

Supplement to
THE RELATIONSHIPS OF BISERIAL GRAPTOLITES

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TAXA

Outgroups:	13. <i>Exigraptus</i>
1. <i>Tetragraptus</i>	14. <i>U. sinodentatus</i>
2. <i>Pendeograptus</i>	15. <i>U. austrodentatus</i> s.l.
3. <i>Didymograptellus</i>	16. <i>U. formosus</i>
4. <i>Expansograptus</i>	17. <i>U. sinicus</i>
5. <i>Holmograptus</i>	18. <i>Oelandograptus</i>
-----	19. <i>Hustedograptus</i>
6. <i>Isograptus</i>	20. <i>Eoglyptograptus</i>
7. <i>Arienigraptus</i>	21. <i>Pseudoclimacograptus</i>
8. <i>Pseudisograptus</i>	22. <i>Archiclimacograptus</i>
9. <i>Maeandrograptus</i>	23. <i>Phyllograptus</i>
10. <i>Perissograptus</i>	24. <i>Glossograptus</i>
11. <i>Cardiograptus</i>	25. <i>Cryptograptus</i>
12. <i>Bergstroemograptus</i>	

CODING NOTES

1. *Tetragraptus* Salter, 1863 sensu stricto

Type species: *Fucoides serra* Brongniart, 1828

1. number of stipes----(0)
2. stipe attitude----(0)
3. arrangement of the stipes----(0)
4. rhabdosome length---(0): among the type material, the maximum length of stipe is 24 mm, but in *T. serra* subsp. 1, it is 58 mm (Cooper & Fortey 1982, Fig. 15e)
5. maximum rhabdosome width----(0): 3.7–4.2 mm (Cooper & Fortey 1982, p. 192)
6. median septum----(0)
7. arienigraptid suture----(0)
8. sicular length---(3): 2.3 mm (Cooper & Fortey 1982, p. 195)

9. facing direction of sicular aperture----(0)
10. metascula projects well beyond $th1^1$ and $th1^2$ ----(0)
11. morphology of rutellum or virgella----(0)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 2.3/0.45 mm = 5.1 (Cooper & Fortey 1982, Fig. 18a,b)
14. prosicular length/sicular length----(1): 0.25/2.3 mm in *T. phyllograptoides triumphans* (Cooper & Fortey 1982, Fig. 22d)
15. nema attitude----(0): in the type specimens of the species, no nema was seen, but in the Spitsbergen material nema is clearly present (Cooper & Fortey 1982, Fig. 18a)
16. symmetry of proximal end----(1)
17. origination of $th1^1$ ----(0): 'Theca 1¹ grows high on the sicula, probably on the prosicula although this structure is not clearly defined' (Cooper & Fortey 1982, p. 195)
18. antivirgellar (antirutellar) origin of $th11$ ----(0)
19. distal part of $th1^1$ ---(1)
20. distance between the budding point of $th1^1$ and the sicular aperture----(3): 2.25 mm in *T. serra* (Cooper & Fortey 1982, Fig. 18a)
21. origination of $th1^2$ ----(0)
22. distance between the highest point of $th1^2$ and sicular aperture----(4): 1.2 mm (Cooper & Fortey 1982, Fig. 18a)
23. the level of the outwards turning point of $th1^1$ and $th1^2$ ----(0)
24. origination of $th2^1$ ----(0)
25. dicalycal theca----(0): $th1^2$ is the dicalycal theca for the first branching, $th3^1$ and $th3^2$ are the dicalycal thecae for the second branching (see Cooper & Fortey 1982, Fig. 5b)
26. number of thecae with downwards extending proximal part----(3)?: only $th1^1$, $th1^2$ and $th2^1$ possess downward growing proximal part? (see *T. phyllograptoides triumphans* in Cooper & Fortey, 1982, p. 201)
27. manubrium length----(0)
28. exposure of proximal part----(0)
29. number of primordial thecae (*sensu* Mitchell 1987)---- (3): 3 pt. ($th1^1$ - $th2^1$), isograptid proximal development (Cooper & Fortey 1982, p.190; Williams & Stevens 1988, Text-fig.13) .
30. number of crossing canals (*sensu* Mitchell 1987)---- (3): 2 cc. ($th1^2$, $th2^1$).
31. thecal form----(0)
32. thecal shape in sections----(1): see *T. phyllograptoides triumphans* (Cooper & Fortey 1982, Fig. 22)
33. prothecal folds----(0)
34. thecal aperture----(3)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(2): about 2 mm, according to Fig. 18a, b of Cooper & Fortey (1982)
41. the number of obverso-reversely overlapped thecae----(0)
42. thecal overlap----(0)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Cooper & Fortey (1982)

- 45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
- 46. last pair of thecae contribute to manubrium----- (0)

2. *Pendeograptus* Boucek and Pribyl, 1953

Type species: *Tetragraptus pendens* Elles, 1898

- 1. number of stipes----- (0)
- 2. stipes attitude---- (4)
- 3. arrangement of the stipes----- (0)
- 4. rhabdosome length----- (1): 12-18mm in length (Elles & Wood 1902, p.63).
- 5. maximum rhabdosome width----- (3): 0.6mm throughout (Elles & Wood 1902, p.63).
- 6. median septum: (0)
- 7. arienigraptid suture: (0)
- 8. sicular length----- (3): 1.6mm (Elles & Wood 1902, p.63), but 2.3-2.65mm (Williams & Stevens 1988, according to *P. cf. pendens*). But in *P. fruticosus*, it is 2.5-3.0mm long (Williams & Stevens 1988, p.39).
The mean length is 2.41mm, falling within range 1.5-2.5, and is thus coded 3.
- 9. facing direction of sicular aperture----- (0)
- 10. metasicula projects long beyond th11 and th12----- (0)
- 11. morphology of rutellum or virgella----- (0): Williams & Stevens (1988, p.38).
- 12. prosicula represented by rod or rods----- (0)
- 13. sicular length/width----- (0): $2.5\text{mm}/0.16=15.6$ (Williams & Stevens 1988, p.38).
- 14. prosicular length/sicular length----- (1): $0.4/2.1=0.19$ (Williams & Stevens 1988, p.39).
- 15. nema attitude----- (0)
- 16. symmetry of proximal end ----- (1)
- 17. origination of th11----- (0): Williams & Stevens (1988, p.38), Maletz (1994, p.32).
- 18. antivirgellar (antirutellar) origin of th11----- (0)
- 19. distal part of th11----- (0): see also *P. fruticosus* (Williams & Stevens, 1988).
- 20. distance between the budding point of th11 and the sicular aperture----- (3): 2.15mm (Williams & Stevens 1988, p.38, see in *P. cf. pendens*).
- 21. origination of th12 ----- (0)
- 22. distance between the highest point of th12 and sicular aperture----- (5): about 0.8mm (Williams & Stevens 1988, p.39).
- 23. the level of the outward-turning point of th11 and th12----- (0)
- 24. origination of th21----- (0)
- 25. dicalycal theca----- (0)
- 26. number of thecae with downwards extending proximal part----- (0)
- 27. manubrium length----- (0)
- 28. exposure of proximal part (according to the position where medium septum starts)----- (0)
- 29. number of primordial thecae (sensu Mitchell 1987)----- (3)
- 30. number of crossing canals (sensu Mitchell 1987)----- (3)
- 31. thecal form----- (0)
- 32. thecal shape in section----- (0?)
- 33. prothecal folds----- (0)

34. thecal aperture----(3): Elles & Wood (1902) and Williams & Stevens (1988).
35. expansion of thecal apertures----(1): see Elles & Wood (1902, Fig.38), but slightly in *P. fruticosus* (see Williams & Stevens 1988, pl.10, fig.10)..
36. thecal apertural excavation----(0)
37. development of thecal spines---- (0)
38. mesial or subapertural spines---- (0)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(2): $1.5\text{mm}+1.0\text{mm}=2.5\text{mm}$ (Williams & Stevens, 1988, p.38, pl.7, fig.14).
41. the number of obverso-reversely overlapped thecae---- (0)
42. thecal overlap---- (4): estimated according to the Fig.38 of Elles & Wood (1902) and Text-fig.26 of Williams and Stevens (1988).
43. genicular flanges on thecae---- (0)
44. thecal apertural processes---- (0)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (0)
46. last pair of thecae contribute to manubrium----- (0)

3. *Didymograptellus* Cooper and Fortey, 1982

Type species: *Graptolithus bifidus* J.Hall 1865 (pars)

1. number of stipes---- (1)
2. stipes attitude---- (4): proximal part pendent (Williams and Stevens 1988, pp.41-44) and (J. Hall, 1865, p.73).
3. arrangement of the stipes---- (0)
4. rhabdosome length---- (0): the maximum stipe length is 35mm (Williams & Stevens 1988, p.43).
5. maximum rhabdosome width---- (1): the maximum widths of the lectotype and topotype are approximately 2.4mm (see Williams & Stevens 1988, Text-fig.29).
6. median septum---- (0)
7. arienigraptid suture---- (0)
8. sicular length---- (4): 1 mm long (Williams & Stevens 1988, p.41).
9. facing direction of sicular aperture---- (0)
10. metasicula projects long beyond th11 and th12---- (0): Williams & Stevens 1988, Pl.13, figs.10-13.
11. morphology of rutellum or virgella---- (0): short rutellum (Williams & Stevens 1988, p.41).
12. prosicula represented by rod or rods---- (0)
13. sicular length/width---- (3): $1\text{mm}/0.25-0.3=4-5$ (Williams & Stevens 1988, p.41)
14. prosicular length/sicular length---- (2): $0.25\text{mm}/1\text{mm}$ (Williams & Stevens 1988, p.41).
15. nema attitude---- (0): "all immature and isolated specimens possess a nema, but this is never found in mature, non-isolated specimens" (Williams & Stevens 1988, p.41). The length is unknown.
16. symmetry of proximal end---- (1)
17. origination of th11---- (0): Th11 buds about 0.2mm below the apex of the prosicula, thus indicating a prosicular origin (Williams & Stevens 1988, p.41)
18. antivirgellar (antirutellar) origin of th11---- (0): Williams & Stevens (1988, pl.13, figs. 10-13)
19. distal part of th11---- (1): Williams & Stevens (1988, Pl.13, fig.13).

