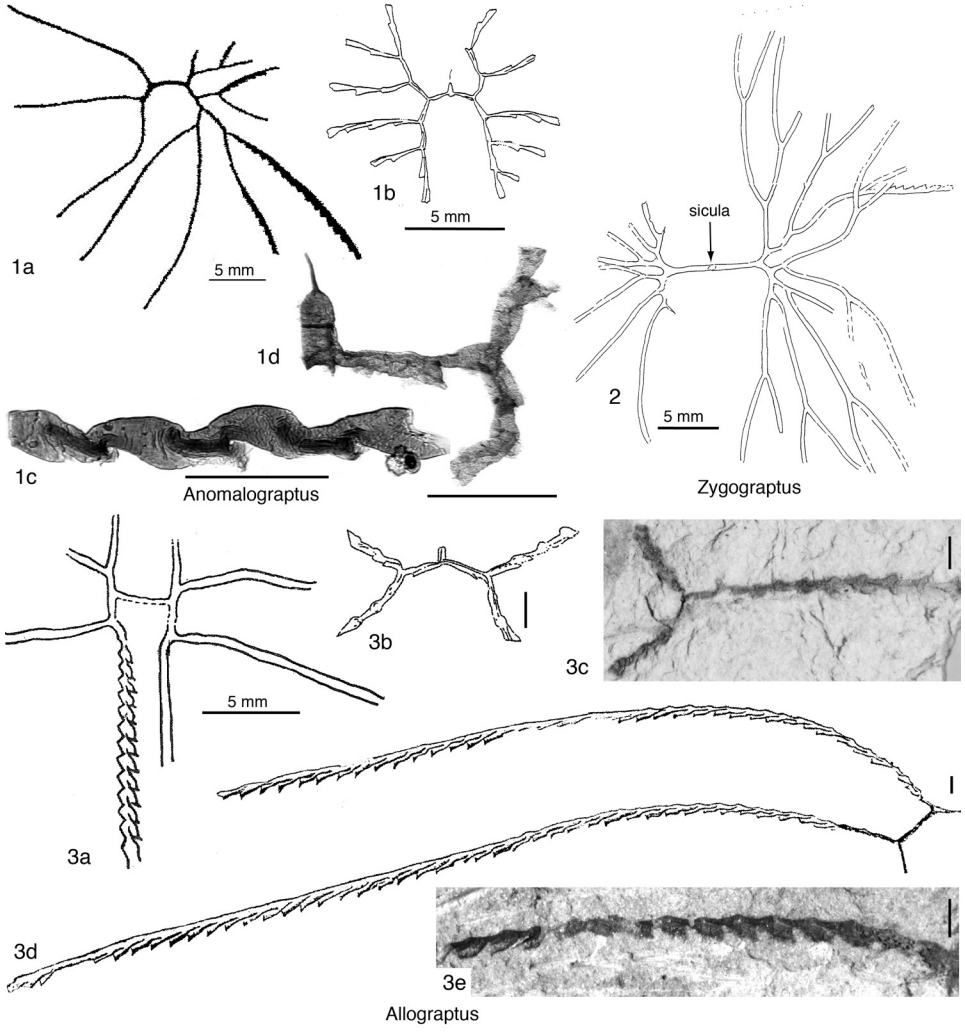

FIG. 11. Sinograptidae (p. 13–14).

CHAO, 1976, p. 131 (type, *?Allograptus fluitans* MU, 1957, p. 391; OD), herein; =*Pseudotetragraptus* HSÜ & CHAO, 1976, p. 129 (type, *P. corniculiformis,* OD), herein]. Multiramous, horizontal to subhorizontal sinograptids with up to three orders of stipes; progressive branching, often with delayed dichotomies; thecae with variably developed prothecal folding, often possessing a geniculum and apertural elaborations. *Middle Ordovician (lower Darriwilian,* Levisograptus austrodentatus *Biozone*–Levisograptus dentatus *Biozone):* ?Australia, China, Canada, Norway.——FIG. 11,*3a*. *A. confertus* (CHU, 1965), holotype, repository unknown (Chu, 1965, fig. 4).——FIG. 11,*3b*. *Allograptus* sp., GSC 102622, Lévis, Quebec, Canada, scale bar, 1 mm (Maletz, 1997, fig. 8G).——FIG. 11,*3c*. **A. mirus,* holotype, NIGP 8867, internal cast, scale bar, 1 mm (new).——FIG. 11,*3d*. *A. corniculiformis* HSÜ & CHAO, 1976, holotype, No. 1575 (repository unknown), scale bar, 1 mm (Hsü & Chao, 1976, pl. 6,*3e*).——FIG. 11,*3e*. *A. fluitans* MU, 1957, holotype, NIGP 8874, scale bar, 1 mm (new).

