# Upper Ordovician graptolites and biostratigraphy of the Röstånga 1 core, Scania, S. Sweden

CHRISTIAN PÅLSSON


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A core drilling at Röstånga in 1997, referred to as Röstånga 1, penetrated a significant portion of the Upper Ordovician-Lower Silurian succession in this classical Lower Palaeozoic outcrop area in W-central Scania. In descending order the Upper Ordovician of the core embraces the following units (stratigraphic thickness in parenthesis): Lindegård Mudstone (27.8 m), Fjäcka Shale (13.6 m), Mossen Formation (0.6 m), Skagen Formation (0.8 m), and Sularp Formation (19.9 m +). Graptolites are described from the Lindegård Mudstone, the Fjäcka Shale, and the Mossen Formation. The grapto-lites are classified into 12 taxa, among which 9 are identified to species. Graptolites are very rare in the Mossen Formation, which has yielded only two specimens of *Pseudoclimacograptus scharenbergi*. The Fjäcka Shale yielded a fairly diverse graptolite fauna, indicative of the *Pleurograptus linearis* Zone. This zone is succeeded by the *Dicellograptus complanatus* Zone, with the zonal index appearing in the lower part of the Lindegård Mudstone immediately above graptolites indicative of the *P. linearis* Zone. No graptolites were recovered from the Skagen Formation and the Sularp Formation.

*Keywords:* Upper Ordovician, *Pleurograptus linearis* Zone, *Dicellograptus complanatus* Zone, graptolites, taxonomy, biostratigraphy, Röstånga, Scania, S. Sweden.

*C. Pålsson* [*christian.palsson@geol.lu.se*], *Department of Geology, Historical Geology and Palaeontology, Sölvegatan 13, SE-223 62 Lund, Sweden.* 17 May 2001.

The Ordovician-Lower Silurian succession in Scania (Skåne), southern Sweden, is stratigraphically more complete than in most other areas of Sweden. Exposures are, however, few and restricted to a few areas, all of which have a very limited geographical extent. Studies in the Röstånga area, west-central Scania (Fig. 1), have revealed a nearly continuous Upper Ordovician-Lower Silurian succession (e.g. Tullberg 1883; Olin 1906; Moberg 1910; Hadding 1913; Pålsson 1996; Bergström et al. 1997; Bergström et al. 1999). Because of the absence of one single continuous outcrop, the Ordovician-Lower Silurian succession has in the past been pieced together from various outcrops along the brooks in this classical Lower Palaeozoic outcrop area. During the summer of 1997, a core drilling was carried out in the Röstånga area. The core, referred to as Röstånga 1, was briefly described by Bergström et al. (1999). The drilling reached a depth of 132.59 m and the core embraces Upper Ordovician-Lower Silurian rocks (Viruan-Llandoverian series). The Upper Ordovician (upper Viruan-Harjuan) of the core is mainly composed of grey or black shales and mudstones. This paper focuses on the graptolite biostratigraphy in the Fjäcka Shale and the lower Lindegård Mudstone (the *Pleurograptus linearis and Dicellograptus complanatus* zones) in the Röstånga 1 core.

## Stratigraphy

The new standard Baltoscandian series is applied herein, and the term Upper Ordovician is used for the series above the base of the *Nemagraptus gracilis* Zone (cf. Bergström et al. 2000). Hence, the middle Viruan-Harjuan series are here referred to the Upper Ordovician. The Baltoscandian stage classification, including the revision by Jaanusson (1995), is also followed (Fig. 2).

The middle Viruan (Haljalan Stage) of Scania consists mainly of a sequence of silicified shales and mudstones, and K-bentonites, referred to as the Sularp Formation (Lindström 1953; Regnéll 1960). The Sularp Formation is assigned to the *Diplograptus foliaceus* (formerly *D. multidens*) Zone (Regnéll 1960; Bergström 1982; Bergström et al. 1997). In the Röstånga area, outcrops of the Sularp Formation have yielded a diverse fauna, consisting of trilobites, graptolites, conodonts,

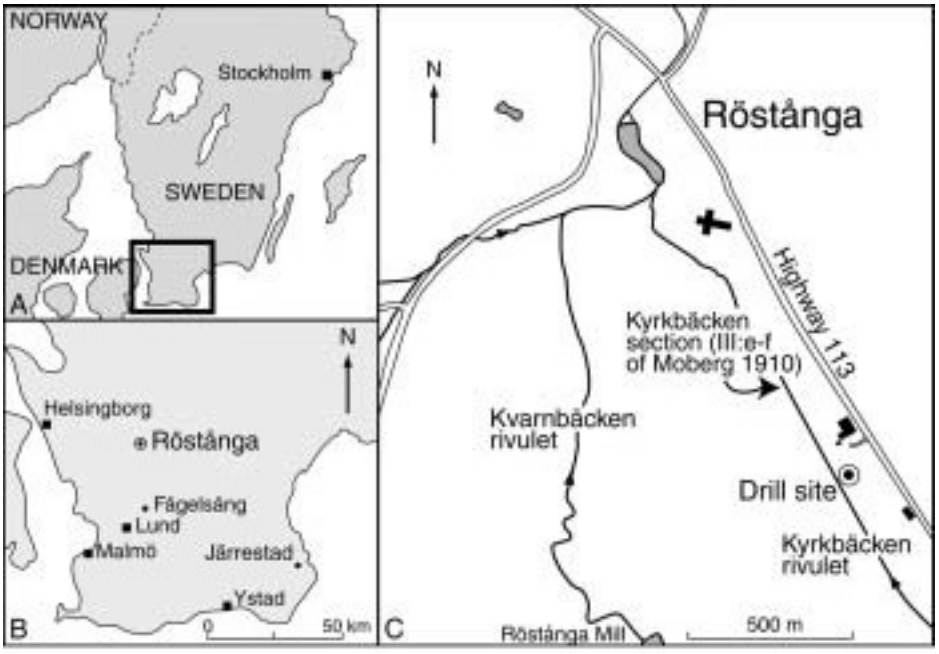


Fig. 1. A. Orientation map of southern Scandinavia. B. Map of Scania, southernmost Sweden, showing the location of Röstånga, Fågelsång, and Järrestad, all located within important areas with Ordovician-Lower Silurian deposits. C. Sketch map of the Röstånga area, showing the location of the Röstånga 1 drilling site (about 1000 m SE of Röstånga Church, between the Kyrkbäcken rivulet and Highway 113; National Grid coordinates 621002 134378).

ostracodes, brachiopods, and echinoderm fragments (e.g. Olin 1906; Moberg 1910; Pålsson 1996; Bergström et al. 1997). The lowermost part of the Röstånga 1 core belongs to the Sularp Formation. It is overlain by the Skagen Formation, formerly known as the Ampyx Limestone (Regnéll 1960; Bergström 1982). This limestone is assigned to the Keilan Stage and is succeeded by a shale and mudstone sequence assigned to the Mossen Formation (Oanduan – Rak-veran Stages).

The Mossen Formation was recognised in the Röstånga area by Pålsson (1996) and Bergström et al. (1997). It was originally described by Skoglund (1963) in Västergötland, south-central Sweden, where it comprises a lower part of dark grey or black shale and an upper part with grey, sometimes calcareous mudstone. At some localities, the Mossen Formation is dominated by calcareous mudstone (Skoglund 1963).

The lower part of the Baltoscandian Harjuan Series in Scania consists of grey to black shales and mudstones. The stratigraphical position and the lithology of this succession suggest that is represents the Fjäcka Shale as described by Jaanusson (1963) and

| Global Series | Balto-scand. Series | British Series | Baltoscand. Stages | Graptolite Zones | Scanian Lithostratigraphic R & F Units SE |
|---|---|---|---|---|---|
| Upper Ordovician | Harjuan | Ashgill | Hirnantian | *N. persculptus* ? ? ? | Kallholn Fm. |
| | | | Jerrestadian | | Lindegård Mudstone |
| | | | | *D. complanatus* | |
| | | | Vasagaardian | *P. linearis* | Fjäcka Shale |
| | Viruan | Caradoc | Rakverian Oanduan | *D. clingani* | Mossen Fm. |
| | | | Keilan | *D. foliaceus* | Skagen Fm. |
| | | | Haljalan | | Sularp Fm. |
| | | | Kukrusian | *N. gracilis* | Dicellograptus Shale |

Fig. 2. Stratigraphical position of the Sularp Formation, the Skagen Formation, the Mossen Formation, the Fjäcka Shale, and the Lindegård Mudstone in Scania (modified after Bergström 1982 and Jaanusson 1995). R = Röstånga area, F = Fågelsång area.

