

ON THE MODE OF BRANCHING IN A NEW SPECIES OF *CLONOGRAPTUS*

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ABSTRACT. The precise nature of dichotomous branching in pyritized specimens of *Clonograptus aureus* sp. nov. of Tremadocian age is described and is compared with Arenigian species of *Loganograptus* and *Goniograptus* from Scandinavia. The manner whereby new branches are generated is analogous to the proximal end development of *Didymograptus minutus*.

ALTHOUGH the mode of development of first-order stipes has been worked out in considerable detail for several multiramous and pauciramous graptolites, little is known about the precise way in which higher order stipes branch laterally or dichotomously. This new material from the Road River Formation in Yukon Territory is therefore of great interest because its exquisitely pyritized rhabdosome indicates how second-, third-, and fourth-order branches are generated. The absence of bithecae in this species indicates that at least one line of clonograptids lost this dendroid characteristic before the close of the Tremadocian.

SYSTEMATIC DESCRIPTION

Family ANISOGRAPTIDAE Bulman 1950
Genus CLONOGRAPTUS Hall and Nicholson 1873
Clonograptus aureus sp. nov.

Text-figs. 1 A-C, 2A, 3 A-C

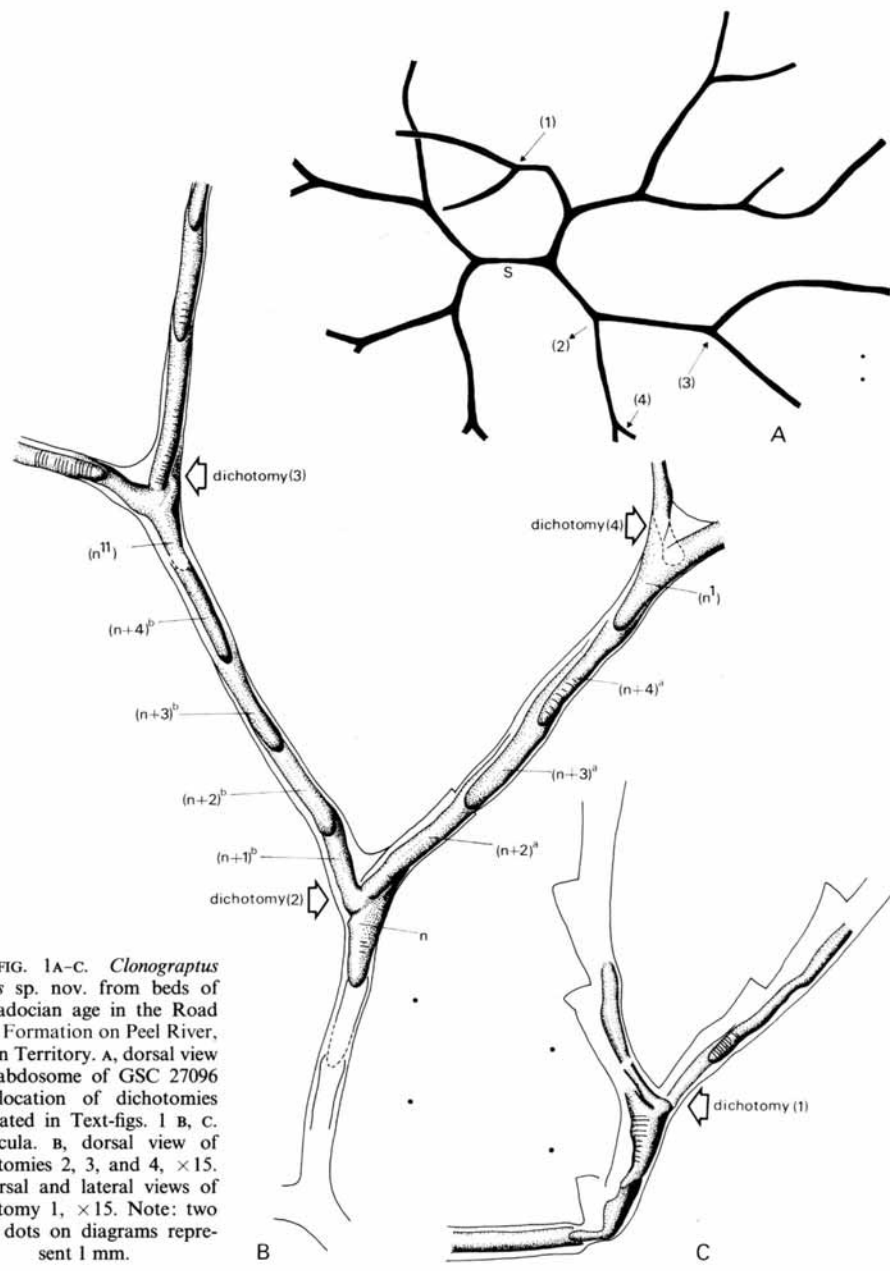
Material. Three incomplete rhabdosomes are available preserved in full relief in pyrite. Illustrated specimens comprising GSC 27096 (Holotype) and 27098 as well as 27097 and 27099 come from the Road River Formation in the Upper Canyon on Peel River, Yukon Territory (65° 56' N., 134° 51' W.).