Holmograptus KOZŁOWSKI, 1954, p. 432 (French translation, p. 124) [**Didymograptus callotheca* BULMAN, 1932, p. 16; OD] [=*Tylograptus* MU, 1957, p. 393, English translation, p. 428 (type, *T. regularis,* OD), herein; =*Paradidymograptus* MU, GEH & YIN in MU & others, 1962, p. 73 (type, *P. acanthonotus,* OD), herein]. Two-stiped pendent or declined to subhorizontal sinograptids; stipes with high, often distally increasing thecal overlap;

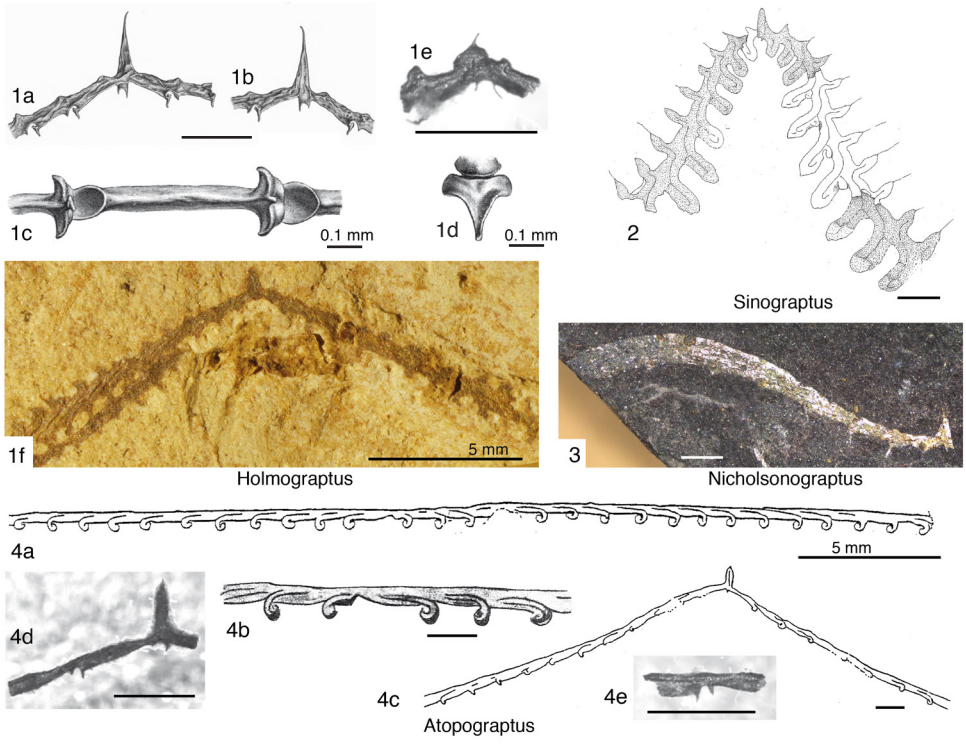

FIG. 12. Sinograptidae (p. 14–16).