Skoglund (1963) from Jämtland, Dalarna (the Siljan district), Östergötland, and Västergötland. The formation has also been recognised in the Röstånga area of Scania (Pålsson 1996; Bergström et al. 1997; Bergström et al. 1999). It is assigned to the *Pleurograptus linearis* Zone (Glimberg 1961; Jaanusson 1963). The graptolite fauna of the Fjäcka Shale comprises e. g. *Diplograptus pristis, Orthograptus quadrimucronatus, Climacograptus styloideus, Pleurograptus linearis,* and *Orthograptus pauperatus* (Olin 1906; Hadding 1915; Thorslund 1935 and 1948 in Wærn et al.; Skoglund 1963). The type section of the Fjäcka Shale is situated along the Fjäcka rivulet in the Siljan district, central Sweden (Jaanusson & Martna 1948). Jaanusson (1963) described the Fjäcka Shale as comprising dark brown to black shales, which in central and south-central Sweden rests on various Upper Ordovician strata. The faunas of the Fjäcka Shale are generally dominated by graptolites. Ostracodes, brachiopods, and trilobites also occur (Jaanusson & Martna 1948; Thorslund in Wærn et al. 1948; Jaanusson 1963; Skoglund 1963). Our knowledge of the graptolites in the *Pleurograptus linearis* Zone of Scania is fairly poor. This is mainly due the fact that exposures are few. The *P. linearis* Zone is accessible in the outcrops along the Kyrkbäcken rivulet (Fig. 1c). These outcrops are situated close to the Röstånga 1 drill-core site (Pålsson 1996; Bergström et al. 1997; Bergström et al. 2000). Glimberg (1961) suggested the presence of the *P. linearis* Zone in the Lindegård drill-core from the Fågelsång area, about 10 km east of Lund, and Moberg (1907, 1910) described the *P. linearis* Zone along the Tommarpsån rivulet in the Järrestad area, south-eastern Scania.

The Lindegård Mudstone (Jerrestadian-Hirnantian stages) of Scania was formerly divided into the Jerrestad Formation and Tommarp Mudstone (cf. Bergström 1982; Pålsson 1996). This division was based more on the fossil content than on the lithology, and Bergström et al. (1999) proposed the term Lindegård Mudstone for this interval, as suggested by Glimberg (1961). As redefined by Bergström et al. (1999), the Lindegård Mudstone consists of grey mudstones and shales with a few K-bentonites and thin limestone intercalations. Its lowermost part is here assigned to the *D. complanatus* Zone.

## Historical review

The Lower Palaeozoic deposits in the Röstånga area, central Scania, have for over a century drawn the attention of the geologists. Ordovician strata along the Kvarnbäcken, the Trappbäcken, and the Kyrkbäcken rivulets were in the late 19th and early 20th centuries described by, e.g. Tullberg (1880, 1882a, 1883), Olin (1906), Moberg (1910), Hadding (1913, 1922), and Troedsson (1918). The Ordovician of the Röstånga area has subsequently been studied by Ekström (1937), Pålsson (1996), Bergström et al. (1997), and Bergström et al. (1999). Previous works in the Röstånga area were briefly reviewed by Pålsson (1996) and Bergström et al. (1999).

Ordovician strata are fairly well exposed along the Kyrkbäcken rivulet. Tullberg (1880) noted that deposits now assigned to the Sularp Formation were overlain by shales yielding species of *Climacograptus* and *Dicellograptus*. The upper part of the succession along the Kyrkbäcken rivulet was referred to as Trinucleus Shale (Tullberg 1880). Olin (1906) recorded dark grey to black shales with *Diplograptus pristis* (Hisinger, 1837), succeeded by shales with *D. complanatus* Lapworth, 1880. Furthermore, Olin (1906) described the *D. complanatus* and *Staurocephalus clavifrons* zones. The boundary between the Chasmops and the Trinucleus beds was placed at the base of the *Dicellograptus complanatus* Zone. Olin (1906) also recorded specimens of *Orthograptus truncatus* (Lapworth, 1877) from the Trinucleus beds. Moberg (1910) briefly described the Trinucleus beds and the unit now recognised as the Sularp Formation. Moberg (1910) also suggested that the K-bentonite bearing interval belonged to the Upper Chasmops Beds or the Zone of *Calymene dilatata*. Hadding (1913) described the *Hustedograptus teretiusculus* and the *Nemagraptus gracilis* zones along the Röstånga rivulet.

## Lithological succession

In ascending order the Upper Ordovician of the Röstånga 1 core comprises the following formations (Fig. 3): the Sularp Formation, the Skagen Formation, the Mossen Formation, the Fjäcka Shale, the Lindegård Mudstone, and the lowermost part of the Kallholn Formation (for an overall lithostratigraphic classification of the core, see Bergström et al. 1999). There are generally no sharp lithologic changes between the formations, and therefore the boundaries are arbitrarily placed within zones of lithologic gradation. The succession dips 35 degrees, and this figure has been used for calculating stratigraphic thickness. The diameter of the Ordovician part of the core is 52 mm. The core is housed at the Department of Geology, Lund University. Unless otherwise indicated, the m-figures below refer to drilling depth.

Sularp Formation 132.59–108.30 m (stratigraphic thickness 19.9 m+)
132.59–131.05 m: Medium grey to black shales and

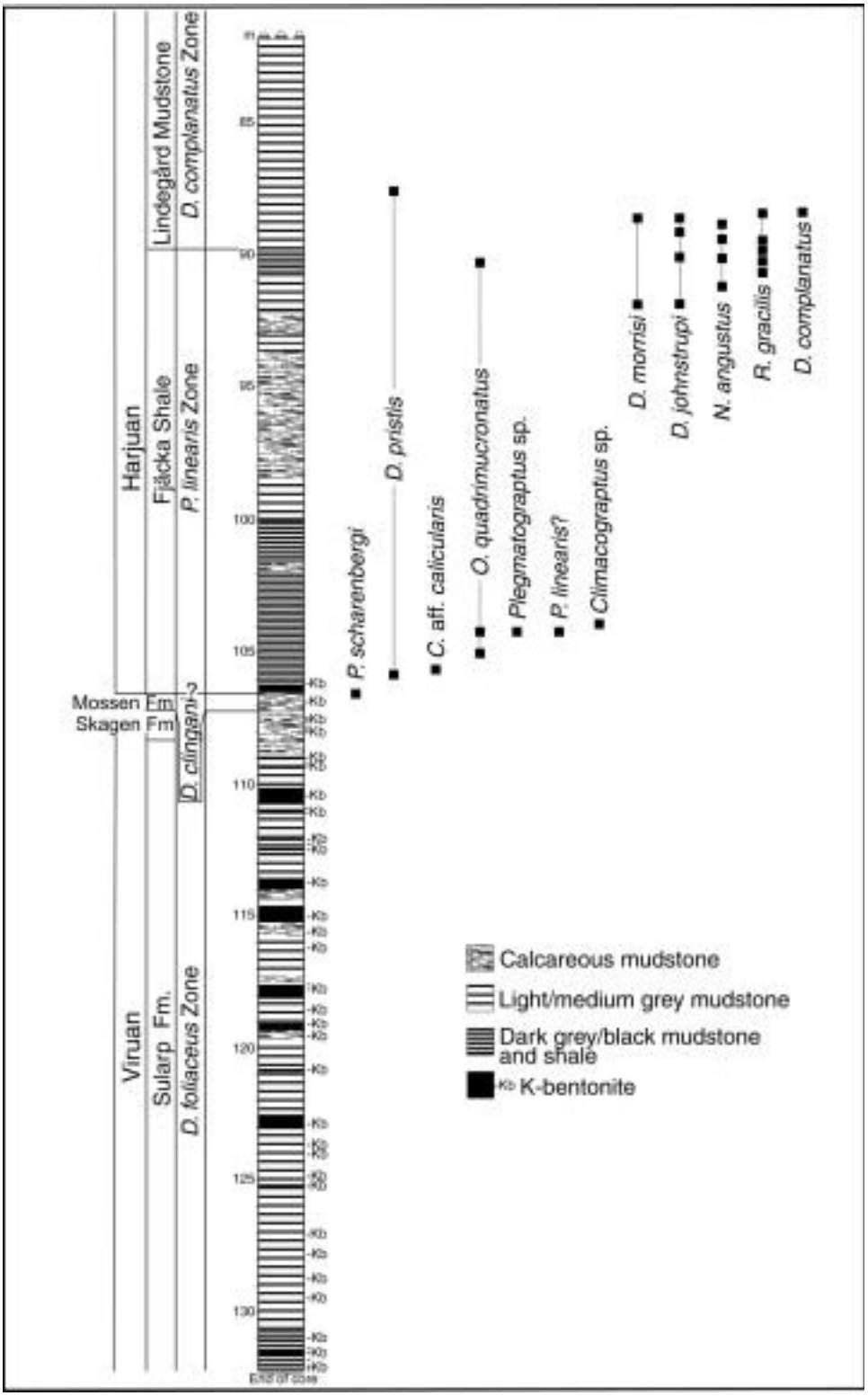


Fig. 3. Lithologic succession, stratigraphic classification, and vertical ranges of graptolites in the Upper Ordovician of the Röstånga 1 core. The m-figures to the left of the column refer to the drilling depth.