Horizon. Upper part of Tremadocian *Bryograptus-Clonograptus* Zone of Jackson and Lenz (1962, p. 33). The approximate stratigraphic relationship is known to be 60 metres below the base of *Tetragraptus approximatus* Zone and 120-150 metres above the top of the *Staurograptus* Zone. In 1969 the writer recollected at this stratigraphic level and found *Adelograptus* cf. *victoriae* (T. S. Hall), *Adelograptus*(?) *antiquus* (T. S. Hall), *Dictyonema pulchellum* T. S. Hall, and ?*Tetragraptus decipiens* T. S. Hall. Such a fauna is clearly indicative of an La 2 age in Australia.

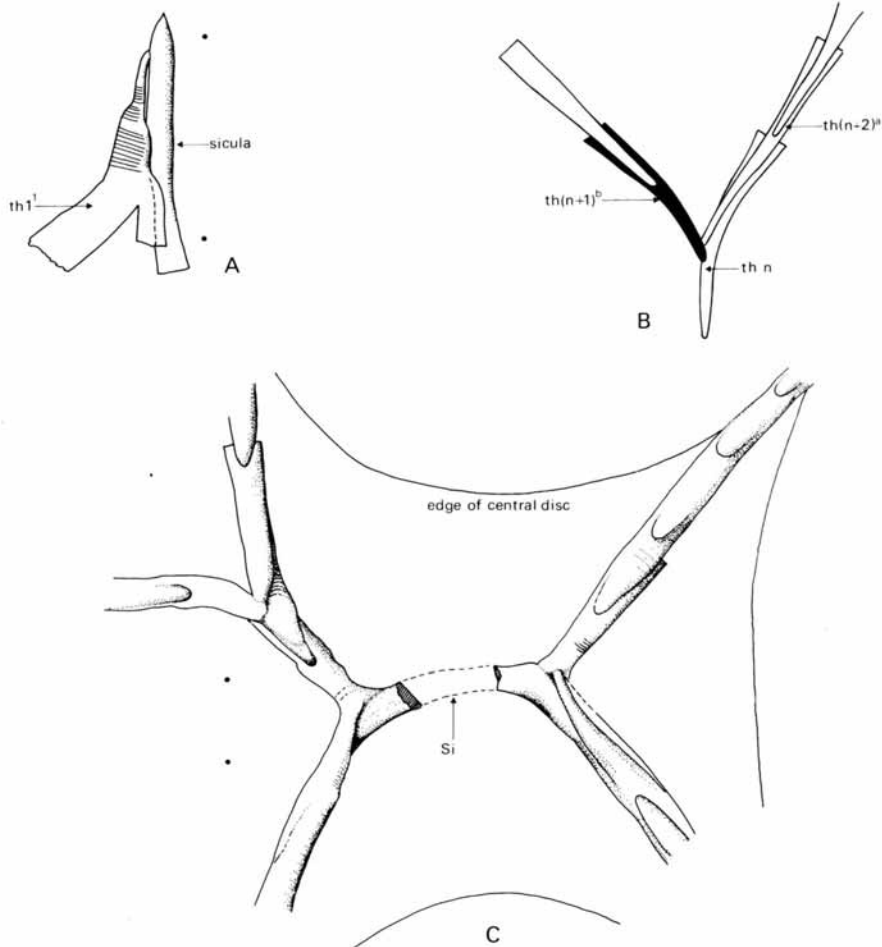
Derivation of name. From Latin *aureus* = golden: referring to colour of pyritized rhabdosome.

Description. Rhabdosome not seen to exceed 25 mm across with dichotomous branching to 5th-order. The funicle is 2.5-2.9 mm long, details of proximal end development not seen. Second-order branches 2-3 mm long diverge so that distally they enclose angles of 110 to 120°; each branch probably composed of 3-4 thecae (see text-fig. 1B). Third and fourth-order branches 3 mm-5.5 mm long and 0.3 mm wide in dorsal view; one fourth-order branch (Text-fig. 1C) preserved in profile is 0.6 mm across thecal aperture, free ventral wall of thecae 1.0 mm long, concave, and inclined at 20°-30°. The thecal rate on third-order stipes is 4 in 4 mm. Associated

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TEXT-FIG. 1A-C. *Clonograptus aureus* sp. nov. from beds of Tremadocian age in the Road River Formation on Peel River, Yukon Territory. A, dorsal view of rhabdosome of GSC 27096 and location of dichotomies illustrated in Text-figs. 1 B, C. S = sicula. B, dorsal view of dichotomies 2, 3, and 4, $\times 15$. C, dorsal and lateral views of dichotomy 1, $\times 15$. Note: two small dots on diagrams represent 1 mm.