thecal apertures elaborate, constricted with variously modified ventral and dorsal lips; prothecal folds may be present as well as spines on prothecae or thecal apertures. *Middle Ordovician (lower Darriwilian,* Levisograptus austrodentatus *Biozone–*Holmograptus lentus *Biozone):* worldwide.——FIG. 12,*1a–d. *H. callotheca* (BULMAN); *1a–b,* holotype, NRM-PZ Cn 71835, in reverse (*a*) and obverse (*b*) views, Grå Vaginatumkalk, Hälludden, Öland, Sweden; scale bar 1 mm (Bulman, 1936, pl. 2,*1–2*); *1c–d*, NRM-PZ Cn 71836, stipe fragment in ventral view (*c*) showing laterally expanded thecal aperture, and geniculum and apertural view (*d*) showing apertural complexity (Bulman, 1936, pl. 2, 10, and 13, respectively).——FIG. 12,*1e. H. spinosus* (RUEDEMANN, 1904), GSC 133523, obverse view, scale bar, 1 mm (Maletz, 2009, fig. 5G).——FIG. 12,*1f. H. regularis* (MU, 1957), holotype, NIGP 8892, flattened specimen, Ningkuo Shale of Tawu, Changshan, China (new).

Atopograptus HARRIS, 1926, p. 59 [**A. woodwardi;* OD]. Horizontal to declined, two-stiped sinograptid tubarium; thecae with strong geniculum and apertural hood. *Middle Ordovician, middle Darriwilian* (*Holmograptus lentus* Biozone–*Nicholsonograptus fasciculatus* Biozone): Australia (Victoria), China, Sweden, Canada.——FIG. 12,*4a–b. *A. woodwardi; 4a,* holotype, NMVP 13352, janograptid specimen, Bendigo east, Victoria, Australia (VandenBerg, 2008b); *4b,* enlargement of proximal end, scale bar, 1 mm (Harris, 1926, fig. 14).——FIG. 12,*4c. A. dubitatus* (HARRIS & THOMAS, 1935), NMVP 31948, Strathfieldsaye, Bendigo, Victoria, Australia, scale bar, 1 mm (VandenBerg, 2008b).——FIG. 12,*4d–e. Atopograptus* sp; *4d,* GSC 133519, proximal end; *4e,* GSC 133519, distal theca; Les Méchins, Quebec, Canada, scale bars, 1 mm (Maletz, 2009, fig. 5).

Sinograptus MU, 1957, p. 400 [**S. typicalis;* OD]. Two-stiped, declined sinograptids with exagerated prothecal and metathecal folds; prothecal and ventral apertural spines present; proximal development isograptid, dextral, with symmetrically placed crossing canals. *Middle Ordovician, Darriwilian* (upper Holmograptus lentus *Biozone*)*:* China, Canada.——FIG. 12,*2. *S. typicalis,* holotype, NIGP 8909, scale bar, 1 mm (Zhang, 2008).

Nicholsonograptus BOUČEK & PŘIBYL, 1952, p. 14 [**Didymograpsus fasciculatus* NICHOLSON, 1869, p. 241; OD] [=*Sinazygograptus* WANG & WU in WANG & others, 1977, p. 305 (type, *S. spinatus,* OD), herein; =*Hemiholmograptus* HSÜ & CHAO, 1976, p. 137 (type, *Azygograptus falciformis* EKSTRÖM, 1937, p. 32, OD), herein]. Sinograptid with a single, strongly S-shaped stipe; thecae with prothecal folds and distally increasing thecal overlap; thecae