mudstones, with six thin K-bentonite beds. The interval is crushed, probably due to faulting.
131.05–122.08 m: Medium grey silicified mudstones with 10 K-bentonite beds.
122.08–112.10 m: Light grey to medium grey mudstones and calcareous mudstones with 7 K-bentonite beds. The mudstones are silicified at various levels.
112.10–108.30 m: Medium grey mudstone with 12 thin K-bentonites.

Skagen Formation 108.30–107.30 m (stratigraphic thickness 0.8 m)
108.30–107.78 m: Medium grey calcareous mudstones and limestones, with 7 K-bentonite beds.
107.78–107.30 m: Dark grey, calcareous mudstone, rich in trilobite fragments.

Mossen Formation 107.30–106.54 m (stratigraphic thickness 0.6 m)
107.38–106.78 m: Light grey to medium grey calcareous mudstone.
106.78–106.54 m: Dark grey to black calcareous mudstone. One K-bentonite bed occurs at 106.77 m. Graptolites are sparse and only two specimens of *Pseudoclimacograptus scharenbergi* (Lapworth, 1876) were found (at 106.64 m). Brachiopods are fairly common.

Fjäcka Shale 106.54–89.95 m (stratigraphic thickness 13.6 m)
106.54–101.30 m: Black mudstone that alters into dark grey at 103.8 m. It is interrupted by a calcareous mudstone at 101.82–101.76 m. One K-bentonite occurs at 106.45–106.44 m. Graptolites encountered: *Pleurograptus linearis* (Carruthers, 1858)? (104.45–104.39 m), *Diplograptus pristis* (Hisinger, 1837) (106.00–105.98 m, 105.96–105.94 m), *Orthograptus quadrimucronatus* (Hall, 1865) (105.05–103.58 m), *Corynoides* aff. *calicularis* Nicholson, 1867 (105.96–105.94 m), *Climacograptus* sp. (104.45–104.40 m; 104.32–104.31 m), and *Plegmatograptus* sp. (104.60–104.58 m; 104.47–104.44 m).
101.30–89.95 m: Dark grey mudstone/calcareous mudstone intercalated by three hard, dark limestone beds at 96.01–95.95 m, 97.71–97.64 m, and 92.80–92.20 m. At 90.67–89.95 m the lithology alternates between black shales/mudstones and dark grey mudstones. Graptolites encountered: *Dicellograptus johnstrupi* Hadding, 1915 (91.75–71.72 m; 90.04–90.01 m), *Dicellograptus morrisi* Hopkinson, 1871 (91.78–91.73 m), *Diplograptus pristis* (Hisinger, 1837) (91.07–91.02 m), *Rectograptus gracilis* (Roemer, 1861) (90.57–90.55 m; 90.39–90.35 m; 90.30–90.27 m; 90.01–89.96 m), *Orthograptus quadrimucronatus* (Hall, 1865) (90.30–90.27 m), and *Normalograptus angustus* (Perner, 1895) (91.75–91.73 m; 90.30–90.27 m).

Lindegård Mudstone 89.95–56 m (stratigraphic thickness 27.8 m)

Mainly light grey to medium grey mudstone and greenish grey calcareous mudstone. Graptolites encountered: *Dicellograptus complanatus* Lapworth, 1880 (88.56–88.55 m), *Dicellograptus johnstrupi* Hadding, 1915 (90.04–90.01 m; 89.38–89.36 m; 88.44–88.42 m), *Dicellograptus morrisi* Hopkinson, 1871 (88.47–88.42 m), *Diplograptus pristis* (Hisinger, 1837) (88.47–88.44 m), *Rectograptus gracilis* (Roemer, 1861) (88.47–88.44, 88.84–88.81 m), and *Normalograptus angustus* (Perner, 1895) (89.38–89.36 m; 88.47–88.44 m).

# Systematic palaeontology

*Repository*. All figured specimens are housed in the collections at the Department of Geology, Lund University, Sweden (LO). High level taxonomic classification is from Fortey & Cooper (1986) and Mitchell (1987).

Family Dicranograptidae Lapworth, 1873
Genus *Pleurograptus* Nicholson, 1867
*Pleurograptus linearis* (Carruthers, 1858)?
Fig. 5L

*Material*. – Four small flattened fragments, i. e. three loose stipe parts, and one sicula with stipes, all from 104.45–104.39 m.

*Remarks*. – Parts of the apex of the sicula are probably resorbed, the remaining part is 1 mm long. The virgella is thin and inconspicuous. $Th1^1$ and $th1^2$ grow upwards and are non-spinose. The width of the rhabdosomes varies between 0.2 and 0.45 mm which seems to agree with the proximal parts of *Pleurograptus linearis* from Dob's Linn, as measured by Williams (1982). In the specimens at hand, no more than three thecae are visible at most. The thecae are long and slender, and no cladia are found.

Moberg (1907, Pl. 1, figs 1–3) figured three specimens of *Pleurograptus linearis* from south-eastern Scania. I have examined the slabs with these specimens, and proximal parts with cladia were found. These parts are closely comparable to the Röstånga 1 specimens, with respect to the width and the outline of the thecae.

The small fragments from Röstånga 1 resemble fragmentary specimens of *Leptograptus flaccidus* Elles and Wood, 1903, but the sicula of L. flaccidus is longer and

