

THE HIRNANTIAN GRAPTOLITES
NORMALOGRAPTUS PERSCULPTUS AND
'*GLYPTOGRAPTUS*' *BOHEMICUS*:
STRATIGRAPHICAL CONSEQUENCES OF THEIR
SYNONYMY

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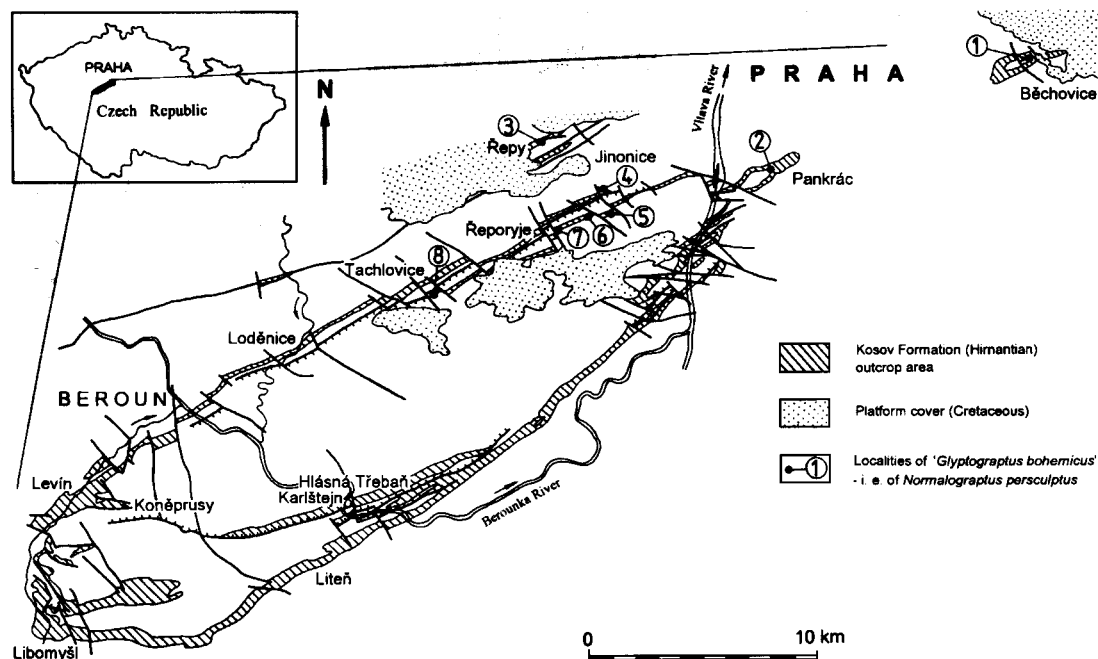
ABSTRACT. It is demonstrated that '*Glyptograptus*' *bohemicus* is a junior subjective synonym of *Normalograptus persculptus*. The first appearance of *N. persculptus* appears to be diachronous, posing problems for Hirnantian biozonation. In China, *N. persculptus* co-occurs with *N. extraordinarius*. We favour here an extension downwards of the existing *persculptus* Biozone, the base being defined by the incoming of *N. persculptus*, with the lower part of the biozone designated the *extraordinarius* Subzone.

THERE has not been agreement among graptolite workers as to the taxonomic and stratigraphical relations between *Normalograptus persculptus* (Elles and Wood, 1907) and '*Glyptograptus*' *bohemicus* Marek, 1955. Many authors (e.g. Štorch 1982, 1988; Wang *et al.* 1983; Chen and Lin 1984; Li 1984; Mu and Lin 1984; Ni 1984; Fu and Song 1986; Wang 1987; Mu 1988; Fang *et al.* 1990; Melchin *et al.* 1991) considered the two taxa to be distinct and used them as index species for two separate biozones within the Hirnantian Stage (Ashgill Series, Ordovician). Below the *persculptus* Biozone, which is recognized globally, a *bohemicus* Biozone has been introduced in the graptolite biozonal schemes of Bohemia, China and Arctic Canada. Other authors (Koren' and Sobolevskaya 1983; VandenBerg *et al.* 1984; Štorch 1994), however, have considered *N. persculptus* and '*G.*' *bohemicus* to be synonyms. Herein we redescribe the type and all other available Bohemian specimens of '*G.*' *bohemicus* and compare them with Welsh material of *N. persculptus*. Brief comparison with selected Chinese material is also included. We demonstrate that '*G.*' *bohemicus* is a junior subjective synonym of *N. persculptus* and discuss the stratigraphical consequences of this synonymy.