20. distance between the budding point of th11 and the sicular aperture----- (5): approximately 0.8mm (=1mm-0.2mm) as calculated according to the measurements by Williams and Stevens (1988).
21. origination of th12----- (0): see Williams and Stevens (1988, Pl.13, fig.11).
22. distance between the highest point of th12 and sicular aperture----- (5): 0.3-0.5mm, calculated according to Williams and Stevens (1988, p.43).
23. the level of the outward-turning point of th11 and th12----- (0)
24. origination of th21----- (0)
25. dicalycal theca----- (0): "Th12 is dicalycal, also giving rise to th22" (Williams & Stevens 1988, p.43).
26. number of thecae with downwards extending proximal part----- (0)
27. manubrium length----- (0)
28. exposure of proximal part (according to the position where medium septum starts)----- (0)
29. number of primordial thecae (sensu Mitchell 1987)----- (3)
30. number of crossing canals (sensu Mitchell 1987)----- (3): th12 and th21 (Williams & Stevens 1988, Pl.13, fig.11-13).
31. thecal form----- (0): (Williams & Stevens 1988, Text-fig.28 A-DD).
32. thecal shape in section----- (0): Williams & Stevens (1988, Pl.13, figs.10-13).
33. prothecal folds----- (0)
34. thecal aperture----- (3): Williams & Stevens (1988, p.43)
35. expansion of thecal apertures----- (1)
36. thecal apertural excavation----- (0)
37. development of thecal spines----- (0)
38. mesial or subapertural spines----- (0)
39. the position of longest thecae in the stipes----- (1)
40. length of first pair of thecae----- (3): 0.5mm+0.5mm, as measured in Pl. 13, fig.13 of Williams & Stevens (1988).
41. the number of obverso-reversely overlapped thecae----- (0)
42. thecal overlap----- (0): approximately 4/5 or even more, see Hall (1965, Pl.3, fig.10)
43. genicular flanges on thecae----- (0)
44. thecal apertural processes----- (0)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (0)

4. *Expansograptus* Boucek & Pribyl, 1951

Type species: *Graptolithus extensus* Hall 1858

1. number of stipes----- (1)
2. stipes attitude----- (0)
3. arrangement of the stipes----- (0)
4. rhabdosome length----- (0): 35mm for one stipe in the lectotype (see Cooper & Fortey 1982, Fig.40d)
5. maximum rhabdosome width----- (2): 1.5mm (Williams & Stevens 1988, p.46)
6. median septum----- (0)
7. arienigraptid suture----- (0)
8. sicular length----- (3): 1.5-1.6mm (Cooper & Fortey 1982),

9. facing direction of sicular aperture----- (0)
10. metasicula projects long beyond th11 and th12----- (0)
11. morphology of rutellum or virgella----- (0): see Cooper and Fortey (1982, Fig.40e).
12. prosicula represented by rod or rods----- (0)
13. sicular length/width----- (2): 1.5/0.3mm=5, width according to Fig.40e of Cooper & Fortey (1982).
14. prosicular length/sicular length----- ?
15. nema attitude----- (0)
16. symmetry of proximal end----- (1): see the lectotype (Cooper & Fortey 1982).
17. origination of th11----- (0)
18. antivirgellar (antirutellar) origin of th11----- (0): see Williams & Stevens (1988, Text-fig.31c).
19. distal part of th11----- (1)
20. distance between the budding point of th11 and the sicular aperture----- (4): between 1-1.5mm, estimated according to Text-fig.31c of Williams & Stevens (1988).
21. origination of th12----- (0)
22. distance between the highest point of th12 and sicular aperture----- (5): 0.7-0.9mm, estimated according to Text-fig.31c of Williams & Stevens (1988).
23. the level of the outward-turning point of th11 and th12----- (0)
24. origination of th21----- (0)
25. dicalycal theca----- (0): isograptid proximal development (Cooper & Fortey 1982, p.233).
26. number of thecae with downwards extending proximal part----- (4)
27. manubrium length----- (0)
28. exposure of proximal part (according to the position where medium septum starts)----- (0)
29. number of primordial thecae (sensu Mitchell 1987)----- (3)
30. number of crossing canals (sensu Mitchell 1987)----- (3)
31. thecal form----- (0)
32. thecal shape in section----- (0): Williams & Stevens (1988, pl.14, fig.18)
33. prothecal folds----- (0)
34. thecal aperture----- (0)
35. expansion of thecal apertures----- (1)
36. thecal apertural excavation----- (0)
37. development of thecal spines----- (0)
38. mesial or subapertural spines----- (0)
39. the position of longest thecae in the stipes----- (0)
40. length of first pair of thecae----- (3): 0.5+0.5mm=1mm, measured according to the text-fig.31c of Williams and Stevens (1988)
41. the number of obverso-reversely overlapped thecae----- (0)
42. thecal overlap----- (4)
43. genicular flanges on thecae----- (0)
44. thecal apertural processes----- (1)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (0)

5. *Holmograptus Kozłowski, 1954*Type species: *Didymograptus callotheca* Bulman, 1932

1. number of stipes----- (1)
2. stipes attitude----- (1): based on *H. callotheca*.
3. arrangement of the stipes----- (0)
4. rhabdosome length----- (1): less than 10mm as shown by Bulman (1932) and Kozłowski (1954), but these specimens are probably immature forms. According to the other species of *Holmograptus*, e.g. *H. cf. leptograptoides*, *H. sp.A* and *H. bovis*, where there could be more than 9 thecae (see in Williams and Stevens 1988), the maximum length should definitely exceed 10mm.
5. maximum rhabdosome width----- (3): 0.4mm on fourth theca, it seems likely that the maximum width will not exceed 1 mm.
6. median septum: (0)
7. arienigraptid suture: (0)
8. sicular length: (4): 0.8-1.0mm (Bulman 1932),
9. facing direction of sicular aperture: (0)
10. metasicula projects long beyond th11 and th12: (1): projecting considerably, see Bulman (1936, pl.2, figs.1-15).
11. morphology of rutellum or virgella: (0): rutellum, see Bulman (1936, pl.2, figs.1-15).
12. prosicula represented by rod or rods: (0)
13. sicular length/width: (2): 0.8-1/0.15-0.2=5-6, Bulman (1932, p.18).
14. prosicular length/sicular length----(2): 0.35/0.85-1mm=0.38, based on *H. sp.A*. (Williams & Stevens, 1988, p.86).
15. nema attitude----(0)
16. symmetry of proximal end---- (1): roughly symmetrical, see Bulman (1936, pl.2).
17. origination of th11----(0): it seems quite likely to have a prosicular origin in *H. callotheca* as in *H. sp.A*.
18. antivirgellar (antirutellar) origin of th11----(0).
19. distal part of th11----(1)
20. distance between the budding point of th11 and the sicular aperture: (4): should be less than 1mm, as the sicular length is only 1mm.
21. origination of th12----(0)
22. distance between the highest point of th12 and sicular aperture----(5).
23. the level of the outward-turning point of th11 and th12----(0): seemly the same in *H. callotheca*, but typically different of sigmagraptid type in *H. cf. leptograptoides* and *H. sp.A*, see Williams & Stevens (1988, text-fig.80).
24. origination of th21:----(0)
25. dicalycal theca: (0).
26. number of thecae with downwards extending proximal part----(4): only 2 thecae, th21 probably has a short downward-growing proximal part.
27. manubrium length----(0)
28. exposure of proximal part (according to the position where medium septum starts) (Text-fig. 3-3)---- (0)
29. number of primordial thecae (sensu Mitchell 1987)----- (3)
30. number of crossing canals (sensu Mitchell 1987)---- (3)
31. thecal form---- (3): see Bulman (1932, 1936) and Kozłowski (1954).

32. thecal shape in section---- (0)
33. prothecal folds----(1)
34. thecal aperture----(5?): the apertural structures of *H. callotheca* are very complicated, and more or less similar to 'high ventral lips with lateral lobes'.
35. expansion of thecal apertures----(0): prominent expansions present, see Bulman (1932, text-fig.3) and Kozłowski (1954, fig.6).
36. thecal apertural excavation----(2)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(2)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): approximately 1.2mm, measured on Text-fig.5 of Bulman (1932).
41. the number of obverso-reversely overlapped thecae: (0)
42. thecal overlap---- (5)
43. genicular flanges on thecae----(1)
44. thecal apertural processes----(0?)
45. presence of second rutellum, or anti-virgellar rutellum, or spine: (1): second rutellum.
46. last pair of thecae contribute to manubrium----(0)

6. *Isograptus* Moberg, 1892

Type species: *Isograptus gibberulus* (Nicholson 1875)

We based our coding mainly on the description of the species by Bulman (1932).

1. number of stipes----(1)
2. stipe attitude----(2)
3. arrangement of the stipes----(0)
4. rhabdosome length----(1): 20 mm (Bulman, 1932, p. 25)
5. maximum rhabdosome width----(1): 2.5 mm (Bulman 1932, p. 25)
6. median septum----(0)
7. arienigraptid suture----(1): see I. 'gibberulus' (present paper, Text-fig.7B)
8. sicular length----(0): approximately 5 mm (Bulman 1932, p. 24)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (0)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 5/0.8–0.9 mm = 5.6–6.3
14. prosicular length/sicular length----(1): 0.25–0.3/2–3 mm = 0.1–0.13 (Williams & Stevens 1988, p. 66; *Isograptus victoriae lunatus* Harris 1933)
15. nema attitude:----(0)
16. symmetry of proximal end----(0)
17. origination of th11----(0): see Bulman (1932, p. 24)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(0)
20. distance between the budding point of th11 and the sicular aperture----(0): 4.9–5.5 mm (Bulman 1932,

- text-fig. 1a; pl. 1, fig. 2)
21. origination of th12----(0)
 22. distance between the highest point of th12 and sicular aperture----(1): 4.3 mm (Bulman 1932, text-fig. 1a)
 23. the level of the outwards turning point of th11 and th12----(1): actually th11 is almost straight, but th12 does curve gently proximally (Bulman 1932, text-fig. 1).
 24. origination of th21----(0)
 25. dicalycal theca----(0)
 26. number of thecae with downwards extending proximal part----(0): see Bulman (1932, pl. 1, fig. 3)
 27. manubrium length----(0)
 28. exposure of proximal part----(0)
 29. number of primordial thecae (sensu Mitchell 1987)---- (3) : 3 pt. (th11-th21).
 30. number of crossing canals (sensu Mitchell 1987)----(3): 2 cc. (th12, th21).
 31. thecal form----(0)
 32. thecal shape in sections----(0): see Bulman (1932, pl. 1, fig. 5)
 33. prothecal folds----(0)
 34. thecal aperture----(3): concave but with apertural processes.
 35. expansion of thecal apertures----(0)
 36. thecal apertural excavation----(0)
 37. development of thecal spines----(0)
 38. mesial or subapertural spines----(0)
 39. the position of longest thecae in the stipes----(2): see Bulman (pl. 1, figs 3-5)
 40. length of first pair of thecae----(1): about 4 mm (Bulman 1932, text-fig. 1a)
 41. the number of obverso-reversely overlapped thecae----(0)
 42. thecal overlap----(0)
 43. genicular flanges on thecae----(0)
 44. thecal apertural processes----(0): see Bulman (1932)
 45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
 46. last pair of thecae contribute to manubrium----- (0)

7. *Arienigraptus* Yu & Fang, 1981

Type species: *A. jiangxiensis* Yu & Fang 1981

Coding is based on the type species.