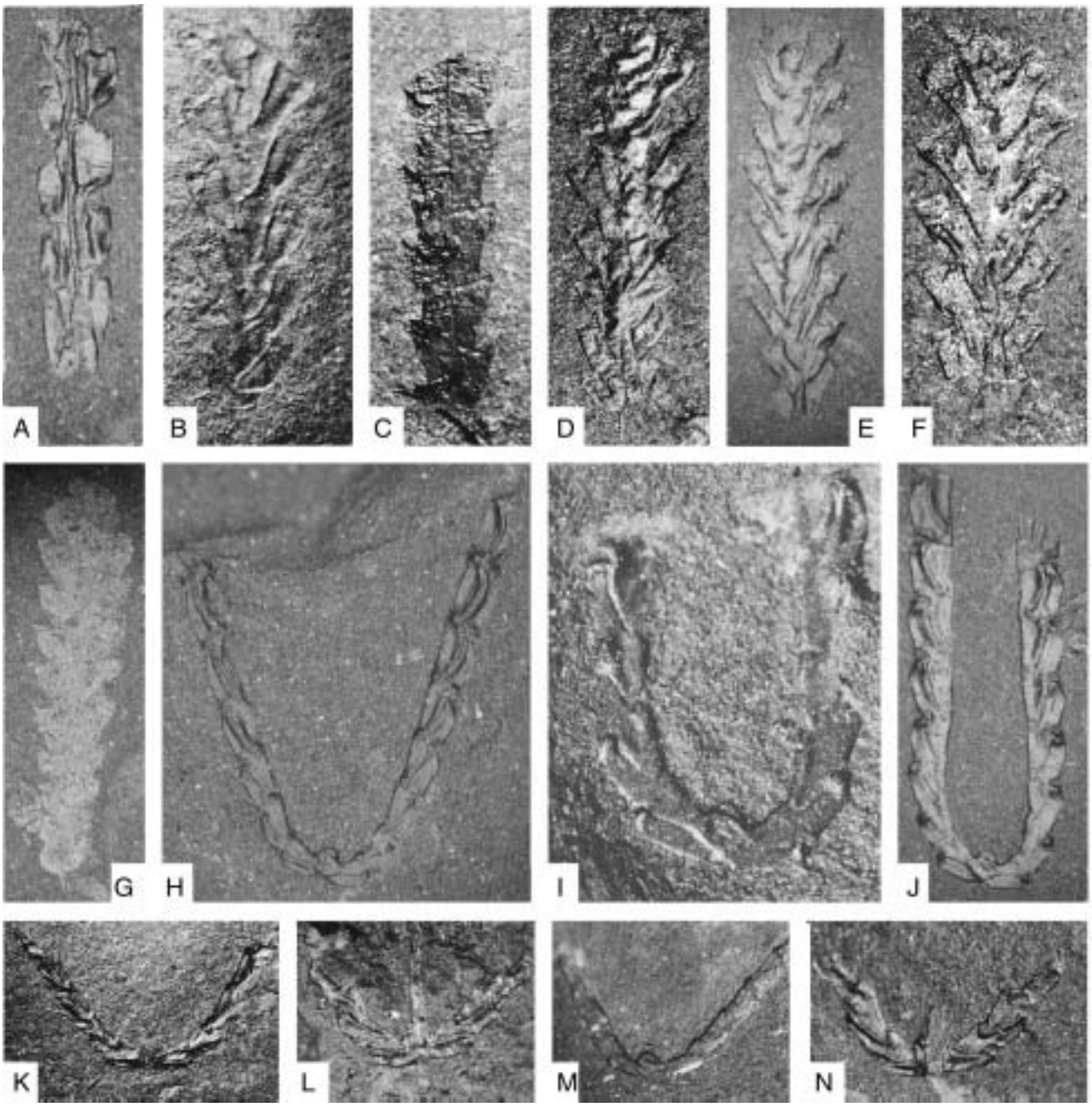


Fig. 4. Graptolites from the Röstånga 1 core. *A. Normalograptus angustus*; same specimen as *7G*; LO 8090t; 88.45–88.44 m; *D. complanatus* Zone; ×9.6. *B. Rectograptus gracilis*; LO 8545t; internal mould; 90.57–90.55 m; *P. linearis* Zone; ×13.4. *C. Orthograptus quadrimucronatus*; LO 8546t; 86.65–86.64 m; *P. linearis* Zone; ×14.8. *D-F. Rectograptus gracilis*. *D*. same specimen as 7C; LO 8547t; 88.48–88.47 m; *D. complanatus* Zone; ×11.5. E. LO 8548t; 88.48–88.47 m; *D. complanatus* Zone; ×11.3. *F.* LO 8549t; 90.30–90.27 m; *P. linearis* Zone; ×11.1. *G. Diplograptus pristis*; same specimen as 6C; LO 8092t; 105.96–105.94 m; *P. linearis* Zone; ×12.4. *H-K. Dicellograptus johnstrupi*; H. LO 8550t; 89.38–89.36 m; *P. linearis* Zone; ×10.5. *I*. LO 8551t; 88.47–88.48 m; *D. complanatus* Zone; ×20. *J*. same specimen as 5A; LO 8552t; 88.48–88.42 m; *D. complanatus* Zone; ×5.8. *K*. LO 8553t; 89.38-89.36 m; *P. linearis* Zone; ×8. *L. Dicellograptus morrisi*; LO 8554t; 88.45–88.44 m; *D. complanatus* Zone ×11.7. *M-N. Dicellograptus johnstrupi*. *M.* LO 8555t; 89.38–89.36 m; *P. linearis* Zone; ×7.9. *N*. LO 8556t; 88.48–88.42 m; *D. complanatus* Zone; ×9.6.

thinner, and th1[1] and th1[2] have a different growth pattern (cf. Elles & Wood 1918, Pl. 14, figs a-g, Pl. 16, fig. 7, Pl. 17, fig. 1; Williams 1982, fig. 4a-e).

Genus *Dicellograptus* Hopkinson, 1872
*Dicellograptus complanatus* Lapworth, 1880
Fig. 5J

1882a *Dicellograptus complanatus* – Tullberg, p. 18
1883 *Dicellograptus complanatus* – Tullberg, p. 4.
1906 *Dicellograptus complanatus* – Olin, p. 25.
1910 *Dicellograptus complanatus* – Moberg, pp. 116–117.
1970 *Dicellograptus complanatus* Lapworth - Toghill, pp. 12–14, Pl. 4–6, text-figs 2g-l, 4b [synonymy to date].
1997 *Dicellograptus complanatus* Lapworth, 1880 – Goldman & Bergström, pp. 984–986, text-figs 11L-M [synonymy to date].

*Material*. - One specimen from the interval 88.56–88.55 m.

*Description*. - As in many *Dicellograptus* species the sicula is broken off or resorbed. The virgella is 0.3 mm. The distance between the apertures of th1[1] and th1[2] is 1.43 mm. The free ventral wall of th1[1] is 0.6 mm long and 0.23 mm wide, and at th1[2] it is 0.63 mm long and 0.25 mm wide. The free ventral walls of the second thecae pair are 0.53 mm long and 0.23 mm wide. At the aperture of th1, the rhabdosome is 0.5 mm wide, at th4 it is 0.66 mm wide and at th9 the width is 0.73 mm. The thecal excavations occupy 1/3–1/2 of the rhabdosome width. Thecal overlap is 0.66 mm proximally and 1.0 mm distally. 2Trd is 1.6 mm proximally (th3 and th4), and 1.8 mm distally (th9 and th10). Small mesial spines, 0.2 mm long, are found up to the third thecae pair. The thecal density is 11 in 10 mm. The thecae have a straight free ventral wall, and slightly introverted apertures.

*Remarks*. – *Dicellograptus complanatus* was described by Toghill (1970) and Williams (1987). The specimen described herein agrees well with their descriptions. Tullberg (1882a, 1883), Olin (1906), and Moberg (1910) reported its occurrence in the outcrops in the Röstånga area, but they did not figure any specimens.

*Occurrence*. – *Dicellograptus complanatus* is a widespread species and has been recorded from the uppermost *P. linearis* – *D. complanatus* zones or equivalent strata in North America (Goldman & Bergström 1997), Europe (Skoglund 1963; Nilsson 1977; Williams 1987), and Russia (Koren' & Sobolevskaya 1983).

*Dicellograptus johnstrupi* Hadding, 1915
Fig. 4I-K, M-N, 5A, D-I, K

1915 *Dicellograptus Johnstrupi* n. sp. - Hadding, p. 24, Pl. 3, Fig. 12-18.
1948 *Dicellograptus johnstrupi* Hadding – Henningsmoen (in Wærn et al.), pp. 401–402, text-fig. 2.
1963 *Dicellograptus johnstrupi* Hadding, 1915 – Skoglund, pp 32–33, Pl. 1, figs 4-9.

*Material*. – Several specimens preserved in relief from the intervals 91.75–91.72 m, 90.04–90.01 m, 89.38–89.36 m, and 88.44–88.42 m.

*Description*. – Most of the sicula is generally lost, but in one specimen it is intact. In this specimen it is 1.0 mm long and provided with in a 1 mm long nema and a 0.36 mm long virgella. The first theca starts to grow 0.5 mm below the apex of the sicula, and continues to grow downwards until it passes the aperture of the sicula by 0.06 mm. It then turns to grow perpendicularly to the sicula for 0.43 mm. Just below the aperture (0.1 mm below) it turns upwards towards the stipe. Th1[2] grows in a similar way. The length of th1[1] is 0.56–0.66 mm long (free ventral wall) and 0.13–0.16 mm wide. Th1[2] is longer, 0.6–0.73 mm long and 0.16–0.20 mm wide. The second thecae pair has a free ventral wall of 0.53–0.6 mm and is slightly wider (0.2–0.23 mm). The third thecae pair has a longer free ventral wall, up to 0.8 mm and is 0.2 mm wide. The width of the rhabdosome is 0.4 mm proximally, and the thecal excavation is 0.13 mm. The stipes are getting slightly wider distally, 0.46 mm at the aperture of th5, 0.5 mm at th10 and 0.66 at th20. Thecal excavations occupy 1/3–1/2 of the rhabdosome width. In the first 10 mm, the thecal count is 11, distally it is 9 thecae in 10 mm. Thecal overlap is 0.4 mm proximally and 0.7 mm distally. 2Trd (two theca repeat distance) across th2-3 is 0.97–1.4 mm and 1.7 mm across th6-7. The distance between the apertures of th1[1] and th1[2] is 1.33–1.56 mm. Small sub-apertural spines occur 0.2 mm below the apertures of the 5 first thecae. The thecae are curved and the introversion starts at the point where the sub-apertural spine is located. The apertures of the first two thecae have a direction of about 45° towards the stipe. The remaining apertures are almost horizontal.