STRATIGRAPHICAL FRAMEWORK FOR THE BOHEMIAN MATERIAL

All the Bohemian specimens of '*G.*' *bohemicus* come from the uppermost beds of the Kosov Formation (Text-figs 1–2). This is a glacio-eustatically controlled regressive-transgressive sequence, c. 100 m thick, of Hirnantian age. Diverse, deep-shelf Rawtheyan faunas, which characterize the clayey shales of the underlying Králův Dvůr Formation, disappear just below the base of the Kosov Formation (Štorch and Mergl 1989), and are replaced by the low-diversity *Mucronaspis* Assemblage, which occurs in Hirnantian deeper-water environments. The base of the Kosov Formation is marked by two levels of pebbly glacio-marine diamictites (Brenchley and Štorch 1989). These suggest that, in the early Hirnantian, at an early stage of regression, floating ice extended over the Prague Basin. The continuing regression is documented by the overlying, rhythmically bedded tempestites. The middle part of the Kosov Formation is suggestive of a temporary sea-level rise, being composed of a shaly sequence with few thin siltstone intercalations.

The upper part of the Kosov Formation is represented by another rhythmically bedded tempestite unit. This has, above its sharp erosional base, several thick beds of coarse sandstones and

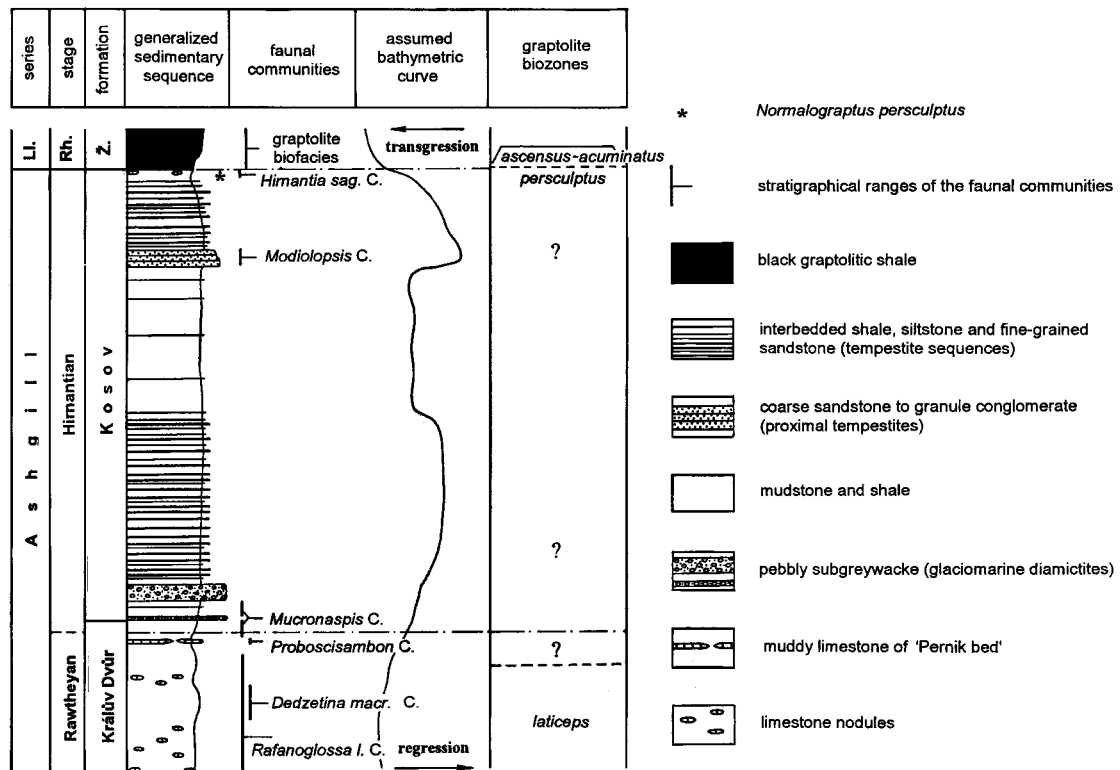


TEXT-FIG. 1. Localities where *Normalograptus persculptus* (formerly '*Glyptograptus*' *bohemicus*) has been found in the Barrandian area in Bohemia, with Gauss-Krueger grid references: 1 – Běchovice, X5551248, Y3457177; 2 – Pankrác, X5547359, Y3460644; 3 – Řepy, X548661, Y3450474; 4 – Nové Butovice, X5546447, Y3453087; 5 – Jinonice-Nová Ves, X5545574, Y3453632; 6 – Velká Ohrada, X5545512, Y3452675; 7 – Reporyje, X5445061, Y3451663; 8 – Tachlovice, X5547359, Y3446006.