1. number of stipes----(1)
2. stipe attitude----(1)
3. arrangement of the stipes----(0)
4. rhabdosome length----(2): 2.8 mm long (Zhang, 1993, p. 72)
5. maximum rhabdosome width----(1): the whole rhabdosome, rather than the ventral-ventral width of biserial rhabdosome, is approximately 2–2.5 mm wide. The width of stipe is unavailable.
6. median septum----(0)
7. arienigraptid suture---- (3): see Text-fig.8 (present paper)
8. sicular length----(2): the length range 2.8–3.5 mm (Zhang, 1993, p. 72; present paper, Text-fig. 8a, b).

Cooper & Ni (1986) described an average length of 5.2 mm (4.6–6.0), which is much longer than the specimens herein. Discussing and clarifying the relationships between these two groups of specimens is beyond the scope of this paper. Here we code according to the JCY specimens.

9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (0)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 3.4/0.5 mm, according to the Text-fig. 8a, b (present paper)
14. prosicular length/sicular length----?
15. nema attitude----(0): maximum length 2 mm (Zhang, 1993, p. 72)
16. symmetry of proximal end----(0)
17. origination of th11----(0): th11 buds from near the apex of the sicula, and therefore is regarded as from the prosicula.
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(0): basically pendent, but slightly declined.
20. distance between the budding point of th11 and the sicular aperture----(3): 2.6–2.9 mm (present paper, Text-fig. 8a, b)
21. origination of th12----(0)
22. distance between the highest point of th12 and sicular aperture----(3): 2–2.3 mm (Zhang 1993, p. 72; present paper, Text-fig. 8a, b)
23. the level of the outwards turning point of th11 and th12----(1): th21 (instead of th11) turn outwards at the same level as th12.
24. origination of th21----(0)
25. dicalyca theca----(0): th12 is the dicalyca theca.
26. number of thecae with downwards extending proximal part----(0): there are 8 thecae in total with downward-growing proximal part.
27. manubrium length----(1): the length is approximately 1–1.1 mm.
28. exposure of proximal part----(0)
29. number of primordial thecae (sensu Mitchell 1987)----(3): 3 pt. (th11–th21)
30. number of crossing canals (sensu Mitchell 1987)----(3) : 2 cc. (th12, th21), see present paper (Text-fig. 8a–d)
31. thecal form----(0): the normal thecal form is unavailable, but it is believed that the thecae are of shape similar to that of isograptids, presumably there are reclined distal stipes. See also Cooper and Ni (1986), Zhang (1993, pl. 3, figs 1, 5, 8)
32. thecal shape in sections----(2)?
33. prothecal folds----(0)
34. thecal aperture----(3)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(2)
40. length of first pair of thecae----(2): usually 2.9–3 mm including the rutellum (present paper, Text-fig. 8a, b)
41. the number of obverso-reversely overlapped thecae----(1): only th11 is superimposed.

42. thecal overlap----(0): almost completely overlapped (Zhang, 1993, p. 73)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Yu & Fang (1981)
45. presence of second rutellum, or anti-irrigellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (4): see present paper (text-fig.8)

8. *Pseudisograptus* Beavis, 1972

Type species: *Didymograptus caduceus manubriatus* Hall 1914

We based our coding mainly on the specimens of *P. manubriatus manubriatus* from Victoria, Australia (Cooper & Ni, 1986), except those with special notes. The original type specimens of the species were regarded as lost, and neotype was designated by Cooper and Ni (1986).

1. number of stipes----(1)
2. stipe attitude---- (1)
3. arrangement of the stipes----(0)
4. rhabdosome length----(1): maximum 13 mm (Cooper & Ni, 1986, p. 330)
5. maximum rhabdosome width----(0): they are 3.1 mm × 2 (stipe) (Cooper & Ni, 1986, p. 330)
6. median septum----(0)
7. arienigraptid suture---- (4): plaited suture (present paper, Text-figs.9,15)
8. sicular length----(0): its average is 4.8 mm (Cooper & Ni 1986, p. 330). This is the shortest among the subspecies of manubriatus. The longest sicula is from *P. m. harrisi*, 11.2 mm (present paper, Text-fig. 9d). In *P. m. koi*, it is 7.5 mm (present paper, Text-fig. 9g), and in *P. m. janus* is about 8.3 mm (present paper, Text-fig. 9f).
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (2): lamelliform virgella as observed in most immature specimens, but probably lanceolate form in adult specimens (see present paper (eg. text-fig.9A,G)).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(0): in *P. m. manubriatus*, the width of the sicular apertures are unknown although the sicular length is 4.8 mm on average, but in *P. m. janus* the length is 7 mm and the apertural width is 0.4 mm, $7/0.4 = 17.5$ (Zhang 1993, p. 81). In *P. m. harrisi*, it is $11.25 \text{ mm} / 0.67 \text{ mm} = 16.8$ (present paper, Text-fig. 9a, d).
14. prosicular length/sicular length----(0): in the type species it is unknown, but in *P. m. janus* it is $0.6 \text{ mm} / 7 \text{ mm}$, $< 1/10$ (Zhang 1993, p. 81).
15. nema attitude----(0)
16. symmetry of proximal end----(0)
17. origination of th11----(1): see *P. m. koi* (Zhang, 1993, p. 76).
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(1)
20. distance between the budding point of th11 and the sicular aperture----(0): 5.8–6.4 mm in *P. m. janus* (Zhang, 1993, p. 81; present paper, Text-fig. 9f), and 6.2 mm in *P. m. koi* and 7.9 mm in *P. m. harrisi* (present paper, Text-fig. 9d, g)

21. origination of th12----(1)
22. distance between the highest point of th12 and sicular aperture----(0): 6.7 mm in *P. m. harrisi*, and 5 mm in *P. m. manubriatus* (present paper, Text-fig. 9f, g).
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0): left-handed origination
25. dicalyca theca----(1): th12 was previously regarded as the dicalyca theca (Cooper & Ni, 1986, p. 354), but according to the intensive investigation on the exquisite pyritic specimens of *P. m. janus* and *P. m. koi* from JCY area, both th22 and th31 originates from th21 respectively, the origination point is very close to that of th21 (present paper, Text-figs. 9b,f; 15c,d).
26. number of thecae with downwards extending proximal part----(0): in *P. m. manubriatus*, 'the manubrium is composed of the proximal portions of at least five pairs of thecae' (Cooper & Ni, 1986), and in *P. m. koi* and *P. m. janus*, there are six pairs of proximal thecae (present paper, Text-fig. 9f, g), whereas in *P. m. harrisi* there are seven pairs of thecae with downward-growing proxmal parts (present paper, Text-fig. 9a).
27. manubrium length----(1): We use the length in the type species *P. m. manubriatus*, 0.7 mm (Cooper & Ni, 1986, p. 330), but in *P. m. harrisi* it is as long as 3.2 mm (present paper, Text-fig. 9a).
28. exposure of proximal part----(0)
29. number of primordial thecae (sensu Mitchell 1987)----(2): 4 pt. (th11–th22)
30. number of crossing canals (sensu Mitchell 1987)----(2) : 3 cc. (th12–th21), see present paper (Text-fig.15).
31. thecal form----(0)
32. thecal shape in sections----(2): see *P. m. harrisi* in present paper (Text-figs.9a,d; 15a).
33. prothecal folds----(2)
34. thecal aperture----(1)
35. expansion of thecal apertures----(1): see *P. m. harrisi* in present paper (Text-fig. 9a).
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(2): the thecal length in *P. m. manubriatus* is unknown, but the th11 in *P. m. harrisi* is 7.8 mm long, which seems to be longer than distal ones and so is used herein.
40. length of first pair of thecae----(0)
41. the number of obverso-reversely overlapped thecae:----(2): in *P. m. harrisi*, there are four pairs of thecae are superimposed in this way (present paper, Text-fig. 9a)
42. thecal overlap----(0): according to *P. m. harrisi* (present paper, Text-fig. 9a)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Cooper & Ni (1986)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (4)

9. *Maeandrograptus* Moberg, 1892

Type species: *M. schmalensei* Moberg 1892

We borrowed from Sedgwick Museum the three specimens described by Jenkins (1980) for re-investigation,

on which some of our codings are based.

1. number of stipes----(1)
2. stipe attitude----(2)
3. arrangement of the stipes----(0)
4. rhabdosome length----(1): not stated in the original description (?). But according to a measurement based on the original figures (which are times 4 according to the length of sicula), the maximum length is about 9 mm (Moberg 1892, Tafl. 8, figs 8-10). It is 22 mm long in one of the specimens described by Jenkins (1980, Fig.5, A51040).
5. maximum rhabdosome width----(1): the maximum width measured according the original figures is 2-2.1 mm (Morberg 1892, Tafl. 8, fig. 10)
6. median septum----(0): the two stipes are not scandent.
7. arienigraptid suture----(2?): the suture might be plaited or similar to that of Parisograptus as shown in some specimens of obverse view, but at moment we do not know exactly, see Bulman (1932, Text-fig.2a, pl.2, fig.8). More well-preserved specimens of reverse view are demanded for the definite coding.
8. sicular length----(2): 2.5 mm in length as stated, but measured from the text-figures it is 2.6-2.8 mm (Bulman 1932). The length of 2.5 mm is confirmed by the specimens of Jenkins (1980).
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12---- (1): see Bulman (1932, p. 27): the sicula projects about 0.5 mm beyond the proximal end, but in other specimens (pl. 2, figs 7, 8) there is no projection. The projection is apparently present also in one of the specimens described by Jenkins (1980, Fig. 6B, A23227).
11. morphology of rutellum or virgella----- (0)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 2.5 mm /0.3 mm (Bulman 1932)
14. prosicular length/sicular length----(1): 0.2/2.12 mm = 0.09 (Beavis 1972, Fig. 2a; present paper, Text-fig. 7h), but the specimen is considerably different from types of *M. schmalenseei* in the origination of th11, and consequently the genus. The prosicula can be identified in Jenkins's (1980, Fig.5, Cat. no. A51040) specimens based on the presence of longitudinal lines, with a length of 0.35 mm, while the total sicular length is 2.5 mm.
15. nema attitude----(0): present, see Bulman (1932, p. 26)
16. symmetry of proximal end:----(1)
17. origination of th11----(0): in some specimens from the type locality in Sweden, th11 buds probably from prosicula (see Beavis 1972, Fig. 2c; Jenkins 1980, p. 296, 299), but in some other specimens th11 also shows a metasicular origin (Beavis 1972, Fig. 2a, 2b, 3a). According to Bulman's description, th11 buds from the one quarter of the total length from the apex (Bulman 1932, p. 26), but uncertain whether it is prosicula or metasicula. *According to the illustrations of Bulman (1932, Text-fig. 2a, b), th11 possesses an origination on anti-rutellum, but this was not stated in the text, and some other figures, including the lectotype, show a normal origin of th11. According to our re-investigation of the specimens with cat. no. A51040, th11 buds from exactly the basal prosicula (present paper, Text-fig. 7h).
18. antivirgellar origin of th11----(0): see Beavis (1972) and Jenkins (1980, Fig. 5)
19. distal part of th11----(3): see Bulman (1932, Text-fig. 2a, b)
20. distance between the budding point of th11 and the sicular aperture ----(3): 2/2.2 mm (Bulman 1932, Text-fig. 2a)
21. origination of th12----(0): see Bulman (1932, Text-fig. 2a)