*Remarks*. – Hadding (1915) described *Dicellograptus johnstrupi* from Bornholm, and found that it has a wider axil and different orientation of its stipes than *Dicellograptus morrisi* Hopkinson, 1871. *D. johnstrupi* also has shorter and more slender proximal thecae than *D. morrisi*. Williams (1987) noted the similarity in thecal style between *Dicellograptus complanatus* and *D. johnstrupi*, but found that *D. johnstrupi* has more introverted apertures and weaker inclined supragenicular

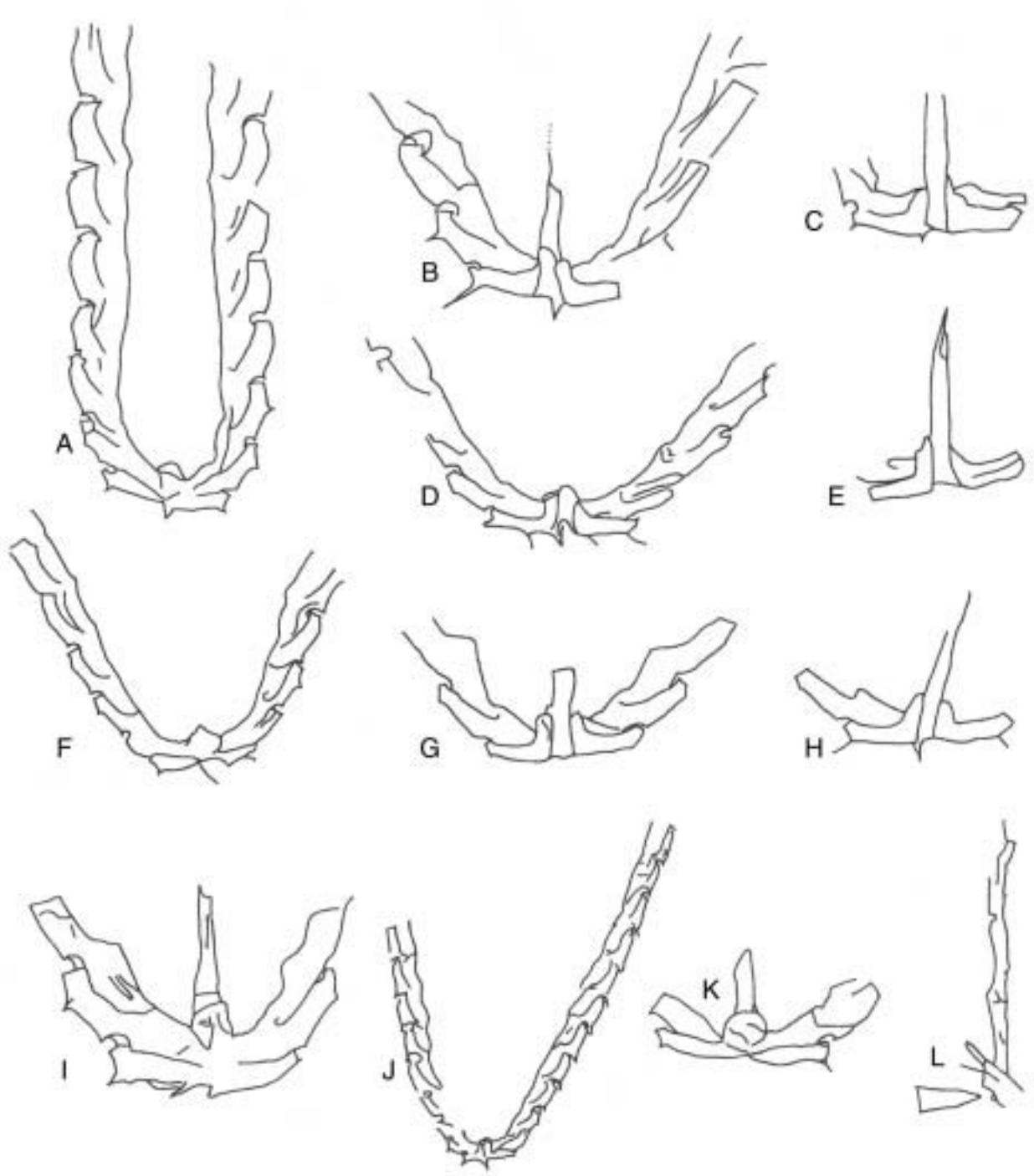


Fig. 5. Graptolites from the Röstånga 1 core; Camera lucida drawings. *A*. *Dicellograptus johnstrupi*; same specimen as *4J;* LO 8552t; 88.48–88.42 m; *D. complanatus* Zone; ×10. *B-C*. *Dicellograptus morrisi*; *B*. LO 8557t; 88.45–88.44 m; *D. complanatus* Zone; ×16.4. *C*. LO 8558t; 88.45–88.44 m; *D. complanatus* Zone; ×15.5. *D-I*. *Dicellograptus johnstrupi*; *D*. LO 8559t; *P. linearis* Zone; 89.38–39.36 m; ×13.8. *E*. LO 8578t; *D. complanatus* Zone; 88.48–88.47 m ×15.5. *F*. LO 8560t; 89.38–89.36 m; *P. linearis* Zone; ×10.2. *G*. LO 8561t; 91.73–91.72 m; *P. linearis* Zone; ×17.8. *H*. LO 8562t; 91.73–91.72 m; *P. linearis* Zone; ×15.6. *I*. LO 8563t; 88.48–88.47 m; *D. complanatus* Zone; ×27.5. *J*. *Dicellograptus complanatus*; LO 8564t; 88.56–88.55 m; *D. complanatus* Zone; ×5.6. *K*. *Dicellograptus johnstrupi*; LO 8565t; 91.73–91.72 m; *P. linearis* Zone; ×16.3. *L*. *Pleurograptus linearis*?; LO 8566t; 104.45–104.39 m; *P. linearis* Zone; ×10.5.

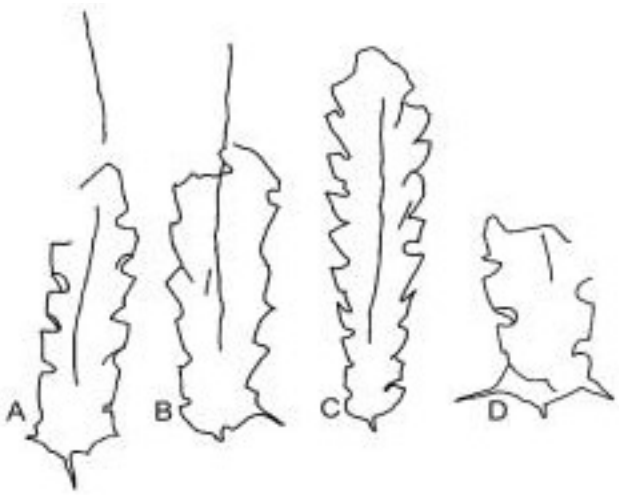


Fig. 6. *Diplograptus pristis* (Hisinger, 1837); Camera lucida drawings; all specimens from 105.96–105.94 m; *P. linearis* Zone; Fjäcka Shale, the Röstånga 1 core. *A*. LO 8567t; ×9.1. *B*. LO 8093t; ×9.5. *C*. Same specimen as *4G;* LO 8092t; ×7.8. *D*. LO 8568t; ×11.3.

walls. Furthermore *D. johnstrupi* has a slightly narrower rhabdosome and more slender proximal thecae than *D. complanatus*.

*Occurrence*. – Skoglund (1963) recorded this species from the Fjäcka Shale in Västergötland, central Sweden, and Hadding (1915) reported it from the *P. linearis* Zone of Bornholm.