conglomerates. According to Brenchley and Štorch (1989), these indicate a second regressive event with the shelf channelled and coarse material supplied from the shore. The sedimentary structures described by Brenchley and Štorch (1989), ichnofacies described by Mikuláš (1993), and very low diversity bivalve assemblage listed by Havlíček (1982) all come from the period of maximum glacio-eustatic regression at the base of the upper tempestite unit of the Kosov Formation. The bathymetric curve of Štorch (1990) for the Kosov Formation fits well the bathymetric changes suggested by, for example, Brenchley (1984) and Brenchley *et al.* (1991). The remainder of the upper, rhythmically bedded tempestite unit was deposited during a transgression which accelerated towards the top of the Kosov Formation.

The uppermost part of the Kosov Formation was deposited under deeper-subtidal conditions, well below storm-wave base. In the north-east part of the Barrandian area it is composed of heavily bioturbated mudstones, with a varied, brachiopod-dominated *Hirnantia* Fauna (Marek and Havlíček 1967; Štorch 1986) and '*G.*' *bohemicus*. This fauna has been recorded at Běchovice, Jinonice-Nová Ves, Nové Butovice, Pankrác, Řepy, Tachlovice (borehole) and Velká Ohrada (Text-fig. 1).

Both the *Hirnantia* Fauna and the graptolite rhabdosomes are confined to this rather thin (50 mm–4.5 m thick) horizon. The highest identifiable '*G.*' *bohemicus*, found together with uncommon brachiopods, were about 70 mm below the base of the overlying black Silurian shales, which yield *Normalograptus angustus* (Perner), *Akidograptus ascensus* Davies and *Neodiplograptus lanceolatus* Štorch and Šerpagli. At some localities described by Štorch (1986; Řepy, Vočkov and Želkovic) 20–30 mm of black and white, laminated shale forms the transition from the pale mudstones to the Silurian black shales, without any apparent gap in sedimentation. This



TEXT-FIG. 2. The upper Ashgill stratigraphy of the Barrandian area, Bohemia, showing the stratigraphical level of Bohemian specimens of *Normalograptus persculptus* (formerly '*Glyptograptus bohemicus*'). The thickness of the Kosov Formation varies between 40 and 150 m. Abbreviations: C. – community; Li. – Llandovery; Rh. – Rhuddanian; Ž. – Želkovice Formation. Not drawn to scale.

transitional bed, still below the first appearance of *A. ascensus*, contains poorly preserved normalograptids, including the specimens referred by Štorch (1982, 1986) to '*G. bohemicus-persculptus*'.

The *Hirnantia* Fauna and '*G.*' *bohemicus* have been recorded in the Barrandian area at the same level from which *Normalograptus persculptus* and associated graptolites are reported elsewhere. Although the two species could be regarded as coeval, palaeogeographically restricted subspecies, because of their identical dimensions and morphology, we prefer to consider '*G.*' *bohemicus* to be a junior subjective synonym of *N. persculptus* (Elles and Wood).

Institutional abbreviations are: GSM, British Geological Survey, Keyworth, Nottingham; L, National Museum, Prague; PŠ, Štorch collection, Czech Geological Survey, Prague.

SYSTEMATIC PALAEOLOGY

Family NORMALOGRAPTIDAE Štorch and Serpagli, 1993

Genus NORMALOGRAPTUS Legrand, 1987

Type species. By original designation, *Climacograptus scalaris normalis* Lapworth, 1877, from the Birkhill Shales, Dob's Linn, Scotland.

Diagnosis (modified from Melchin and Mitchell 1991). Rhabdosome suboval to nearly circular in cross section. Median septum straight or slightly wavy in the proximal part, usually complete. Early astogeny of Pattern H, with th2 or, rarely, some later theca dicalycal. Proximal end relatively narrow, rounded, asymmetrical. Climacograptid to almost glyptograptid thecae have angular or sigmoidal genicular curvature.