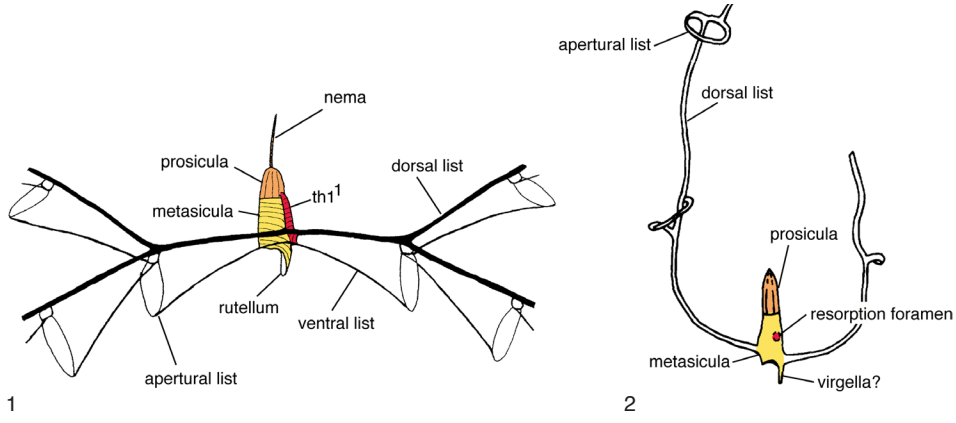

FIG. 13. Morphology of the Abrograptidae. *1, Jiangshanites* (?) *dubius* MALETZ, 1993 with prosicular origin of th1[1] and rutellate sicular aperture (adapted from Maletz, 1993, fig. 1); *2, Dinemagraptus warkae* KOZŁOWSKI, 1951, showing metasicular origin of th1[1] (resorption foramen) and possible presence of virgellar spine (adapted from Finney, 1980, fig. 11).

with distinct geniculum and introverted apertures; thecal apertures elaborated as in *Holmograptus*, often with long ventral spines; sicular aperture with ventral rutellum and even longer dorsal, often curved rutellum. *Middle Ordovician (Darriwilian,* Nicholsonograptus fasciculatus *Biozone):* worldwide.——Fig. 12,*3*. **N. fasciculatus* (NICHOLSON), LO 3315T, holotype of *Azygograptus falciformis* EKSTRÖM, 1937, Röstånga, Scania, Sweden, scale bar, 1 mm (new).

Family ABROGRAPTIDAE Mu, 1958

[Abrograptidae Mu, 1958, p. 261]

Tubarium either multiramous or consisting of two reclined uniserial or biserial stipes, scandent and possibly dipleural; sicula completely sclerotized with strongly developed rutellum; fusellum of stipes reduced, preservable parts consisting of lists outlining thecae; thecal apertures represented by circular lists attached to ventral and dorsal lists; proximal-end development dichograptid, probably isograptid, dextral. *Middle Ordovician* (*lower Darriwilian,* Levisograptus austrodentatus *Biozone*)–*Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* China, UK, Poland, Canada, USA.

The Abrograptidae are here regarded as a family closely related to the Sigmagraptidae. The inclusion is based on the shape and development of the sicula and the origin of the first theca in isolated material of *Jiangshanites* (?) *dubius* found in the *Levisograptus austrodentatus* Biozone of western Newfoundland. It is the only abrograptid for which isolated material exists, with the exception of the poorly understood *Dinemagraptus*. *J.*(?) *dubius* has a small, cone-shaped sicula with a prosicular origin of th1[1] (Fig. 13.1), but the later proximal development is not shown in the specimens, as the crossing canals are not sclerotized. The species produces a multiramous tubarium in which the first distal branching occurs after the production of the first thecal pair. *Dinemagraptus warkae* is known from a single proximal end showing a sicula with a possible virgellar spine and a metasicular origin of th1[1], indicated by a resorption foramen in the middle of the metasicula (Fig. 13.2).

The recognition of the abrograptids is generally based on fragmented list structures on shale surfaces, and in many specimens, the development is uncertain. *Protabrograptus* is very poorly preserved, for example, and cannot be recognized as a genuine graptolite.

Abrograptus MU, 1958, p. 261 (English text, p. 264) [**A. formosus;* OD]. Reclined, two-stiped abrograptid; stipes composed of two longitudinal filaments and apertural rings or crossbars, forming rectangular meshes; sicula with one crossing canal; development probably corresponding to *bifidus* stage of dichograptid type. *Middle*