*Dicellograptus morrisi* Hopkinson, 1871
Fig. 4L, 5B-C

1983 *Dicellograptus morrisi* Hopkinson, 1871 – Williams in Williams and Bruton, pp. 169–170, figs 10D, 14A-E [Synonymy to date].

*Material*. – One specimen from the interval 91.78–91.73 m, and two specimens preserved in relief from the interval 88.47–88.42 m.

*Description*. – In large specimens the sicula is broken off, but in a small one, it is preserved. The sicula is 1.3 mm long, and provided with a 0.2 mm long virgella. The distance between the apertures of $th1^1$ and $th1^2$ is 1.40–1.53 mm. The length of $th1^1$ is 0.60–0.73 mm (free ventral wall) and it is 0.21 mm wide. The free ventral wall of $th1^2$ is 0.60–0.66 mm long and 0.22 mm wide. The next two thecae pairs have a length between 0.53 and 0.73 mm and their width is 0.23–0.27 mm. Small mesial spines, located 0.13–0.30 mm below the apertures, occur on the first three thecae pairs. The rhabdosome width varies between 0.46 and 0.50 mm across the aperture of th1, to 0.73 mm across th9. Thecal excavations occupy 1/3 of the width of the rhabdosome. Thecal overlap is 0.56 (proximally)–0.7 mm (distally). 2Trd between th2–3 is 1.46 and 1.6 mm between th6-7. In the proximal part, 7 thecae in 5 mm are counted.

*Remarks*. – Skoglund (1963) noted small mesial spines on the first 11 thecae pairs. The specimens described by Toghill (1970) have no such spines, and the Röstånga 1 specimens have mesial spines on the three first thecae pairs. *Dicellograptus johnstrupi* and *Dicellograptus morrisi* are closely similar, but Williams (1982) noted differences in their thecal style.

*Occurrence. – Dicellograptus morrisi* occurs in the *D. clingani* and *P. linearis* zones of S. Scotland (Williams 1982; Zalasiewicz et al. 1995), the Fjäcka Shale of Sweden (Skoglund 1963), and the *P. linearis* Zone of Norway (Williams in Williams & Bruton 1983). Mitchell et al. (1998) reported it from the *D. complanatus* Zone of the Argentine Precordillera.

Family Orthograptidae Mitchell, 1987
Genus *Orthograptus* Lapworth, 1873
*Orthograptus quadrimucronatus* (Hall, 1865)
Fig. 4C, 7J

1915 *Orthograptus quadrimucronatus* – Hadding, p.12, fig. 3.
1995 *Orthograptus quadrimucronatus* (Hall, 1865) – Goldman, pp. 525–530, figs 10.1–10.19, 11.1–11.6, 15.1–15.5, 17.5–17.9 [Synonymy to date].

*Material*. – 14 specimens from the interval 105.05–103.58 m, and one from 90.30–90.27 m.

*Remarks*. – The specimens are long, about 40 mm. The proximal portions are missing, but the distal thecae are distinct with small apertural spines.

*Occurrence. – Orthograptus quadrimucronatus* occurs in the upper Middle-Upper Ordovician world-wide (Elles & Wood 1907; Hadding 1915; Nilsson 1977; Vanden-Berg & Cooper 1992; Goldman 1995).

Family Archiretiolitidae Bulman, 1955.
Genus *Plegmatograptus* Elles & Wood, 1908
*Plegmatograptus* sp.
Fig. 7K

*Material*. – One specimen from the interval 104.60–104.58 m and several crushed ones from 104.47–104.44 m.

*Remarks*. – The most complete specimen (104.60–104.58 m) is flattened and only a few details are visible. The

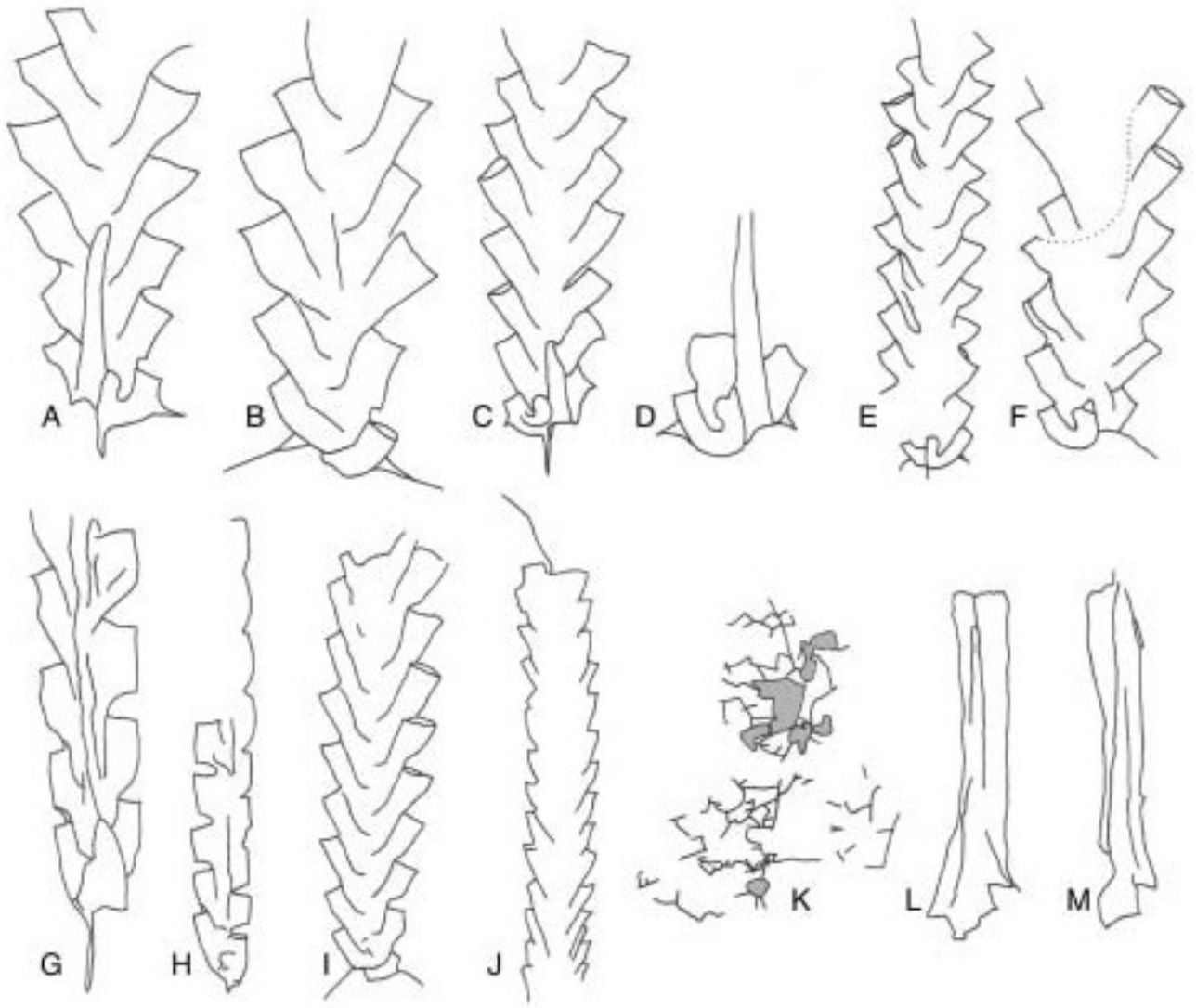


Fig. 7. Graptolites from the Röstånga 1 core; Camera lucida drawings. *A-F. Rectograptus gracilis*; *A*. LO 8569t; 88.48–88.47 m; *D. complanatus* Zone; ×16.2. *B*. LO 8570t; 88.48–88.47 m; *D. complanatus* Zone; ×17.4. *C*. Same specimen as *4D;* LO 8547t; 88.48–88.47 m; *D. complanatus* Zone; ×11.8. *D*. Juvenile specimen; LO 8572t; 88.48–88.47 m; *D. complanatus* Zone; ×23. *E*. LO 8088t; 90.30–90.27 m; *P. linearis* Zone; ×7.3. *F*. LO 8573t; 90.30–90.27 m; *P. linearis* Zone; ×10.4. *G-H. Normalograptus angustus*; *G*. Same specimen as 4A; LO 8090t; 88.45–88.44 m; *D. complanatus* Zone; ×11.2. *H*. LO 8574t; 89.38–89.36 m; *P. linearis* Zone; ×8.6. *I. Rectograptus gracilis*; LO 8575t; 90.57–90.55 m; *P. linearis* Zone; ×8.7. *J. O. quadrimucronatus*; LO 8576t; 104.47–104.44 m; *P. linearis* Zone; ×4.4. *K. Plegmatograptus* sp.; LO 8577t; 104.60–104.58 m; *P. linearis* Zone; ×6.3. *L-M. Corynoides* aff. *calicularis. L*. LO 8571t; 105.96–105.94 m; *P. linearis* Zone; ×11. *M*. LO 8094t; 105.96–105.94 m; *P. linearis* Zone; ×8.3.

rhabdosome is 7.0 mm long, excluding the nema, and the width of the lacinia is 5.1 mm. The specimen resembles *Plegmatograptus*? *chuchlensis* Pribyl, 1949 as figured by Štorch (1989, p. 183, fig. 3a) from the upper Králùv Dvùr Formation of the Prague Basin. The specimens occur on surfaces covered with pyritized spicules.