Remarks. The original conception of the genus, reflected in the diagnoses given by Legrand (1987) and Štorch and Serpagli (1993), has been extended to embrace the late Ordovician and early Silurian glyptograptid-like species with Pattern H astogeny.

Normalograptus persculptus (Elles and Wood, 1907)

Text-figures 3–5

- 1865 *Diplograptus persculptus* (Salter?), Salter, p. 25 [see Strachan 1971].
- 1907 *Glyptograptus persculptus* Salter; Elles and Wood, p. 257, pl. 31, fig. 7a–c; text-fig. 176a–b.
- 1929 *Glyptograptus* aff. *persculptus* Salter; Davies, p. 10, text-fig. 11A.
- 1929 *Glyptograptus persculptus* mut.; Davies (*pars*), p. 11, text-figs 11, 13, 16–19 (*non* 12, 14).
- 1929 *Glyptograptus persculptus* mut. *omega* nov., Davies, text-figs 15, 20.
- 1955 *Glyptograptus bohemicus* Marek, p. 7, pl. 1, figs 1–4.
- 1971 *Glyptograptus* (*G.*) *persculptus persculptus* (Salter); Strachan, p. 37.
- 1973 *Glyptograptus persculptus* (Salter); Mikhaylova, p. 15, pl. 3, figs 4–6.
- non* 1974 *Glyptograptus persculptus* (Salter); Hutt, p. 28, pl. 8, figs 9–12.
- 1975 *Glyptograptus persculptus* (Salter); Bjerreskov, p. 30, text-fig. 11a–c.
- 1977 *Glyptograptus bohemicus* Marek; Jaeger, pl. 1, figs 4, 6, 9, 11, 17.
- 1977 *Glyptograptus* aff. *bohemicus* Marek; Koren' and Sobolevskaya, figs 5–7.
- 1977 *Glyptograptus persculptus* (Salter); Rickards *et al.*, pl. 2, fig. 4, text-figs 8, 53
- 1978 *Glyptograptus persculptus* (Salter); Sennikov, p. 142, text-fig. 3i, k.
- 1980 *Glyptograptus?* *persculptus* (Salter); Koren' *et al.*, pl. 43, figs 2–3.
- 1980 *Glyptograptus?* *persculptus* (Salter) forma B; Koren' *et al.*, p. 150, pl. 45, figs 1–6; pl. 46, figs 1–6 (?7–8); text-fig. 45a–zh.
- 1982 *Glyptograptus bohemicus* Marek; Štorch, pl. 2, figs 5–6.
- 1983 *Glyptograptus persculptus* Salter; Koren' and Sobolevskaya, p. 144, pl. 42, figs 4–10; pl. 43; text-fig. 54 (*pars*).
- 1983 *Diplograptus bohemicus* (Marek); Mu *et al.* (*pars*), pl. 2, figs 3, 10 (*non* 4).
- 1983 *Glyptograptus persculptus* (Salter); Wang *et al.*, p. 139, pl. 8, figs 3–6; pl. 9, figs 5, 10–11.
- 1983 *Diplograptus bohemicus* (Marek); Wang *et al.*, pl. 7, figs 1–3, ?11.
- 1983 *Glyptograptus persculptus* (Salter); Williams, p. 622, pl. 66, figs 1–3.
- 1984 *Glyptograptus persculptus* (Salter); Chen and Lin, p. 193, pl. 1, figs 1–6; pl. 2, figs 3–9; text-fig. 1.
- 1984 *Diplograptus bohemicus* (Marek); Ge, p. 411, pl. 3, figs 10–14, ?15; text-fig. 3.
- 1984 *Diplograptus bohemicus* (Marek); Li, p. 335, pl. 8, fig. 6, ?1–5.
- 1984 *Glyptograptus persculptus* (Salter); Lin and Chen, pl. 1, figs 1–2.
- ?1984 *Glyptograptus lungmaensis* Sun; Lin and Chen (*pars*), p. 209, pl. 1, figs 3, 6 (*non* 4–5).
- ?1984 *Diplograptus bohemicus* (Marek); Mu and Lin, p. 53, pl. 3, figs 1–3.
- 1984 *Glyptograptus persculptus* (Salter); Mu and Lin, p. 54, pl. 3, fig. 6; pl. 6, fig. 9.
- 1984 *Diplograptus bohemicus* (Marek); Ni, p. 323, pl. 2, figs 6–8.
- 1984 *Glyptograptus?* *persculptus* (Salter); VandenBerg *et al.*, p. 10, figs 8–9.
- 1986 *Diplograptus bohemicus* (Marek); Fu and Song, p. 76, pl. 4, fig. 6 (?*non* 5); text-fig. 6g.
- 1986 *Glyptograptus persculptus* (Salter); Fu and Song, p. 80, pl. 4, figs 23–24, (?*non* 22).
- 1986 *Glyptograptus bohemicus* Marek; Štorch, pl. 3, fig. 8.
- ?1987 *Glyptograptus persculptus* (Salter); Wang, p. 370, pl. 45, fig. 1.
- 1987 *Diplograptus bohemicus* (Marek); Wang, p. 375, pl. 43, fig. 1.
- 1990 *Diplograptus bohemicus* (Marek); Fang *et al.*, p. 46, pl. 1, figs 11–12; pl. 2, figs 2–3; pl. 4, fig. 6.