22. distance between the highest point of th12 and sicular aperture----(4): 1.8 mm (Bulman 1932, Text-fig. 2a)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0): according to Bulman (1932, p. 26), th21 is derived from th12 as in *Isograptus*, but it arises sooner in *Maeandrograptus* than it does in *Isograptus*.
25. dicalycal theca----(0): see Bulman (1932, p. 26)
26. number of thecae with downwards extending proximal part:----(2): there are 5 primordial thecae with downward-growing proximal part.
27. manubrium length----(0)
28. exposure of proximal part----(0)
29. number of primordial thecae (sensu Mitchell 1987)---- (3?): see Bulman (1932), Jenkins (1980, Fig. 6).
30. number of crossing canals (sensu Mitchell 1987)---- (3?): 2 cc. (th12 and th21 probably).
31. thecal form----(2): the thecae strongly undulate proximally and gradually straighten distally.
32. thecal shape in sections----(1): inferred according to the figs. 6–9 of plate 2 (Bulman, 1932).
33. prothecal folds----(1): there are gently and broadly undulating dorsal walls.
34. thecal aperture----(1): proximally it is strongly waving, but distally becomes gradually even.
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(1)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(2): usually 2.2–2.4 mm as measured according to the text-fig. 2 of Bulman (1932), and the length of 10th theca is 7 mm, with a width of 0.25 mm.
41. the number of obverso-reversely overlapped thecae----(1): th11 and th21 are superimposed by th12.
42. thecal overlap----(1): according the proximal thecae (Bulman 1932)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Bulman (1932)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (0)

10. *Perissograptus* Williams & Stevens, 1988

Type species: *Tetragraptus pygmaeus* Ruedemann 1904

1. number of stipes----(0)
2. stipe attitude----(2)
3. arrangement of the stipes----(0)
4. rhabdosome length----(2): less than 2 mm (Williams & Stevens 1988, p. 89)
5. maximum rhabdosome width----(3): maximum 1.0 mm (Williams & Stevens 1988, p. 89)
6. median septum----(0)
7. arienigraptid suture----(0)
8. sicular length----(4): 1.2–1.3 mm (Williams & Stevens 1988, p. 89)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(1)

11. morphology of rutellum or virgella---- (0): Williams & Stevens (1988, pl.24, figs.10, 12).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): $1.2-1.4/0.15-0.2 = 8-7$ (Williams & Stevens 1988, p. 89)
14. prosicular length/sicular length----(1): $0.25/1.4 = 0.18$ (Williams & Stevens 1988, p. 89)
15. nema attitude----(0)
16. symmetry of proximal end----(1)
17. origination of th11----(0): th11 buds from the base of prosicula (Williams & Stevens 1988, p. 89; present paper, Text-fig. 7e, f)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(2)
20. distance between the budding point of th11 and the sicular aperture ----(4): 1.2 mm (Williams & Stevens 1988, pl. 24, Fig. 12)
21. origination of th12----(0)
22. distance between the highest point of th12 and sicular aperture----(4): 1.1 mm (Williams & Stevens 1988, pl. 24, Fig. 12)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0)
25. dicalycal theca----(0): th12 is dicalycal for first branching, th21 and th22 are dicalycal for the second branching (Williams & Stevens 1988, p. 89)
26. number of thecae with downwards extending proximal part----(4): th11 and th12 (see Williams & Stevens 1988, pl. 24, Fig. 11)
27. manubrium length----(0)
28. exposure of proximal part----(0)
29. number of primordial thecae (sensu Mitchell 1987)---- (3): 3 pt. (th11–th21), isograptid proximal development (see Williams & Stevens, 1988, Text-fig.13, Pl.29).
30. number of crossing canals (sensu Mitchell 1987)---- (3?): 2 cc. (th12–th21), however, th21 does not seem to grow across the sicula in some specimens (see Williams & Stevens 1988, eg. Pl.29, figs.7, 14).
31. thecal form----(0): see Ruedemann (1947, p. 307, pl. 51, figs 14-17, distal thecae are available). According to Williams and Stevens (1988): the proximal thecae are curving and 'bulbous', whereas the distal thecae are not available.
32. thecal shape in sections----(0)
33. prothecal folds----(0)
34. thecal aperture----(3)
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0): with pronounced apertural selvage (Williams & Stevens 1988, p. 88)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0)?
40. length of first pair of thecae----(3): 0.9 mm for th11 (Williams & Stevens 1988, pl. 29, Fig. 13)
41. the number of obverso-reversely overlapped thecae---(0)
42. thecal overlap----(4)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Williams & Stevens (1988)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (1): Williams & Stevens (1988, p.88).

46. last pair of thecae contribute to manubrium----- (0)

11. *Cardiograptus* Harris & Keble, 1916

Type species: *Cardiograptus morsus* Harris & Keble, 1916

Since the proximal structures of *C. morsus* are not well known, the following coding is based mainly on *C. amplus* Hsu, except those noted.

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(2)
4. rhabdosome length----(0): >60 mm (Zhang 1993, p. 115)
5. maximum rhabdosome width----(0): 8 mm (Zhang 1993, p. 115)
6. median septum----(0): there is only median suture, no median septum.
7. arienigraptid suture---- (2): see Text-fig. 10A,B (present paper).
8. sicular length----(2): 3–3.1 mm (Xiao et al. 1990, p. 154; Zhang 1993, p. 111)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (0)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 3/0.4–0.5 mm = 6–7.5 (Zhang 1993, p. 111)
14. prosicular length/sicular length---(1): 0.3/3 mm, based on *C. ordovicicus* (see Zhang, 1993, p. 116)
15. nema attitude----(1)
16. symmetry of proximal end----(0): present paper, Text-fig. 10a, b
17. origination of th11----(0): th11 originates from level only 0.3 mm from the sicular apex, suggesting an origination from prosicula (Zhang 1993, p. 119).
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(0)
20. distance between the budding point of th11 and the sicular aperture----(3): 2.5–2.7 mm (Zhang 1993, text-fig. 20.10)
21. origination of th12----(0)
22. distance between the highest point of th12 and sicular aperture----(3): 2 mm (Zhang 1993, p. 111)
23. the level of the outwards turning point of th11 and th12----(1)
24. origination of th21----(0)
25. dicalycal theca----(0)
26. number of thecae with downwards extending proximal part----(2): there are 5 such thecae.
27. manubrium length----(1): 1 mm (Zhang 1993, text-fig. 21.2)
28. exposure of proximal part----(1)
29. number of primordial thecae (sensu Mitchell 1987)---- (3): 3 pt. (th11–th21).
30. number of crossing canals (sensu Mitchell 1987)----(3): 2 cc. (th12 and th21), present paper (Text-fig. 10a, b)
31. thecal form----(0)
32. thecal shape in sections----(2)?

33. prothecal folds----(0)
34. thecal aperture----(3)
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0): >5 mm (Zhang 1993, p. 112)
40. length of first pair of thecae----(2): 2.8 mm (Zhang 1993, text-fig. 20.10)
41. the number of obverso-reversely overlapped thecae----(1): only th11 and th21 are superimposed in this way.
42. thecal overlap----(0)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (0)
46. last pair of thecae contribute to manubrium---- (2): th22 and th31, see present paper (Text-fig.10A,B).

12. *Bergstroemograptus* Finney & Chen, 1984

Type species: *Cardiograptus crawfordi* Harris, 1926

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(5)
4. rhabdosome length----(2): 6-9 mm long (Finney & Chen 1984, p. 1198)
5. maximum rhabdosome width----(0): 4-7 mm, see Finney & Chen (1984, p. 1198)
6. median septum----(0?)
7. arienigraptid suture----(0)
8. sicular length----(2): 3 mm, see Whittington & Rickards (1969, p. 816)
9. facing direction of sicular aperture----(0)
10. metascula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (1): 'the virgella is similarly platelike but may be as long as 1.0mm' (Whittington & Rickards 1969, p.816).
12. prosicula represented by rod or rods----(0): see the paratypes of *C. crawfordi* (Finney & Chen 1984, Fig. 3C, D)
13. sicular length/width----(2): $3/0.4 = 7.5$, Whittington & Rickards (1969, p. 816)
14. prosicular length/sicular length----?
15. nema attitude----(1)
16. symmetry of proximal end----(0)
17. origination of th11----(?)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(0)
20. distance between the budding point of th11 and the sicular aperture----(3): $3-0.5 = 2.5$, Whittington & Rickards (1969, p. 816)
21. origination of th12----(0?): see Whittington & Rickards (1969, text-fig. 11g)

22. distance between the highest point of th12 and sicular aperture----(3): the origination level of th12 is almost the same as th11 (see Whittington & Rickards 1969, p. 816)
23. the level of the outwards turning point of th11 and th12----(1)
24. origination of th21----(1?)
25. dicalycal theca----(0)
26. number of thecae with downwards extending proximal part----(0)
27. manubrium length----(1): from th12 to the budding point of th41, the length is estimated as 0.5 mm (Whittington & Rickards (1969, text-fig. 10b)
28. exposure of proximal part (according to the positions where medium septum starts)----(3)
29. number of primordial thecae (sensu Mitchell 1987)---- (2?): 4 p.t. (th11, th12, th21? and th22).
30. number of crossing canals (sensu Mitchell 1987)----(2?): 3 cc. see Whittington & Rickards (1969, text-fig. 10a, b)
31. thecal form----(0)
32. thecal shape in sections----(0)
33. prothecal folds----(0)
34. thecal aperture---(3)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(2): th11 and th12 = 2 mm, while th61–th71 = 1.5 mm (Whittington & Rickards 1969, p. 816)
40. length of first pair of thecae----(2)
41. the number of obverso-reversely overlapped thecae----(3)
42. thecal overlap----(0)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Whittington & Rickards (1969, text-fig. 10a, b)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (1)
46. last pair of thecae contribute to manubrium---- (3): th32 and th31, see Whittington and Rickards (1969, text-fig.10, and 11G?)