Family Diplograptidae Lapworth, 1873, emend. Mitchell, 1987

Genus *Pseudoclimacograptus* Pribyl,1947
*Pseudoclimacograptus scharenbergi* (Lapworth, 1876)

*Material*. – Two specimens from 106.64 m.

*Remarks*. – The specimens are from a calcareous mudstone and they are poorly preserved. The largest specimen has 7 thecae pairs, and the proximal part is intact, excluding the virgella and the spine on th1[1]. Hadding (1913, pl.3, figs. 20-27; 1915, pl. 2, fig. 15) described and figured *P. scharenbergi* from Scania and Bornholm.

*Occurrence*. – *Pseudoclimacograptus scharenbergi* is a common species in the Upper Ordovician of north-eastern North America (*N. gracilis-D. foliaceus* zones; Riva 1974). In Scania, Sweden, it has been recorded from the *H. teretiusculus-D. clingani* zones (Nilsson 1977).

Genus *Climacograptus* Hall, 1865, emend. Mitchell, 1987
*Climacograptus* sp.

*Material*. – One flattened specimen from the interval 104.45–104.40 m and three specimens from 104.32–104.31 m.

*Remarks*. – The material is flattened and poorly preserved. Thecae can only bee seen in one specimen. The supragenicular wall is 0.67 mm long proximally, and the geniculum is weak. The rhabdosome is 0.7-0.8 mm wide across the second thecae pair. The thecal apertures are 0.2 mm wide and slightly introverted. Thin lines are visible along the rhabdosome, but it is not possible to determine whether it is a median septum or a virgula. The specimens resemble *Climacograptus styloideus* Hall, 1865, as illustrated by Skoglund (1963), but the rhabdosomes are more slender.

Genus *Diplograptus* M'Coy, 1850
*Diplograptus pristis* (Hisinger, 1837)
Fig. 4G, 6A-D

1837 *Prionotus pristis* – Hisinger, p.114, Pl. 35, fig. 5.
1881 *Diplograptus pristis* Hisinger – Törnquist, pp. 443–445, Pl. 2, figs. 8a-g.
1882b *Diplograptus* ? *pristis* Hisinger – Tullberg, pp. 10–11, Pl. 1, figs. 2–10.
1891 *Diplograptus pristis* Hisinger – Törnquist, pp. 26–27, Pl. 1, figs. 18–22.
1907 *Diplograptus* (*Orthograptus*) *pristis* (Hisinger) – Elles & Wood, p. 245, figs. 165a-c.
1940 *Diplograptus pristis* (Hisinger) – Thorslund, p. 23.
1949 *Diplograptus pristis* (Hisinger) – Pribyl, Pl. 4, figs. 6–7, Pl. 5, fig. 1.
1963 *Diplograptus pristis* (Hisinger, 1837) – Skoglund, pp. 43–45, p. 4, figs. 1–5.

*Material*. – One specimen from the interval 106.00–105.98 m, one from 105.96–105.94 m, one from 91.07–91.02 m, and four from 88.47–88.44 m.

*Description*. – The largest rhabdosome is 8.5 mm long. The thecal density is 7 in 5 mm. Among the shorter specimens (< 5 mm) 6 thecae in 4 mm is counted. The rhabdosomes are 0.85–1.10 mm wide across th1[1], and at 4 mm length their breadth varies between 1.20 and 1.85 mm. Th1[1] grows smoothly upwards and at its aperture a small apertural flange is present in some specimens. The first three thecae are climacograptid in style. Distal thecae have weak geniculum and are of climacograptid-orthograptid type.

*Remarks*. – *Diplograptus pristis* has previously been described and discussed by Skoglund (1963). The material described herein matches Skoglund´s description, but it is smaller and slightly thinner. *D. pristis* is similar to *Amplexograptus compactus* (Elles and Wood, 1907), especially in the proximal part, but the species can be separated by the thecal style, since the thecae of *A. compactus* has more pronounced geniculum (Williams in Williams & Bruton 1983).

Hisinger's (1837) type specimen from Dalarna, central Sweden, as figured by Tullberg (1882b, Pl. 1, figs 2-3), has climacograptid thecae up to the 6th thecae pair, then orthograptid style. No apertural spines at th1[1] and th1[2] are shown in Tullberg´s (1882b) illustrations.

*Occurrence*. – Thorslund (1940) collected *Diplograptus pristis* from the *P. linearis* Zone of Jämtland, and Skoglund (1963) recorded it from the Fjäcka Shale of Västergötland, Östergötland, Dalarna, and Jämtland, Sweden.

Genus *Rectograptus* Pribyl, 1949
*Rectograptus gracilis* (Roemer, 1861)
Fig. 7D-F, I

1861 *Retiolites gracilis* n. sp. – Roemer, p. 31, pl. 5, fig. 1.
1963 *Orthograptus gracilis* (Roemer, 1861) – Skoglund, pp. 46–48, pl. 4, fig. 6, pl. 5, figs. 5, 7. [synonymy to date].

*Material*. – Two specimens from the interval 90.57–90.55 m, one specimen from 90.39–90.35 m, six specimens from 90.30–90.27 m, one specimen from 90.01–89.96 m, three specimens from 88.84–88.81 m, and 12 from 88.47–88.44 m. All specimens are preserved in relief.

*Description*. – The longest specimen is 6.2 mm. The apex of the sicula is generally not visible. The sicula is, however, visible in two specimens, where it is 1.33–1.67 mm long and provided with a short virgula (0.4 mm long). The sicula has two apertural spines (maximum length is 5 mm). The maximum width of the rhabdosome is across the fourth thecae pair (1.5–1.7 mm broad). The thecae number is 7 in the first 5 mm and it is constant in all specimens. Th1[1] grows initially vertically down the sicula and continues for about 0.5 mm until it turns upward in an angle of 40 degrees. It continues to grow in this direction for 0.6 mm until it reaches its origin on the sicula. The thecae shape is simple with a weak geniculum. The only spinose theca is th1[1]. The primordial astogeny corresponds to Pattern G of Mitchell (1987).

*Remarks*. – Bulman (1932) described *Rectograptus gracilis* from the Baltic region, and Skoglund (1963) discussed and illustrated specimens from Västergötland, south central Sweden. The material described herein is closely similar to North American specimens of *Rectograptus peosta* (Hall, 1861) as described by Goldman & Bergström (1997). *R. gracilis* has a wider rhabdosome and a shorter sicula than *R. peosta. R. gracilis* is also similar to the flattened specimens of *Diplograptus peosta* described and illustrated by Hadding (1915, pl. 2, figs 12 and 14), but *R. gracilis* is slightly wider, even though Hadding's specimens are flattened. The width of the rhabdosome might depend on the preservation, and Skoglund (1963, p. 46, fig. 11) illustrated this variation in *R. gracilis*. However, most of the rhabdosomes in Skoglund's material of *R. gracilis* are wider than those of *R. peosta*. Goldman & Bergström (1997) suggested that *R. peosta* may be conspecific to *R. gracilis*. This may be true, but the differences in the width of the rhabdosome, the thecal inclination, and the length of the sicula, suggest that they represent two species.

*R. gracilis* is in many respects similar to *Rectograptus socialis* (Lapworth, 1880), as described by Williams (1987 and 1991), but *R. gracilis* has a shorter sicula. Goldman and Bergström (1997) considered *R. socialis* to be a junior synonym of *R. peosta*.