- 1990 *Glyptograptus persculptus-sinuatus* transient; Fang *et al.*, p. 60, pl. 8, figs 2–3, 6.
 1993 *Diplograptus bohemicus* (Marek); Mu *et al.*, p. 129, pl. 21, figs 1–3, ?4–5.
 1994 *Normalograptus? persculptus* (Elles and Wood); Zalasiewicz and Tunnicliff, p. 704, fig. 5a–c.

Lectotype. Designated by Williams 1983; GSM 11782 from Salter's collection; Ogofau, Pumpsaint, Dyfed, Wales; figured Williams 1983, plate 66, figure 3.

Material. Eighteen specimens of '*Glyptograptus*' *bohemicus* (including the type material of Marek 1955) from the Barrandian area (Bohemia); most are complete, preserved flattened or in partial relief. Numerous specimens of *Normalograptus persculptus* from localities in mid-Wales, preserved flattened and in moderate to full relief. One of us (DKL) has also examined specimens from China figured by Ge (1984), Li (1984), Mu and Lin (1984) and Ni (1984). All specimens are from the Hirnantian (late Ordovician) *N. persculptus* Biozone.

Diagnosis. Rhabdosome straight, widening from 1.0 mm (0.8 mm in relief) to a maximum of 2.0–2.5 mm at a distance of 10–15 mm from the proximal end; median septum complete in early populations, slightly wavy in specimens preserved in relief. Successive delay in the insertion of the median septum appears in stratigraphically late populations. Alternate to subalternate sigmoidally curved thecae of glyptograptid appearance become strongly geniculate in flattened rhabdosomes; thecae overlap for half of their length and number 5–6 in the proximal 5 mm and 8–10 in 10 mm distally.

Description (of Bohemian material). The rhabdosome is up to 28 mm long, excluding the virgella and nema. It widens from 0.8 mm (1.1–1.3 mm when flattened) at the aperture of $th1^1$ to 1.1 mm (1.6 mm when flattened) at $th3^1$, and reaches a maximum of 1.6–1.7 mm (1.9–2.3 mm when flattened) within 8–10 mm of the proximal end. Thecae number 5.5–5.8 in the proximal 5 mm. Distally the thecal count decreases to 10–10.5 in 10 mm.

The sicula, visible for at least 1 mm in obverse view, is conical, with a *c.* 2 mm long virgella. The sicular aperture has a diameter of 0.2–0.25 mm. $Th1^1$ grows downwards, then, 0.15–0.25 mm below the sicular aperture, bends abruptly upwards. The distance between the sicular aperture and the aperture of $th1^1$ is 0.85–0.9 mm. $Th1^2$ grows upwards for its entire length and this gives a distinctive, asymmetrical appearance to the proximal end.