13. *Exigraptus* Mu, 1979

Type species: *E. clavus* Mu, 1979

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): 15 mm in *E. clavus* (present paper, Text-figs.11,12), and 13 mm in *E. uniformis* (Zhang, 1993, p. 124)
5. maximum rhabdosome width----(0): the maximum width is 3.8 mm (present paper, Text-fig. 11c)
6. median septum----(3)
7. arienigraptid suture----(4): see present paper (Text-figs.11,12).
8. sicular length----(0): as described by Chen et al. (1995), the length is 3 mm. In Ni & Xiao (1994, p. 17), it

is 4.4 mm long. However, one of our new specimens with the sicula almost completely exposed indicates, that the length is about 5.2 mm (present paper, Text-fig. 11d). The specimen is vertically elongated and horizontally compressed. to some extent, and was corrected by comparison with normal specimen (e.g. Text-fig. 11c) when measuring the sicular length.

9. facing direction of sicular aperture----(1)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (2): probably 'lanceolate virgella', see present paper (text-fig.11C,D).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(1): 5.2/0.5 mm = 10.4 (present paper, Text-fig. 11d)
14. prosicular length/sicular length----?
15. nema attitude----(2)?: this should be tested again by making cross section.
16. symmetry of proximal end----(1): this genus show some transitional characters between symmetry and asymmetry of th11 and th12 (e.g. present paper, Text-fig. 11c, e)
17. origination of th11----(1)?
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(2)
20. distance between the budding point of th11 and the sicular aperture----(1): 4.6 mm (present paper, Text-fig. 11a)
21. origination of th12----(1)
22. distance between the highest point of th12 and sicular aperture----(2): 3.2 mm (present paper, Text-fig. 11a)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(1): it seems that th21 originates from the reverse side of th12 (present paper, Text-fig. 11a)
25. dicalycal theca----(2): most specimens show dicalycal theca as th22, but needs to be confirmed as a few specimens also show a possible dicalycal theca of th12. Ni & Xiao (1994) regarded th12 as the dicalycal theca.
26. number of thecae with downwards extending proximal part----(1): there are 6 thecae (3 pairs) with downward-growing proximal portions (present paper, Text-fig. 11c).
27. manubrium length----(2): 1.7–1.9 mm (present paper, Text-fig. 11a, c)
28. exposure of proximal part---- (1)
29. number of primordial thecae (sensu Mitchell 1987)----(0): 6–7 pt. (th11–th32)
30. number of crossing canals (sensu Mitchell 1987)----(0): 4 cc. (th12–th31), present paper (Text-figs 11, 12)
31. thecal form----(0)
32. thecal shape in sections----(2): based on present 3-dim specimens.
33. prothecal folds----(2): strong proximally (present paper, Text-fig. 11e)
34. thecal aperture----(2): based on flattened specimens.
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(0)
37. development of thecal spines----(3): thecal spines developed (Mu et al. 1979; Chen 1982)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(2): distal theca (th10) is 2.8 mm long, whereas th5 is 2.3 mm long. But the th11 is more than 3 mm according to Text-fig. 11d (present paper).

40. length of first pair of thecae----(1): th11 is 3.8 mm long and th12 is 3 mm (present paper, Text-fig. 11d)
41. the number of obverso-reversely overlapped thecae----(2): there three pairs superimposed in this pattern.
42. thecal overlap----(0): see present paper, Text-fig. 11c.
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Mu et al. (1979, p. 129), Chen et al. (1995, p. 54)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (3): see present paper (text-fig.11A, C)

14. *Undulograptus sinodentatus* (Mu & Lee, 1958)

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): more than 13 mm, see Chen et al. (1995, p. 60)
5. maximum rhabdosome width----(1): 2.8 mm, see Chen et al. (1995, p. 60)
6. median septum----(3)
7. arienigraptid suture---- (4): see Text-fig.13G (present paper).
8. sicular length----(1): 4 mm long, Chen et al. (1995, p. 60)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (2)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(1): $4/0.35-0.4$ mm = 10–11, measured from pl. 5, fig. E (Chen et al. 1995), but $4/0.2-0.3$ = 13–20 (Zhang 1993, p. 134)
14. prosicular length/sicular length----(?)
15. nema attitude----(2)
16. symmetry of proximal end----(1)
17. origination of th11----(1)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(2)
20. distance between the budding point of th11 and the sicular aperture----(?)
21. origination of th12----(1?)
22. distance between the highest point of th12 and sicular aperture----(4): 1.8 mm measured from Fig. 28B of Chen et al. (1995, p. 62)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(1)
25. dicalycal theca----(2)
26. number of thecae with downwards extending proximal part----(1): until th31 and th32
27. manubrium length----(1): approximately 1.2 mm, based on Fig. 28B of Chen et al. (1995)
28. exposure of proximal part----(1)
29. number of primordial thecae (sensu Mitchell 1987)----(0): 6 p.t. (th11–th32)
30. number of crossing canals (sensu Mitchell 1987)----(1): 4 cc. (th12, th21, th22 and th31), see present paper (Text-fig. 13f, g)

31. thecal form----(2)
32. thecal shape in sections----(0)
33. prothecal folds----(2)
34. thecal aperture----(1)
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(1)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0): proximally 2.2 mm, distally 3 mm (Zhang 1993, p. 134)
40. length of first pair of thecae----(2): 2.2 mm, *ibid*
41. the number of obverso-reversely overlapped thecae----(2)
42. thecal overlap----(2): see Mu & Lee (1958, p. 404)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): present paper (Text-fig. 13f, g)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (3): see present paper (text-fig.13G)

15. *Undulograptus austrodentatus* (Harris & Keble, 1932) *sensu lato*

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes--(3)
4. rhabdosome length----(1): the maximum length reach 15 mm (Chen et al., 1995, p. 61)
5. maximum rhabdosome width----(2): the width proximally is 1.2–1.5 mm, whereas that distally is 1.8–2.0 mm (Chen et al. 1995, p. 61). The Australian specimens show a proximal width of 1.3 mm, and a maximum width of 1.6–1.9 mm (Bulman 1963, p. 679)
6. median septum----(2)
7. arienigraptid suture----(4)
8. sicular length----(1): It was commonly measured 4 mm, the same as *U. sinodentatus* (Chen et al., 1995, p. 60- 61). However, the lengths vary quite greatly. In the present paper, the siculae of some specimens are more than 4 mm long, e.g. in the Text-fig. 13a the broken sicula is 4.6 mm long, and it seems likely the true length might exceed 5 mm. The long sicula also result from the slight elongation as shown by this specimen. Whereas in some other specimens the sicular lengths are less than 4 mm, e.g. 3.8 mm in Text-fig. 13b of present paper. Therefore the sicular length of *U. austrodentatus* is taken as within the range of 3.5–4.5 mm. Li (1994, p. 68) described a length of 2.3 mm. It is also worth noting here that the sicular length of *U. sinicus* is only 1.3 mm (Mitchell 1994, Fig. 2E-G; Chen et al. 1995, p. 63).
9. facing direction of sicular aperture: (0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (2): see, eg., present paper (text-fig.13J).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(0): we use data from Ningkuo Formation. In *U. austrodentatus*, it is about 20 (4/0.2), and in *U. sinodentatus*, it is 16 (4/0.2–0.3 mm) (Zhang 1993, p. 134, 139). The illustration by Mitchell (1994, Fig.1C) also show a sicular length of 5 mm. In isolated specimens of *U. primus* from

Newfoundland, the sicular length is about 1.3–1.4 mm, the sicular apertural width is 0.3 mm (Mitchell 1994, p. 55).

14. prosicular length/sicular---?: The isolated specimens from Newfoundland with the sicular length 1.1-1.2 mm and the prosicula 0.25–0.3 mm (Williams & Stevens 1988, p. 90) were assigned by Mitchell (1994, p. 58) into two species: *U. primus* (Legg) and ‘*Climacograptus*’ *pungens* (Ruedemann 1904), and therefore cannot be used herein. The measures are also similar to those of *U. sinicus*. For more information of *U. primus* from Newfoundland, see also Mitchell (1994, p. 55): the sicular length is about 1.4-1.5 mm with the length of prosicula 0.4–0.5 mm.
15. nema attitude---(2): nema embedded by rhabdosome to become virgula (Chen et al. 1995, Fig. 28G).
16. symmetry of proximal end---(1)
17. origination of th11---(1): No specimens show the boundary between the prosicula and metasicula, this conclusion comes from the very low origination of th11. Usually the prosicula is much shorter than metasicula. The total sicular length is commonly 4 mm., and the distance between the origination point and the sicular aperture is usually 2.0–2.8 mm (present paper, Text-fig. 13a–b), as prosicula of this age is usually quite short compared with metasicula, it is convincing that the th11 buds from the upper part of metasicula.
18. antivirgellar (antirutellar) origin of th11---(0)
19. distal part of th11---(3)
20. distance between the budding point of th11 and the sicular aperture---(4): 1.8–2 mm (Zhang 1993, p. 139; present paper, Text-fig. 13b)
21. origination of th12--- (1): In two juvenile specimens it shows basically streptoblastic (present paper, Text-fig. 13a), while in others the origination part is wrapped and unavailable.
22. distance between the highest point of th12 and sicular aperture---(4): 1.5 mm (present paper, Text-fig. 13)
23. the level of the outwards turning point of th11 and th12---(0)
24. origination of th21---(1): In Text-fig. 13a (present paper), it is basically right-handed.
25. dicalycal theca---(2): Th22 always serves as the dicalycal theca (*U. austrodentatus*, *U. sinodontatus*, *U. sinicus*).
26. number of thecae with downwards extending proximal part---(2): Commonly, th11, th12, th21 and th22 have proximal parts extending downwards, whereas from th31 on, the proximal parts are horizontal or upwards (present paper, Text-fig. 13a, c). However, in *U. sinodontatus*, there are 6 thecae with downwards-growing proximal part (Chen et al. 1995, Fig. 28B).
27. manubrium length---(1): commonly 0.9–1.1 mm (present paper, Text-fig. 13a)
28. exposure of proximal part:---(2): in adults the proximal parts of th11 and th12 are usually enclosed by their succeeding thecae (Chen Xu et al. 1995, Fig. 28C-E, G-H; present paper, Text-fig. 13b–c, j).
29. number of primordial thecae (sensu Mitchell 1987)---(1): 5 pt. (th11–th31), see Mitchell (1990, p. 243; 1994, p. 54, Fig. 3)
30. number of crossing canals (sensu Mitchell 1987)---(1): 4 cc. (th12–th31)
31. thecal form---(2): sigmoidally, but straightening gradually distally (present paper, Text-fig. 13j).
32. thecal shape in sections---(2): see Bulman (1963, text-figs 2, 3)
33. prothecal folds---(1): prothecal folds are prominent in the proximal part, but fade distally (present paper, Text-fig. 13j).
34. thecal aperture---(1): usually gently sigmoidal with the dorsal side concave and the ventral side convex, and ventral lips especially the first pair of thecae (Mitchell 1994, Fig. 1; present paper, Text-fig. 13c, j)
35. expansion of thecal apertures---(0)

36. thecal apertural excavations----(1): In all specimens of *U. austrodentatus*, the excavations are not prominent. However, in *U. primus* they are prominent as climacograptids (Mitchell, 1994).
37. development of thecal spines----(2): there are usually spines only in the first pair of thecae (Mitchell 1994, Fig. 11)
38. mesial or subapertural spines----(0): commonly there are no mesial spines are found in the austrodentatus group. Williams and Steven (1988, p. 91, pl. 34, figs 11-13) illustrated some isolated specimens identified as *U. austrodentatus americanus* with prominent subapertural or mesial spines. Those specimens were regarded as being *U. primus* and '*Climacograptus*' *pungens* by Mitchell (1994).
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(1): the length is difficult to measure due to their strong curvature. The downwards-extending proximal portion is 2 mm long, and the horizontally extending distal part is 1 mm (Chen et al. 1995, Fig. 28C-E), so the total length is approximately 3 mm.
41. the number of obverso-reversely overlapped thecae----(1): there are 4 thecae overlapped in this way: th11, th12, th21 and th22
42. thecal overlap----(3): it is measured as 3/5 (Chen et al. 1995, p. 63)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(1): see Chen et al. (1995, p. 62)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (0)
46. last pair of thecae contribute to manubrium---- (2): th32 seems growing immediately upwards after origination, see Chen, Zhang & Mitchell (1995).