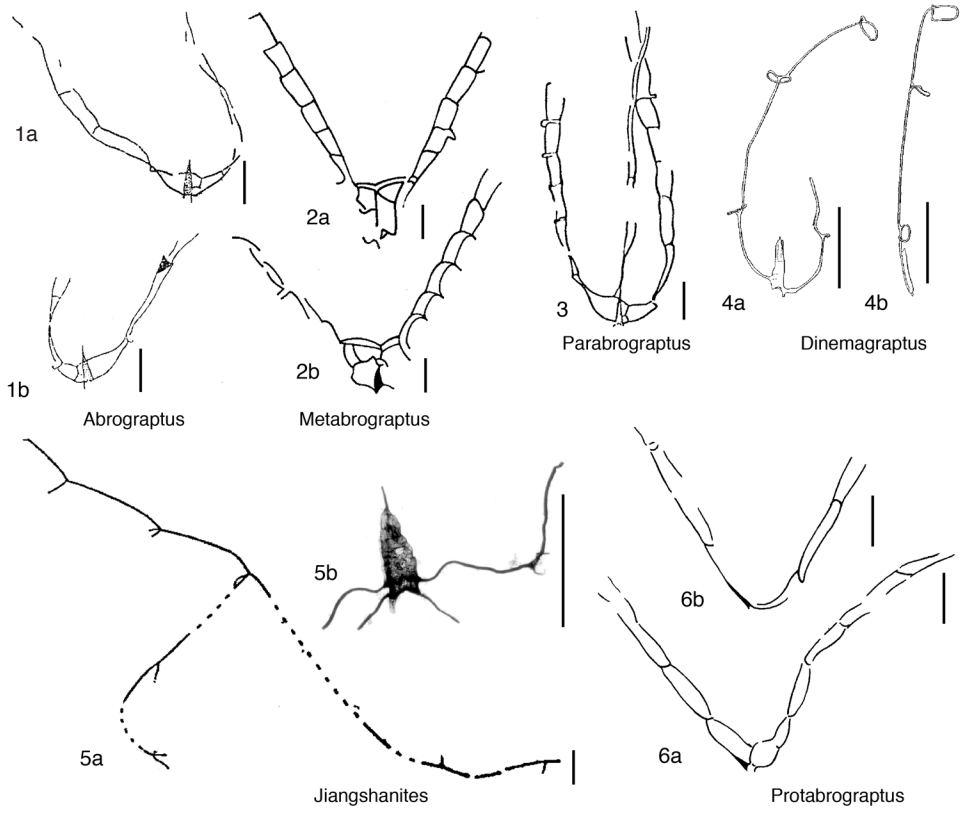

FIG. 14. Abograptidae (p. 16–18).

Ordovician (upper Darriwilian, Hustedograptus teretiusculus *Biozone)–Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* China, Canada, USA.——FIG. 14,*1a–b. *A. formosus; 1a,* paratype, NIGP 9402; *1b,* holotype, NIGP 9397 (type material for both missing at NIGP); *Nemagraptus gracilis* Biozone, Kiangshan, Chekiang, China; scale bars, 1 mm (Mu, 1958, pl. 1).

Dinemagraptus KOZŁOWSKI, 1951, p. 292 (French text, p. 87) [**D. warkae;* OD]. Reclined, two-stiped abograptid; stipes reduced to dorsal and apertural lists; sicula completely sclerotized. *Middle Ordovician (upper Darriwilian,* ?Hustedograptus teretiusculus *Biozone*)*–Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* China, Poland.——FIG. 14.*4a–b. *D. warkae,* glacial boulder, Stara Warka, ~50 km south of Warsaw, Poland, scale bars, 1 mm (Kozłowski, 1951, fig. 1).

Jiangshanites MU & QIAO, 1962, p. 3 (English text, p. 7) [**J. ramosus;* OD]. Multiramous abograptid; completely sclerotised sicula with sclerotized initial part of first theca; prosicular origin of th1[1]; thecae constructed of dorsal, ventral, and apertural lists. [The type material is very incomplete and a sicula is not recognizable in the specimens.] *Middle Ordovician (Darriwilian,* Levisograptus austrodentatus *Biozone)–Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* China, Canada.——FIG. 14,*5a. *J. ramosus,* syntype, NIGP 13240, fragment, scale bar, 1 mm (Mu & Qiao, 1962, pl. 2,12).——FIG. 14,*5b. J.* (?) *dubius* MALETZ, 1993, GSC 102774, sicula with incomplete first thecal pair, Western Brook Pond, south section, Newfoundland, Canada, scale bar, 1 mm (Maletz, 1993, fig. 2,1).