*Occurrence. - Rectograptus gracilis* occurs in the *D. complanatus* Zones of Bornholm (Poulsen, 1936), the Lindegård Mudstone of Scania (Glimberg 1961), and in the Jonstorp Formation of Västergötland (Thorslund 1938; Skoglund 1963).

Genus *Normalograptus* Legrand, 1987
*Normalograptus angustus* (Perner, 1895)
Fig. 4A, 7G, H

1975 *Climacograptus angustus* (Perner, 1895) – Bjerreskov, pp. 23, fig. 9A.
1988 *Scalarigraptus angustus* (Perner, 1895) – Riva, p. 232, figs 3a-u.
1989 *Scalarigraptus angustus* (Perner, 1895) – Štorch, pp. 178–181. Pl. 2, figs 3, 4, 5, 8, text-figs 2E-J [Synonymy to date].

*Material*. – One specimen from the interval 91.75–91.73 m, one from 90.30–90.27 m, one from 89.38–89.36 m, and one from 88.47–88.44 m.

*Description*. – The largest specimen is 8.5 mm long. The width of the rhabdosome is 0.76–0.80 mm across the first thecae pair and 0.86 mm across the fourth and 1.0 mm distally. 2Trd is 1.5 mm across $th2^2$-$th3^2$ and 2.0 mm at $th8^2$-$th9^2$. The thecae are of glyptograptid-climacograptid type. Their apertures are gently everted or straight, and are 0.26 mm wide. The suprageniculare wall is 0.6 mm long, gently curved and ended in a sharp geniculum. The sicula is 0.86 mm long and 0.43 mm wide at its aperture. The virgella is thin and projected downwards. The median septum is straight, and the primordial astogeny pattern corresponds to Pattern H of Mitchell (1987).

*Remarks*. – Skoglund (1963) described isolated specimens of *Normalograptus angustus* and indicated the presence of a septum that would be "the proximal part of a median septum". A straight median septum is present in the material described herein.

Graptolites with Pattern H astogeny (Mitchell 1987) are multitudinous. *Normalograptus angustus* is similar to *Normalograptus brevis* (Elles and Wood, 1906), but the sicula of *N. angustus* is shorter and slightly wider, and its rhabdosome is slightly narrower.

*Occurrence*. – *Normalograptus angustus* occurs in the Fjäcka Shale (*P. linearis* Zone) or equivalent beds in Sweden and Bornholm, Denmark (Skoglund 1963), in the upper *pacificus* Zone of the Kolyma Region, Russia (Koren' & Sobolevskaya 1983), and in the *N. angustus* Horizon in the upper Králùv Dvùr Formation of the Prague Basin, Bohemia (Štorch 1989). *N. angustus* has a long stratigraphic range, and Bjerreskov (1975) recorded this species from the *persculptus, acuminatus*, and *acinaces* zones of Bornholm.

Family Corynoididae Bulman, 1944
Genus *Corynoides* Nicholson, 1867
*Corynoides* aff. *calicularis* Nicholson, 1867
Fig. 7L, M

*Material*. – Six flattened specimens from the interval 105.96–105.94 m

*Description*. – The rhabdosome is straight or gently curved. In most specimens the apex of the sicula is broken off. In one small specimen, however, a 0.02 mm long nema is visible. Two thecae bud 1.3 mm from the apex of the sicula.

The length of the rhabdosome varies from 4.6–6.5 mm. The sicula is long and slender (about 0.20–0.25 mm wide proximally), and its aperture is 0.4–0.6 mm wide. At the apertural margin, two conspicuous flanges are pointing either downwards or perpendicularly to the direction of the sicula. The two thecae are 0.2 mm wide. Th1 begins its growth close to the apex of the sicula. It grows downwards, parallel along the sicula for 5.4–5.9 mm where its aperture is situated. Th1 wid-

ens towards the aperture. Th2 begins to grow on the opposite side of th1, slightly below the origin of th1. It continues to grow in a similar way as th1 for 4.4–4.5 mm. The maximum width of the rhabdosome, at the level of the aperture of th2, is 0.87 mm.

*Remarks*. – The genus *Corynoides* and the species *Corynoides curtus* and *Corynoides calicularis* have previously been discussed by Riva (1974) and Williams (1995). They concluded that the species concept is mainly based on the length of the rhabdosome. According to their (Riva 1974; Williams 1995) measurements, specimens with a rhabdosome ranging from 4.5–13.0 mm can be regarded as *C. calicularis*. Hence, *C. curtus* is a junior synonym of *C. calicularis*.

The material described herein is similar to *Corynoides calicularis* as described by Riva (1974) and Williams (1995), but has wider rhabdosomes. The shape of the rhabdosome in *C.* aff. *calicularis* is straight or gently curved. The curvation is, however, reversed compared to *C. calicularis*. *C.* aff. *calicularis* occurs at a somewhat higher stratigraphic level in the Röstånga 1 core (lowermost *P. linearis* Zone) than *C. calicularis* (*N. gracilis-D. clingani* zones; Riva 1974; Williams 1995; Pålsson submitted).

*Occurrence*. - *Corynoides* aff. *calicularis* occurs in the lowermost part of the Fjäcka Shale (*P. linearis* Zone) in the Röstånga 1 core, Scania.

## Concluding remarks

No graptolites have been encountered in the Sularp Formation in the Röstånga 1 core. In the outcrops along the Kyrkbäcken rivulet, however, pyritized graptolites representing e. g. *Pseudoclimacograptus scharenbergi* occur sparsely in the silicified and calcareous mudstones. When dissolving the calcareous mudstones in hydrochloric acid, all graptolites fell into indeterminable pieces. Based on the stratigraphic position, and the studies by Nilsson (1977), Pålsson (1996), Bergström et al. (1997), and Bergström et al. (1999), the Sularp Formation is assigned to the *Diplograptus foliaceus* (formerly *D. multidens*) Zone.

Graptolites are very rare in the Mossen Formation of the Röstånga 1 core, and only two specimens of *Pseudoclimacograptus scharenbergi* were recovered. This species has a long stratigraphical range, and in Scania it ranges from the lower *Hustedograptus teretiusculus* Zone into the middle *Dicranograptus clingani* Zone (Hadding 1913; Nilsson 1977).

The graptolites recovered from the interval 106.54–88.56 m in the Röstånga 1 core are indicative of the *Pleurograptus linearis* Zone. This zone can be divided into a lower and an upper part. The lower part is characterized by the presence of *Diplograptus pristis, Corynoides* aff. *calicularis, Orthograptus quadrimucronatus, Plegmatograptus* sp., *Pleurograptus linearis*? and *Climacograptus* sp. The upper part contains *Diplograptus pristis, O. quadrimucronatus, Dicellograptus morrisi, Dicellograptus johnstrupi, Normalograptus angustus,* and *Rectograptus gracilis*.

*Pleurograptus linearis* seems to be rare in Sweden, and the zone was formerly known as the *Climacograptus styloideus* Zone (Hadding 1915). Graptolites such as *C. styloideus, Normalograptus angustus,* and *Diplograptus pristis* have been used for correlations with the *P. linearis* Zone and equivalent layers (Glimberg 1961; Skoglund 1963). The *P. linearis* Zone is present in the Lindegård drill-core from the Fågelsång area, where it consists of 3.2 m with grey to black shales (Glimberg 1961). However, in the Koängen drill-core, taken 4.2 km west of the Lindegård drill-site, Nilsson (1977) found no evidence of the *P. linearis* Zone.

The occurrence of *Pleurograptus linearis*? at 104.45–104.39 m in the Röstånga 1 core suggests the presence of the *P. linearis* Zone. The lower boundary of the *P. linearis* Zone is placed at the first appearance of *Diplograptus pristis* (106.00 m).

The *Pleurograptus linearis* Zone is succeeded by the *Dicellograptus complanatus* Zone. The appearance of *D. complanatus* at 88.56 m indicates the boundary between the two zones. *D. complanatus* occurs about 1.40 m above the base of the Lindegård Mudstone. However, the base of the zone is drawn where the dark mudstone of the Fjäcka Shale is overlain by the lighter grey calcareous mudstone of the Lindegård Mudstone. This change in lithology is also known from Västergötland where the Fjäcka Shale is overlain by the lower Jonstorp Formation (Skoglund 1963).

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