16. *Undulograptus formosus* (Mu & Lee, 1958)

Type species of *Undulograptus* Boucek, 1973

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): maximum length 12 mm (Zhang 1993, p. 147)
5. maximum rhabdosome width----(2): 1–1.3 mm
6. median septum----(2): in proximal part it is strongly zig-zag, but distally become gradually straight.
7. arienigraptid suture----(0?): the descending portion of th21 seems too short to form a suture with that of th12.
8. sicular length----(3): 2 mm, the apex reaches the level equivalent to the apertures of th31 (Zhang 1993, p. 147)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (2?): based mainly on Mu (1958, text-fig.10).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(1): 2/0.15–0.2 (Zhang 1993, p. 147)
14. prosicular length/sicular length----?
15. nema attitude----(2)
16. symmetry of proximal end---- (1)
17. origination of th11----(1)

18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(4)
20. distance between the budding point of th11 and the sicular aperture----(4): approximately 1 mm (Zhang 1993, p. 147)
21. origination of th12----(1): see Zhang (1993, p. 147)
22. distance between the highest point of th12 and sicular aperture----(5): the budding point is 0.5 mm from sicular aperture (Zhang 1993, p. 147)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(1): see Zhang (1993, p. 147)
25. dicalycal theca----(1)
26. number of thecae with downwards extending proximal part----(2): there are 4 thecae with downward-growing proximal part (present paper, Text-fig. 13i)
27. manubrium length----(1)?: 0.4 mm, estimated from reverse view (Zhang 1993, text-fig. 25.14)
28. exposure of proximal part----(2): the medium septum starts from just below the aperture of th12.
29. number of primordial thecae (sensu Mitchell 1987)----(2): 4 pt. (th11–th22)
30. number of crossing canals (sensu Mitchell 1987)----(2): 3 cc. (th12–th22), see Mitchell (1987, p. 358, text-fig. 1)
31. thecal form----(2): the proximal thecae are sigmoid.
32. thecal shape in sections----(0)?: estimated according to figures in Chen et al (1995, pl. 5, fig. H)
33. prothecal folds----(1)
34. thecal aperture----(0): see Mu & Lee (1958)
35. expansion of thecal apertures---- (0)
36. thecal apertural excavation----(1)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0): the distal thecae are 2.5 mm long in maximum (Zhang 1993, p. 149, fig. 10)
40. length of first pair of thecae---- (2): about 1.6 mm = 1 (proximal) + 0.1 (horizontal) + 0.5 (upwards) (Zhang 1993, p. 147)
41. the number of obverso-reversely overlapped thecae----(1): only th11 and th12 are superimposed.
42. thecal overlap----(4): see Zhang (1993, p. 149); present paper, Text-fig. 13h, i)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(1)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (1): see Chen, Zhang & Mitchell (1995, pl.5, fig.H) and present paper (text-fig.13I).

17. *Undulograptus sinicus* (Mu & Lee, 1958)

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(2): 4.3 mm (Mu & Lee 1958, p. 408)

5. maximum rhabdosome width----(3): 0.85 mm (Mu & Lee, 1958, p. 408)
6. median septum----(2): see Chen et al. (1995, Fig. 28G)
7. arienigraptid suture---- (4): speculated on the basis of many figures (e.g. present paper, text-fig.14)
8. sicular length----(4): 1.3 mm (Chen et al. 1995, p. 63), 1.2 mm (see Mitchell 1992, Fig. 1D)
9. facing direction of sicular aperture----(0): basically downwards but the apertural portion curves strongly dorsally (see Chen et al. 1995, Fig. 29A, C, E)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (2?): in some immature specimens, it appears like lanceolate virgella, but in some other (probably mature) specimens it appears like a spinous virgella (see eg. Chen, Zhang & Mitchell 1995, Fgi.29E).
12. proscicula represented by rod or rods----(0)
13. sicular length/width----(2): 1.3/0.23 mm = 5.6 (see Chen et al. 1995, Fig. 29B)
14. proscicular length/sicular length----(2): according to Mitchell (1992, Fig. 1D)
15. nema attitude----(2)
16. symmetry of proximal end----(1)
17. origination of th11----(1)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(4)
20. distance between the budding point of th11 and the sicular aperture----(5): 0.9 mm (according to Fig. 29B of Chen et al. 1995)
21. origination of th12----(1): see Chen et al. (1995, Fig. 29A, B, E)
22. distance between the highest point of th12 and sicular aperture----(5): 0.8 mm (according to Fig. 29B of Chen et al. 1995)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(1)?
25. dicalycal theca----(2): present paper, Text-fig. 14a, b
26. number of thecae with downwards extending proximal part----(2)
27. manubrium length----(1)?: 0.8 mm according to Chen et al. (1995, Fig. 28E)
28. exposure of proximal part----(2)
29. number of primordial thecae (sensu Mitchell 1987)----(1): 5 pt.
30. number of crossing canals (sensu Mitchell 1987)----(1): 4 cc., see Mitchell (1994, Fig. 2)
31. thecal form----(3)
32. thecal shape in sections----(1)?: estimated according to figures (Zhang 1993, pl. 10, fig. 2; pl. 11, fig. 1)
33. prothecal folds----(2)
34. thecal aperture----(5): see Williams & Stevens (1988, Pl. 34, Figs 11-13 = *U. sinicus* Mu & Lee), Chen et al. (1995, Fig. 29C-E)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(2)
37. development of thecal spines----(0)
38. mesial or subapertural spines---- (2)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): 1.3 mm (Mu & Lee 1958, p. 408), 1.2 mm measured according to Fig. 29B of Chen et al. (1995)
41. the number of obverso-reversely overlapped thecae----(1)
42. thecal overlap----(2): Mu & Lee (1958, p. 408)

43. genicular flanges on thecae----(1): see present paper (Text-fig. 10d; 14a, b)
44. thecal apertural processes----(1)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (2): see present paper (text-fig.14B)

18. *Oelandograptus* Mitchell, 1987

Type species: *Glyptograptus austrodentatus oelandicus* Bulman, 1963

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): 10 mm or more (Bulman 1963, p. 682)
5. maximum rhabdosome width----(2): 1.8 mm (Bulman 1963, p. 682)
6. median septum----(3): Bulman (1963, p. 682)
7. arienigraptid suture----(0)
8. sicular length----(3): 1.3–1.8 mm (Bulman 1963, p. 682), 1.8 mm (according to Mitchell 1987, text-fig. 2D)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0): see Mitchell (1987, text-fig. 2B, C, D)
11. morphology of rutellum or virgella----- (3): spinous virgella, see Mitchell (1987, text-fig.2B,C).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 1.7/0.29 mm = 5.9 (see Skevington 1965, p. 60)
14. prosicular length/sicular length----(2): 0.4/1.7 = 0.24, according to Skevington's description; but measured according to the figures, it is 0.6/1.7 = 0.35 (Skevington 1965, Fig. 63)
15. nema attitude----(2)
16. symmetry of proximal end----(1)
17. origination of th11----(1): see Mitchell (1987, text-fig. 2D)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(3)
20. distance between the budding point of th11 and the sicular aperture----(5): 0.9 mm (Mitchell 1987, text-fig. 2D), 1.0 mm (Skevington 1965, Fig. 63)
21. origination of th12----(1)
22. distance between the highest point of th12 and sicular aperture----(5): 0.7 mm (Mitchell 1987, text-fig. 2D), 0.9 mm (Skevington 1965, Fig. 63)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0)
25. dicalyca theca----(1)
26. number of thecae with downwards extending proximal part----(3)
27. manubrium length----(0)
28. exposure of proximal part----(2)
29. number of primordial thecae (sensu Mitchell 1987)----(2): 4 pt. (th11–th22), see Bulman (1963, pl. 97, figs 16-17), Mitchell (1987, p. 358, text-fig. 2)
30. number of crossing canals (sensu Mitchell 1987)----(2): 3 cc. (th12–th22)

31. thecal form----(1)
32. thecal shape in sections----(0): see Skevington (1965, Figs. 65a, b)
33. prothecal folds----(0)
34. thecal aperture----(4): see Mitchell (1987, text-fig. 2J)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(1)
37. development of thecal spines----(0): there are no real spines, but 'spine base' can be seen in the first pairs of thecae (Skevington 1965, Fig. 65a; Mitchell 1987, text-fig. 2C)
38. mesial or subapertural spines----(0): a sub-apertural spine is present on th11 (Skevington 1965, p. 60)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): 1.3 mm (measured according to Mitchell 1987, text-fig. 2C)
41. the number of obverso-reversely overlapped thecae----(1): about 4 thecae (th11, th12, th21 and th22)
42. thecal overlap----(3): about 3/5
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(1): see Bulman (1963, pl. 97, figs 16-17)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (0)
46. last pair of thecae contribute to manubrium---- (0): th12 and th21 form a very short 'manubrium' (see Mitchell 1987, text-fig.2B-D)

19. *Hustedograptus* Mitchell, 1987

Type species: *Diplograptus uplandicus* Wiman, 1895

Most codes are based on Mitchell (1987).