Metabrograptus STRACHAN, 1990, p. 934 [**M. scoticus;* OD]. Biserial-uniserial abograptid; uniserial stipes diverge at an angle of 80° to 110°; sicula sclerotized. *Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* UK (Scotland), USA.——FIG. 14,*2a–b. *M. scoticus; 2a,* holotype, BU 1336b; *2b,* paratype, BU 2150a; Glenkiln Shale, Birnock, UK, scale bars, 1 mm (Strachan, 1990, fig.1A and 1D, respectively).

Parabrograptus MU & QIAO, 1962, p. 2 [*P. tribrachiatus;* OD]. Scandent, ?biserial abograptid; two ventrolateral lists connected with horizontal apertural lists on each side; two vertical lists in the center of

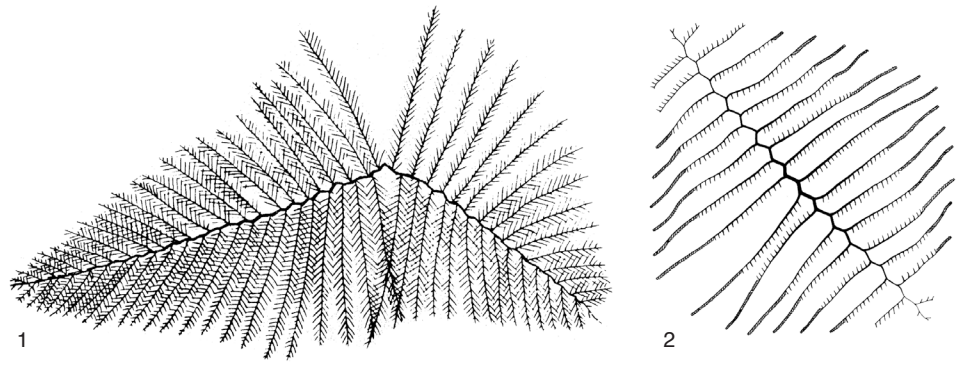

FIG. 15. *Thamnograptus capillaris* (EMMONS, 1855) reconstructions. *1,* RUEDEMANN reconstruction (1947, pl. 43, *7*); *2,* FINNEY reconstruction (1980, fig. 7).

the tubarium, probably connected to the sicula. *Upper Ordovician (Sandbian,* Nemagraptus gracilis *Biozone):* China.——FIG. 14,*3. *P. tribrachiatus,* holotype, NIGP 13236, scale bar, 1 mm (Mu & Qiao, 1962, pl. 2.1).

Protabrograptus NI, 1981, p. 203 [**P. sinicus;* OD]. Minute tubarium with a generally rounded base, consisting of two reclined stipes, composed of two longitudinal filaments (ventral and dorsal) and apertural rings or crossbars; sicula fully preserved, merging into the ventral filament of second stipe [This might not be a graptolite. A sicula cannot be recognized in the type material.] *Middle Ordovician (upper Darriwilian,* Didymograptus jiangxiensis *Biozone):* China (Wuning).——FIG. 14,*6a–b*. *P. sinicus; 6a,* paratype, NIGP 57943; *6b,* holotype, NIGP 57941; Wuning, Jiangxi, China, scale bars, 1 mm (Ni, 1981, fig. 1).

Suborder UNCERTAIN

Family THAMNOGRAPTIDAE Hopkinson & Lapworth, 1875

[Thamnograptidae HOPKINSON & LAPWORTH, 1875, p. 633]

Tubarium consisting of straight or flexuous stipes (first-order branches, number unknown) with widely spaced, second-order lateral branches composed of narrow tubular thecae bearing strongly elongated rutella or hairlike spines; thecae of lateral, second-order branches possibly abruptly changing to dichograptid thecae distally; details of proximal development unknown. *Middle Ordovician (Darriwilian,* Pterograptus elegans *Biozone)–Upper Ordovician (Katian,* Climacograptus bicornis *Biozone):* Australia, China, Sweden, USA.