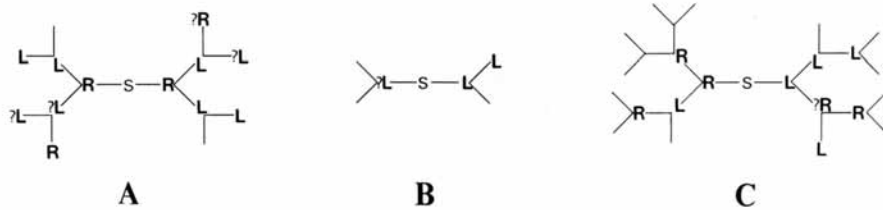


TEXT-FIG. 2A. Pyritized sicula GSC 27098 associated and possibly conspecific with *Clonograptus aureus* sp. nov.; $\times 33$. B. Schematic thecal diagram illustrating dicalycal nature of $th(n+1)^b$; C, proximal end of *Loganograptus kjerulfi* Herrmann from Galgeberg, paratype 73123, Palaeontological Museum Oslo, $\times 13$.

fragmented stipes on same bedding plane believed to belong to this species have a profile width of 0.8 mm across thecal apertures and 11 thecae in 10 mm. Bithecae are apparently absent in all specimens. The details of the sicula are somewhat uncertain. Specimen GSC 27098 may represent the sicula of this species (Text-fig. 2A) in which case it is typically dendroid, consisting of a parallel-sided tube with $th1^1$ originating near apex presumably in the prosicula.

Mode of branching. The precise way in which stipes undergo dichotomous division is best illustrated at points 1, 2, and 3 of text-fig. 1A. Text-figs. 1B, C are enlarged sketches of these branching points and the process is perhaps most clearly shown in dichotomy 2. The third theca on this second-order stipe which is here labelled 'n' (analogous to Jaanusson's 'accessory theca' in *Goniograptus*) is slightly fatter than the preceding theca and in mid-length curves to the right through about 40°. About one-third of the way along the convex side of theca n arises theca (n+1)^b which immediately diverges from theca n to form an angle of about 60° with it. Theca (n+2)^a is derived from the base of theca (n+1)^b and in nearly all cases the junction is marked by a constriction (see text-fig. 1B). Theca (n+1)^b also gives rise to (n+2)^b and is therefore dicalycal. Recognition of dicalycal thecae elsewhere on the rhabdosome is facilitated by the fact that theca (n+2)^b lies considerably closer to the point of dichotomy than does theca (n+3)^a and also by the tendency for the (n+1)^b bearing stipe to diverge at a slightly greater angle from the parent stipe. The paired stipes arising from theca n are of unequal length due to their thecal composition. For example the left stipe which develops from theca (n+1)^b is composed of (n+1)^b + (n+2)^b + (n+3)^b + (n+4)^b + $\frac{1}{3}(n^{11}) = 4\frac{1}{3}$ thecae, whereas the right stipe is composed of (n+2)^a + (n+3)^a + (n+4)^a + $\frac{1}{3}(n^1) = 3\frac{1}{3}$ thecae (excluding the metathecal portion of theca n).

The position of the dicalycal theca in each dichotomy can be on either the left or right side of thecae n, n¹, n¹¹, etc. The dispositions of these dicalycal thecae on individual specimens are plotted in text-fig. 3.



TEXT-FIG. 3A-C. Dispositions of dicalycal thecae in specimens of *Clonograptus aureus* sp. nov. A-C are GSC 27096, 27097, and 27099 respectively. S = sicula, L = left-handed, R = right-handed.

Although GSC 27096 indicated a highly organized pattern in the direction the dicalycal thecae were distributed in each of the four quadrants of the colony it does not apparently hold true for GSC 27099.

Comparisons. The mode of branching observed by the writer in *Loganograptus kjerulfi* Herrmann from the Arenigian at Galgeberg, Norway (see text-fig. 2B) is of identical type. However, the pattern of the positioning of the dicalycal thecae in PMO Paratype 73123 can be seen to be left-handed for second-order stipes and left-handed for one-third-order stipe. This is comparable to GSC 27097 but not to GSC 27096 or 27099.

The described mode of dichotomous branching also closely resembles that suggested by Jaanusson (1965) for *Goniograptus* sp. from Jämtland. However, two

important differences in stipe anatomy exist. Firstly, in *Goniograptus* the positions of the dicalycal thecae are alternately right-handed and left-handed along each main stipe whereas in *Clonograptus* the pattern is not regular. A second difference is that whereas in *Clonograptus aureus* sp. nov. the prothecal segment of $(n+2)^a$ (see text-fig. 1b) is abnormally long by comparison to $(n+1)^b$ the relationship in *Goniograptus* sp. is reversed.

In summary, the manner of stipe dichotomy in *Clonograptus*, *Loganograptus*, and *Goniograptus* and perhaps many other multiramous genera can be compared with proximal end development in dichograptids. When theca n is made analogous to theca 1^1 then the development is of isograptid type in which the dicalycal theca $(n+1)^b = th1^2$ and theca n , like $th1^1$, forms from the first theca of the other stipe. Among the three subtypes of development discussed by Bulman (1955), *Didymograptus minutus* with its single crossing canal seems to afford the best comparison.

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