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): 11.2 mm (according to Mitchell 1987, text-fig. 2K)
5. maximum rhabdosome width----(1): 2 mm in *H. uplandicus* (Mitchell 1987, text-fig.2K), but 2.6 mm in *H. teretiusculus* (Maletz 1997, text-fig. 17A)
6. median septum----(1)
7. arienigraptid suture----(0)
8. sicular length----(3): 1.9 mm (see Mitchell 1987, text-fig. 2E)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (3): see Mitchell (1987, text-fig.2E,F).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(3): 1.9/0.4 mm = 4.8 (see Mitchell 1987, text-fig. 2E)
14. prosicular length/sicular length----(2): 0.6/1.9 mm = 0.3 (see Mitchell 1987, text-fig. 2E)
15. nema attitude----(2)
16. symmetry of proximal end----(2)
17. origination of th11----(1)
18. antivirgellar (antirutellar) origin of th11----(0)

19. distal part of th11----(3)
20. distance between the budding point of th11 and the sicular aperture----(5): 0.8 mm (see Mitchell 1987, text-fig. 2E)
21. origination of th12----(2)
22. distance between the highest point of th12 and sicular aperture----(5): 0.65 mm (see Mitchell 1987, text-fig. 2E)
23. the level of the outwards turning point of th11 and th12----(1)
24. origination of th21----(0)
25. dicalycal theca----(1): th21 or delayed theca (Mitchell 1987, p. 380)
26. number of thecae with downwards extending proximal part----(3)
27. manubrium length----(0)
28. exposure of proximal part----(2)
29. number of primordial thecae (sensu Mitchell 1987)----(2): see Mitchell (1987, text-fig. 2)
30. number of crossing canals (sensu Mitchell 1987)----(2)
31. thecal form----(1)
32. thecal shape in sections----(0)?
33. prothecal folds----(0)
34. thecal aperture----(4): gently concave but with paired cusps (see Mitchell 1987, text-fig. 2F, G, K)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(1)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): 1.3 mm (according to Mitchell 1987, text-fig. 2F)
41. the number of obverso-reversely overlapped thecae----(1): 3 thecae
42. thecal overlap----(5)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(1): see Mitchell (1987, text-fig. 2k)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (2)
46. last pair of thecae contribute to manubrium---- (0)

20. *Eoglyptograptus* Mitchell, 1987

Type species: *Furoides dentatus* Brongniart, 1828

Since the description by Brongniart (1828) is very brief, the coding is mainly based on Bulman (1963) and Mitchell (1987).

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): 20 mm (Brongniart, 1828), 20-30 mm (Bulman 1963, p. 673)
5. maximum rhabdosome width----(1): 2 or 3 mm (Brongniart 1828, p. 70); 2.0-2.2 mm (Bulman 1963, p. 673)

6. median septum----(1)
7. arienigraptid suture----(0)
8. sicular length----(4): 1.3 mm (Bulman 1963, p. 675), 1.4 mm (see Mitchell 1987, text-fig. 3J)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (3): see Mitchell (1987, text-fig.3J).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(3): $1.3/0.32 = 4.1$ (Bulman 1963, p.675); $1.4/0.27 = 5.2$ (according to Mitchell 1987, text-fig. 3J)
14. prosicular length/sicular length----(2): $0.33/1.25 \text{ mm} = 0.27$, see Skevington (1965, p. 56, Figs 60, 61)
15. nema attitude----(2)
16. symmetry of proximal end----(2)
17. origination of th11----(1): see Bulman (1963, text-fig. 1b); Mitchell (1987, text-fig. 3J)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(3)
20. distance between the budding point of th11 and the sicular aperture----(5): 0.6 mm (according to Mitchell 1987, text-fig. 3J)
21. origination of th12----(2): see Bulman (1963, text-fig. 1b); Mitchell (1987, text-fig. 3J)
22. distance between the highest point of th12 and sicular aperture----(5): 0.5 mm (according to Mitchell 1987, text-fig. 3J)
23. the level of the outwards turning point of th11 and th12----(1)
24. origination of th21----(0)
25. dicalycal theca----(2)
26. number of thecae with downwards extending proximal part----(4): only th11 and th12.
27. manubrium length----(0)
28. exposure of proximal part----(2): see Skevington (1965, Fig. 62)
29. number of primordial thecae (sensu Mitchell 1987)----(3): 3 p.t.(th11–th21), th22 rises in a similar way as later thecae, see Bulman (1963, text-fig. 1), Mitchell (1987, text-fig. 3J)
30. number of crossing canals (sensu Mitchell 1987)----(3): 2 cc. (th12 and th21), see Bulman (1963, text-fig. 1)
31. thecal form----(1)
32. thecal shape in sections----(0): see Skevington (1965, Figs 61, 62)
33. prothecal folds----(0)
34. thecal aperture---(4): see Mitchell (1987, text-fig. 3I)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(1)
37. development of thecal spines----(1): see Bulman (1963, text-fig. 1c); Mitchell (1987, text-fig. 3J)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): th11 is only 1 mm long (see Mitchell 1987, text-fig. 3J)
41. the number of obverso-reversely overlapped thecae----(1): th11, th12 and th21
42. thecal overlap----(5)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(1): see Bulman (1963)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)

46. last pair of thecae contribute to manubrium---- (0) : see Mitchell (1987, text-fig.3I,J).

16. *Pseudoclimacograptus* Přibyl, 1947 emend. Mitchell, 1987

Type species: *Climacograptus scharenbergi* Lapworth, 1876

1. number of stipes----(1)
2. stipe attitude:----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(0): 32 mm, see Ruedemann (1947, p. 438, pl. 74, Fig. 54)
5. maximum rhabdosome width----(2): 1.3–2.0 mm, see Ruedemann (1947, p. 438), according to the illustration of Mitchell (1987, text-fig. 6I), only 0.63 mm (incomplete specimen).
6. median septum----(2)
7. arienigraptid suture----(0)
8. sicular length----(4): only 0.9 mm long including the rod-like prosicula and normal metasicula (Mitchell 1987, text-fig. 6C)
9. facing direction of sicular aperture----(0): the sicula is straight (Mitchell 1987, text-fig. 6C, E, G)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (3): see Mitchell (1987, text-fig.6A-E).
12. prosicula represented by rod or rods----(1): see Mitchell (1987, text-fig. 6A-G)
13. sicular length/width----(3): 0.9/0.2 mm = 4.5 (according to Mitchell 1987, text-fig. 6C-F)
14. prosicular length/sicular length----(2): 0.2/0.9 mm (according to Mitchell 1987, text-fig. 6A, C)
15. nema attitude:----(2)
16. symmetry of proximal end----(2): see Mitchell (1987, text-fig. 6F, I)
17. origination of th11---(1): see Mitchell (1987, text-fig. 6B, C)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(4)
20. distance between the budding point of th11 and the sicular aperture----(5): only 0.4 mm (according to Mitchell 1987, text-fig. 6B, C)
21. origination of th12----(2)
22. distance between the highest point of th12 and sicular aperture----(5): 0.4 mm from the upper point of th12 crossing canal to the sicular aperture (according to Mitchell 1987, text-fig. 6C).
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0): the protheca of th21 is formed by flange growing from the distal side of th12 (Mitchell 1987, text-fig. 6G)
25. dicalycal theca----(2): Mitchell (1987, p. 387)
26. number of thecae with downwards extending proximal part----(4): only th11 and th12
27. manubrium length----(0)
28. exposure of proximal part----(2): the proximal part of the genus is different from earliest diplograptids, without the exposure of the proximal part of th11 and th12.
29. number of primordial thecae (sensu Mitchell 1987)----(2): th11–th22
30. number of crossing canals (sensu Mitchell 1987)----(3): th22 grows upwards and has no crossing canal, see Bulman (1947), Mitchell (1987, p. 361, text-fig. 6A-I)
31. thecal form----(3): see Mitchell (1987, text-fig. 6I)

32. thecal shape in sections----(0)
33. prothecal folds----(0)
34. thecal aperture----(0)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation---- (2)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(1): only th11 develops mesial spine (see Mitchell 1987, text-fig. 6I)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): only 0.57 mm long (Mitchell 1987, text-fig. 6C, F)
41. the number of obverso-reversely overlapped thecae----(1): there are 3 thecae superimposed.
42. thecal overlap----(5): only 1/3 (see Mitchell 1987, text-fig. 6I)
43. genicular flanges on thecae----(1): see Jaanusson (1960, text-fig. 7B)
44. thecal apertural processes----(1)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (0)

22. *Archiclimacograptus* Mitchell, 1987

Type species: *Pseudoclimacograptus angulatus sebyensis* Jaanusson, 1960.

The following coding is based on the type species described by Mitchell (1987) and Jaanusson (1960), except for those noted specially.

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(3)
4. rhabdosome length----(1): 23 mm (see *A. riddellensis* by Maletz 1997, text-fig. 25A)
5. maximum rhabdosome width----(2): 1.3 mm (Jaanusson 1960, p. 330)
6. median septum----(2)
7. arienigraptid suture----(0): see Text-fig.2I of Mitchell (1987)
8. sicular length----(4): 1.2 mm (according to Mitchell 1987, text-fig. 2Q)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella----- (3): see Mitchell (1987, text-fig.2I,N,Q).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): 1.2/0.2 mm = 6 (according to Mitchell 1987, text-fig. 2N, Q)
14. prosicular length/sicular length----(2): 0.4/1.2 mm = 0.3 (according to Mitchell 1987, text-fig. 2N, Q)
15. nema attitude----(2)
16. symmetry of proximal end----(1): see Mitchell (1987, text-fig. 2I, Q)
17. origination of th11----(1)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(3)
20. distance between the budding point of th11 and the sicular aperture----(5): 0.5 mm (according to Mitchell 1987, text-fig. 2I)

21. origination of th12----(1): (Mitchell 1987, text-fig. 2I)
22. distance between the highest point of th12 and sicular aperture----(5): 0.45 mm (according to Mitchell 1987, text-fig. 2I)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(1)
25. dicalycal theca----(1)
26. number of thecae with downwards extending proximal part----(3)
27. manubrium length----(1): 0.3 mm (according to Mitchell 1987, text-fig. 2I)
28. exposure of proximal part----(2): see Jaanusson (1960, pl. 4, fig. 8)
29. number of primordial thecae (sensu Mitchell 1987)----(2): th11–th22
30. number of crossing canals (sensu Mitchell 1987)----(2): th12, th21 and th22, see Mitchell (1987, text-fig. 2)
31. thecal form----(3): see Jaanusson (1960, pl. 4, figs 5-9)
32. thecal shape in sections----(0)
33. prothecal folds----(2)
34. thecal aperture----(5): similar to those of *U. primus* (see also Maletz 1997, text-fig. 25A-S)
35. expansion of thecal apertures----(0)
36. thecal apertural excavation----(2)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(1)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): 0.75 mm (according to the text-fig. 2Q of Mitchell 1987)
41. the number of obverso-reversely overlapped thecae----(1): only th11, th12 and th21.
42. thecal overlap----(5): only about 1/3 (see Jaanusson 1960, text-fig. 7D, pl. 4, figs 5, 6, 8)
43. genicular flanges on thecae----(1): see Jaanusson (1960, p. 330, pl. 4, figs 5-9, text-fig. 7D)
44. thecal apertural processes----(1): see Jaanusson (1960, p. 330)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (0)
46. last pair of thecae contribute to manubrium----- (0): th12 and th21 form a very short 'manubrium' (see Mitchell 1987, text-fig.2I).