HOPKINSON and LAPWORTH (1875) established the family Thamnograptidae for the two genera *Thamnograptus* and *Buthograptus* HALL, 1861. FINNEY (1980) revised the family Thamnograptidae and excluded the genus *Buthograptus* as unrecognizable, following BULMAN (1970, p. 139), thus, incorporating a single genus into the family. Numerous species have been included in the genus *Thamnograptus* (referenced in RUEDEMANN, 1947), but most of them consist of slender indeterminable stipe fragments. In the restricted sense, the genus is used herein for a number of multiramous Middle Ordovician, possibly planktic graptoloids with very slender thecae and unknown tubarium development. Silurian taxa are excluded and may belong to other fossil groups. The genus *Wuninograptus* is here included in the Thamnograptidae due to a similar development of the thecae during the Middle Ordovician (late Darriwilian) age. It is the only taxon of the family from which a proximal end has been described. *Wuninograptus* may otherwise be related to *Kinnegraptus*. If *Thamnograptus* is related to *Wuninograptus*, the genus could be included in the Sigmagraptidae.

MORPHOLOGY

The proximal development of the species of *Thamnograptus* is unknown as is the thecal style of most taxa. FINNEY (1980)

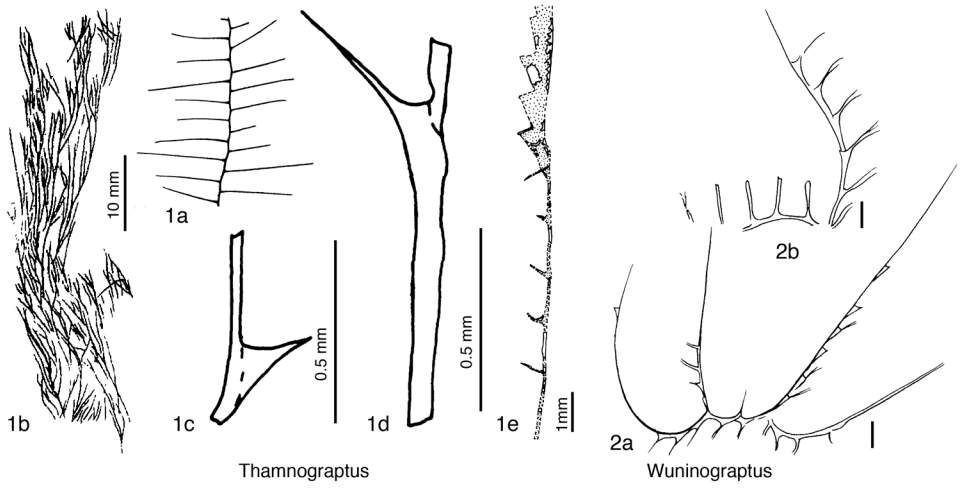

FIG. 16. Thamnograptidae Uncertain (p. 19).

described a few chemically isolated thecae and referred them to *T. capillaris* (EMMONS, 1855). The thecae are parallel sided through most of their length and bear a slightly widening aperture with long and slender ventral apertural spines. The thecal overlap is strongly reduced, but details of the fusellar construction are not available. According to FINNEY (1980), the thecae abruptly change to a dichograptid style in the distal parts of the second-order stipes (Fig. 15.2), but this is not confirmed from isolated material, and the illustrated shale specimens could show accidental associations of thamnograptid and acrograptid stipe fragments. The largest preserved colonies show thickened zigzag central stipes with thinner, alternating lateral stipes, similar to the tubarium construction in *Sigmagraptus*. The style of branching, thus, may be described as monoprogressive. As all known specimens are flattened in shale, no details of the development are available.

Thamnograptus HALL, 1859, p. 519 [**T. typus* (=*Nemagrapsus capillaris* EMMONS, 1855, p. 109, see RUEDEMANN, 1908, p. 205); SD RUEDEMANN, 1908, p. 206]. Tubarium consisting of straight to slightly zigzag shaped, flexible stipes (first-order branches, number unknown) with widely spaced, second-order lateral branches composed of narrow tubular thecae bearing hairlike spines; thecae of lateral, second-order branches abruptly changing to dichograptid thecae distally; proximal development unknown. *Middle Ordovician (Darriwilian,* Pterograptus elegans *Biozone)–Upper Ordovician (Katian,* Nemagraptus gracilis–Climacograptus bicornis *Biozone):* Australia, China, UK, Sweden, USA.——Fig. 16,*1a–e*. **T. capillaris* (EMMONS); *1a,* syntype of *T. typus* HALL, 1859, whereabouts of specimen unknown, scale information unavailable (Hall, 1859, fig. 2); *1b,* neotype (selected by FINNEY, 1980, p. 1190), NYSM 7368, Mount Merino, near Hudson, Columbia County, New York, USA (Ruedemann, 1908, pl. 10,5); *1c–d,* individual thecae of neotype (Finney, 1980, fig. 3); *1e,* OSU 32903, stipe fragment with abrupt change in thecal style, Athens Shale, Alabama, USA (Finney, 1980, fig. 4F).