23. *Phyllograptus* Hall, 1858

Type species: *Phyllograptus typus* Hall, 1858

1. number of stipes----(0)
2. stipe attitude----(3)
3. arrangement of the stipes----(4)
4. rhabdosome length----(0): 35 mm (Cooper & Fortey 1982, p. 282)
5. maximum rhabdosome width----(0): 14 mm (Cooper & Fortey 1982, p. 282)
6. median septum----(2)
7. arienigraptid suture----(0): th21 grows outwards and upwards, and cannot form an Arienigraptid suture, see Cooper & Fortey (Figs.75, 76).
8. sicular length----(4): 1.2–1.4 mm (Cooper & Fortey 1982, p. 280)
9. facing direction of sicular aperture----(0)

10. metasicula projects well beyond th11 and th12----(1): see Cooper & Fortey (1982, Fig. 71j)
11. morphology of rutellum or virgella---- (2): probably lanceolate virgella, see Cooper & Fortey (1982, Fig.71a-b,f-g,i-j).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(3): 1.2-1.4/0.3-0.35 mm = 4 (Cooper & Fortey 1982, p. 280)
14. prosicular length/sicular length----?
15. nema attitude----(2): 0.5 mm (Cooper & Fortey 1982, p. 278, 280)
16. symmetry of proximal end----(1)
17. origination of th11----(0)?: as Cooper and Fortey (1982, p. 280) stated 'origin of th11 is not clear but it appears to arise from either the prosicula or from near the top of the metasicula, on the dorsal side'
18. antivirgellar origin of th11----(1)
19. distal part of th11----(3)
20. distance between the budding point of th11 and the sicular aperture----(4): 1.1 mm (according to Cooper & Fortey 1982, Fig. 71b)
21. origination of th12----(0)
22. distance between the highest point of th12 and sicular aperture----(5): 0.7 mm (according to Cooper & Fortey 1982, Fig. 71b)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0)
25. dicalycal theca----(0): th12 is the dicalycal for the first branching, whereas th31 and th22 are the dicalycal thecae for the second branching (Cooper & Fortey 1982, p. 281)
26. number of thecae with downwards extending proximal part----(4)
27. manubrium length----(0)
28. exposure of proximal part----(2): see the obverse side of *P. typus* (Cooper & Fortey 1982, Fig. 71j)
29. number of primordial thecae (sensu Mitchell 1987)----(3): 3 p.t. (th11–th21)
30. number of crossing canals (sensu Mitchell 1987)----(3): 2 cc. (th12, th21), see Cooper & Fortey (1982, Fig. 71)
31. thecal form----(0)
32. thecal shape in sections----(2).
33. prothecal folds----(0)
34. thecal aperture----(3)
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(1)
40. length of first pair of thecae----(3): 1.2 mm (according to Cooper & Fortey 1982, Fig. 71b, g)
41. the number of obverso-reversely overlapped thecae----(1)?: th11 and th12
42. thecal overlap----(0)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0): see Cooper & Fortey (1982)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (1)
46. last pair of thecae contribute to manubrium----- (0)

24. *Glossograptus* Emmons, 1855Type species: *Glossograptus ciliatus* Lapworth, 1873

The coding is based on the type species except those features specially noted.

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(1)
4. rhabdosome length----(1): in *G. acanthus*, it is about 15 mm (Ni & Cooper 1994, Fig. 3D). In *G. kepingensis*, it is 16.7 mm (exclusive of the virgula and virgella, Mu & Zhan 1966, p. 93)
5. maximum rhabdosome width----(1): 2 mm in *G. sinicus* and *G. kepingensis* (Mu & Zhan 1966, p. 93)
6. median septum----(0)?
7. arienigraptid suture----(2?): There might exist a suture between th12 and th21, speculated according to Finney (1978, Fig. 3I) and the Fig. 29I-K of Chen, Zhang & Mitchell (1995), and Ni & Cooper (1996).
8. sicular length----(3): 1.54 mm (based on Finney 1978, Fig. 3m, n)
9. facing direction of sicular aperture----(0): in the type species, it is facing downwards (see Finney 1978, Fig. 3)
10. metasicula projects well beyond th11 and th12----(0)
11. morphology of rutellum or virgella---- (1)
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(2): $1.54/0.25 = 6.2$ (according to Finney 1978, Fig. 3m, n)
14. prosicular length/sicular length----(1): $0.2/1.54 = 0.13$ (according to Finney 1978, Fig. 3m, n)
15. nema attitude----(1)
16. symmetry of proximal end----(0)
17. origination of th11----(0): see Finney (1978, Fig. 3m, n)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(0)
20. distance between the budding point of th11 and the sicular aperture----(4): 1.4 mm with the virgella exclusive (see Finney 1978, Fig. 3m, n)
21. origination of th12----(0)
22. distance between the highest point of th12 and sicular aperture----(4): 1.3 mm (see Finney 1978, Fig. 3m, n)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0)
25. dicalyca theca----(0)
26. number of thecae with downwards extending proximal part----(0): in total there 10 thecae with pendent proximal part (see Ni & Cooper 1994, Fig. 4)
27. manubrium length----(1): 0.8 mm (see Zhang 1993, pl. 12, fig. 6)
28. exposure of proximal part----(3)
29. number of primordial thecae (sensu Mitchell 1987)----(2): 4 p.t. (th11–th22)
30. number of crossing canals (sensu Mitchell 1987)----(2): 3 cc. (th12, th21 and th22), see Finney (1978, Fig. 3)
31. thecal form----(0): simply straight distally.
32. thecal shape in sections----(1): see Chen et al. (1995, pl. 5, fig. D, *G. acanthus*), and Whittington &

Rickards (1979; text-fig. 4, G. holmi Bulman 1931) as well.

33. prothecal folds----(2): strong proximally, but degenerating distally, see *G. acanthus* by Zhang (1993, pl. 12, figs 1, 2)
34. thecal aperture----(4)
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(0)
37. development of thecal spines----(3)
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----(3): approximately 1.4 mm (inferred according to Finney 1978, Fig. 3)
41. the number of obverso-reversely overlapped thecae----(3)
42. thecal overlap----(0)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0)
45. presence of second rutellum, or anti-virgellar rutellum, or spine---- (0): no evidences of an anti-virgellar rutellum have been found.
46. last pair of thecae contribute to manubrium---- (4): in *G. acanthus*, th51 and th52 are probably the last pair of thecae contributing to manubrium (see Chen, Zhang & Mitchell 1995, Fig.28J). *G. ciliatus* is probably in the same case, see Finney (1978).

25. *Cryptograptus* Lapworth, 1880

Type species: *Diplograptus tricornis* Carruthers, 1859

1. number of stipes----(1)
2. stipe attitude----(3)
3. arrangement of the stipes----(1)
4. rhabdosome length----(1): 20 mm in *C. tricornis* by Bulman (1944, p. 30)
5. maximum rhabdosome width----(2): 1.2 mm (0.8–1.5) (Bulman 1944, p. 30)
6. median septum----(0)?
7. arienigraptid suture----(2?): Speculation based on Finney (1978).
8. sicular length----(3): 2 mm in *C. tricornis* (Bulman 1944, p. 30)
9. facing direction of sicular aperture----(0)
10. metasicula projects well beyond th11 and th12----(0): see *C. schaeferi* by Maletz & Mitchell (1996)
11. morphology of rutellum or virgella---- (1): mainly based on Maletz & Mitchell (1996).
12. prosicula represented by rod or rods----(0)
13. sicular length/width----(3): the length is 2 mm (Bulman 1944, p. 30), and the width as measured according to *C. tricornis* (Bulman 1944, text-fig. 5) and *C. insectiformis* (Maletz & Mitchell 1996, Fig. 6.5),

$$\begin{array}{ccccccc} \text{is} & 0.85 & \text{mm.} & 2/0.85 & = & 2.35. \end{array}$$
 However, in *C. marcidus*, the length is 0.9 mm, whereas the apertural width is 0.3 mm (see Finney 1978, Fig. 5j)
14. prosicular length/sicular length----(1): 0.2–0.3/1.8–2.0 mm = 0.15 according to *C. schaeferi* (Maletz & Mitchell 1996, p. 646). In *C. tricornis*, the sicular length is 2 mm, whereas the prosicular length is unknown.

15. nema attitude----(1)
16. symmetry of proximal end----(0): see *C. schaeferi* Maletz & Mitchell (1996)
17. origination of th11----(1): see *C. schaeferi* by Maletz & Mitchell (1996, Figs 5.1, 5.4)
18. antivirgellar (antirutellar) origin of th11----(0)
19. distal part of th11----(0)
20. distance between the budding point of th11 and the sicular aperture----(4): 1.5 mm in *C. schaeferi* (Maletz & Mitchell 1996, Figs 5.4, 5.6)
21. origination of th12----(0): see *C. schaeferi* by Maletz & Mitchell (1996, Fig. 7.1)
22. distance between the highest point of th12 and sicular aperture----(4): 1.6 mm in *C. schaeferi* (Maletz & Mitchell 1996, Fig. 5.4, 5.6)
23. the level of the outwards turning point of th11 and th12----(0)
24. origination of th21----(0)
25. dicalycal theca----(0)
26. number of thecae with downwards extending proximal part----(2): about 4 thecae (see *C. schaeferi* by Maletz & Mitchell (1996, Fig. 7.1)
27. manubrium length----?
28. exposure of proximal part----(3)
29. number of primordial thecae (sensu Mitchell 1987)----(2)
30. number of crossing canals (sensu Mitchell 1987)----(2): 3 cc. (th12, th21 and th22), see Bulman (1944), Strachan (1985), Maletz & Mitchell (1996, Fig. 7)
31. thecal form----(0)
32. thecal shape in sections----(1): see *C. tricornis* by Bulman (1944, Text-fig. 14), but in *C. antennarius*, it is rectangular, based on an SEM specimen from Huangnitang section, China.
33. prothecal folds----(1)
34. thecal aperture----(0)?
35. expansion of thecal apertures----(1)
36. thecal apertural excavation----(0)
37. development of thecal spines----(0): the two lateral sicular apertural spines are usually regarded in error as thecal spines.
38. mesial or subapertural spines----(0)
39. the position of longest thecae in the stipes----(0)
40. length of first pair of thecae----?
41. the number of obverso-reversely overlapped thecae----(3)
42. thecal overlap----(0)
43. genicular flanges on thecae----(0)
44. thecal apertural processes----(0)
45. presence of second rutellum, or anti-virgellar rutellum, or spine----- (1): in *C. insectiformis*, there is a pronounced antivirgellar rutellum (Maletz & Mitchell 1996, Fig. 6, Fig. 7.1)
46. last pair of thecae contribute to manubrium----- (3?): we do not know very clearly the proximal structure of the type species. Present speculation is based on *C. marcidus*, where th32 and th31 are the last pair of thecae for the manubrium (see Finney 1978, Fig.6B).