Wuninograptus NI, 1981, p. 204 [**W. quadribrachiatus;* OD]. Thamnograptid with 3–4 reclined stipes; sicula and thecae with a long, tongue-shaped apertural process and low thecal overlap; thecal apertures with thickened rim. *Middle Ordovician, upper Darriwilian* (*Didymograptus jiangxiensis* Biozone): China, Argentina.——FIG. 16,*2a-b*. **W. quadribrachiatus; 2a,* holotype, NIGP 54074; *2b,* NIGP 54077, thecal details on fragment showing extended rutella; Jiangxi Province, China; scale bars, 1 mm (Ni, 1981, fig. 2,*4* and 2,*3,* respectively).

NOMINA DUBIA

Taishanograptus LI & GE in LI, GE, & CHEN, 1987, p. 102 [**T. graciliramosus;* OD]. Sigmagraptines with slender stipes and widely spaced, irregularly placed dichotomies; thecae simple, low-inclined tubes of dichograptid type. *Middle Ordovician (lower Darriwilian,* Cardiograptus amplus *Biozone):* China. [The types are extremely poor and the presence of a sicula or proximal end is

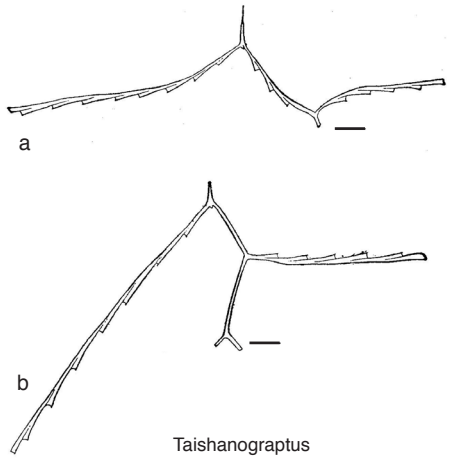

FIG. 17. Nomina Dubia (p. 19–20).

uncertain.]——FIG. 17,*a–b*. **T. graciliramosus; a,* syntype NIGP 76829; *b,* syntype, NIGP 76828; scale bars, 1 mm (Li, Ge, & Chen, 1987, fig. 2).

ABBREVIATIONS FOR MUSEUM REPOSITORIES

BU: Lapworth Museum, Birmingham University, UK
DPM: Departamento de Paleontologia, Universidad Complutense, Madrid, Spain
GSC: Geological Survey of Canada, Ottawa, Canada
LO: Lunds Originale, Department of Geology, Lund University, Sweden
MB.G.: Museum für Naturkunde, Berlin, Germany
MCZ: Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA
NHMUK PI: The Natural History Museum, London, UK
NIGP: Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China
NMVP: Museums Victoria, Melbourne, Australia
NRM-PZ Cn: Naturhistoriska Riksmuseet Stockholm, Sweden
NYSM: New York State Museum, Albany, New York, USA
OSU: Orton Geological Museum, Ohio State University, Columbus, Ohio, USA
OU: Otago University, Department of Geology, Geology Museum, Dunedin, New Zealand
PMO: Natural History Museum, University of Oslo, Paleontological Type collections, Norway
PMU: Palaeontological Collections, Museum of Evolution, Uppsala University, Sweden (previously UM)
SGU: Sveriges Geologiska Undersökning, Uppsala, Sweden
UUG: Czech Geological Survey (Česká geologická služba), Prague, Czech Republic

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