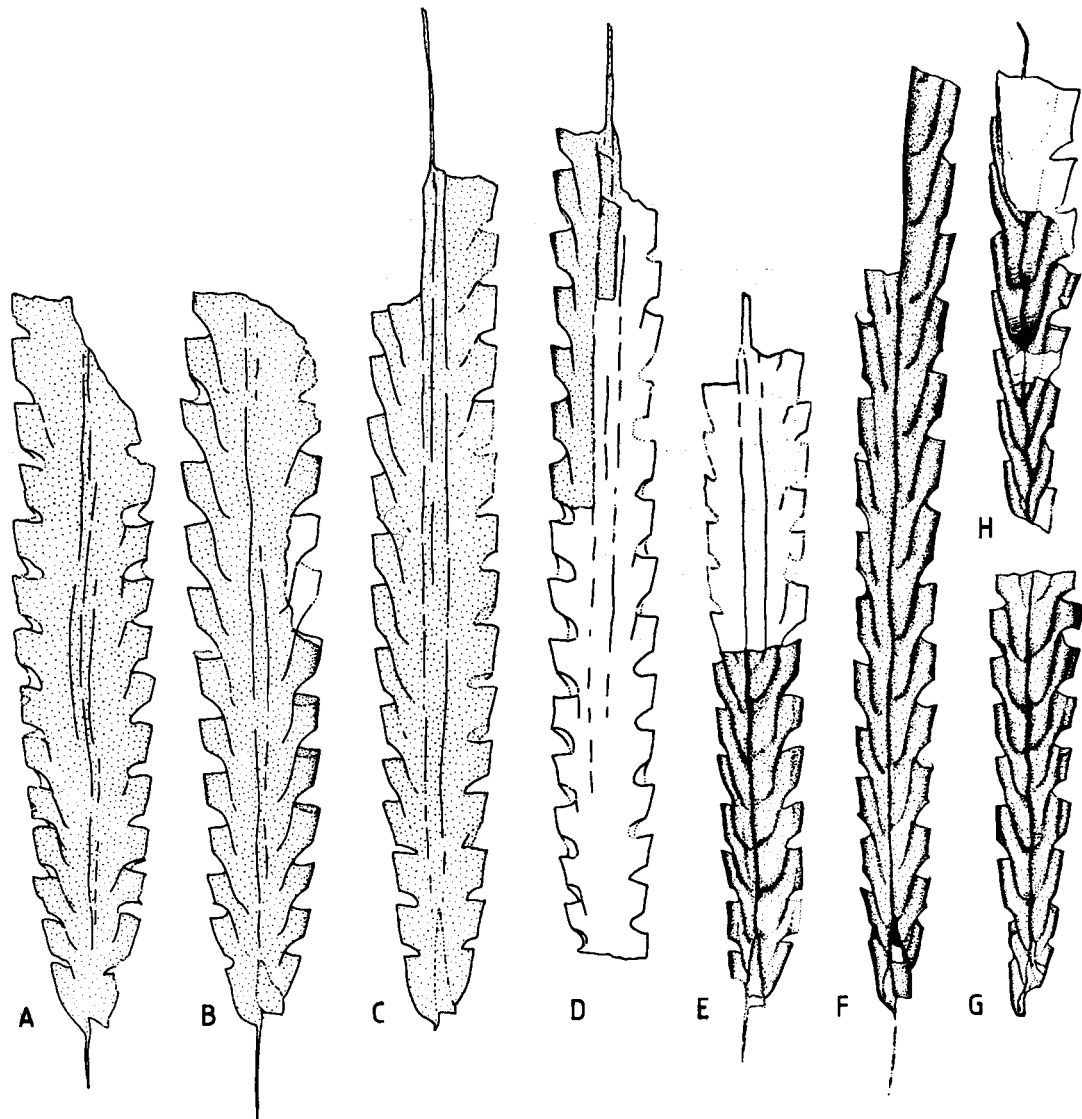
The appearance of the thecae depends upon preservation. Sigmoidally curved thecae with sharp genicula are typical of flattened (including the type) material (from the Jinonice-Nová Ves and Velká Ohrada sections; see e.g. Text-fig. 3A, C). Their supragenicular walls are straight, inclined at *c.* 10° to the rhabdosome axis. Specimens preserved in low relief (from Jinonice, Řepy and Pankrác) and moderate relief (from Pankrác) are of more glyptograptid appearance (Text-fig. 3F–H), but they are still strongly geniculate in some cases. Thecal apertures are straight, horizontal or slightly everted. Thecal excavations occupy *c.* one-fifth of the dorso-ventral width. The subalternate distal thecae are 1.5–1.8 mm long and overlap for up to half their length. Intertheal septa reach to about the level of the aperture of the preceding theca.

The median septum appears to be complete. It is slightly undulating in the proximal part of the rhabdosome. The rhabdosome commonly becomes uniserial distally. The nema is distinctly thickened at the base, probably as a result of distal prolongation of the median septum.

Specimens of *N. persculptus* from mid-Wales are illustrated in Text-figures 4D–E and 5 for comparison with the Bohemian material described above.

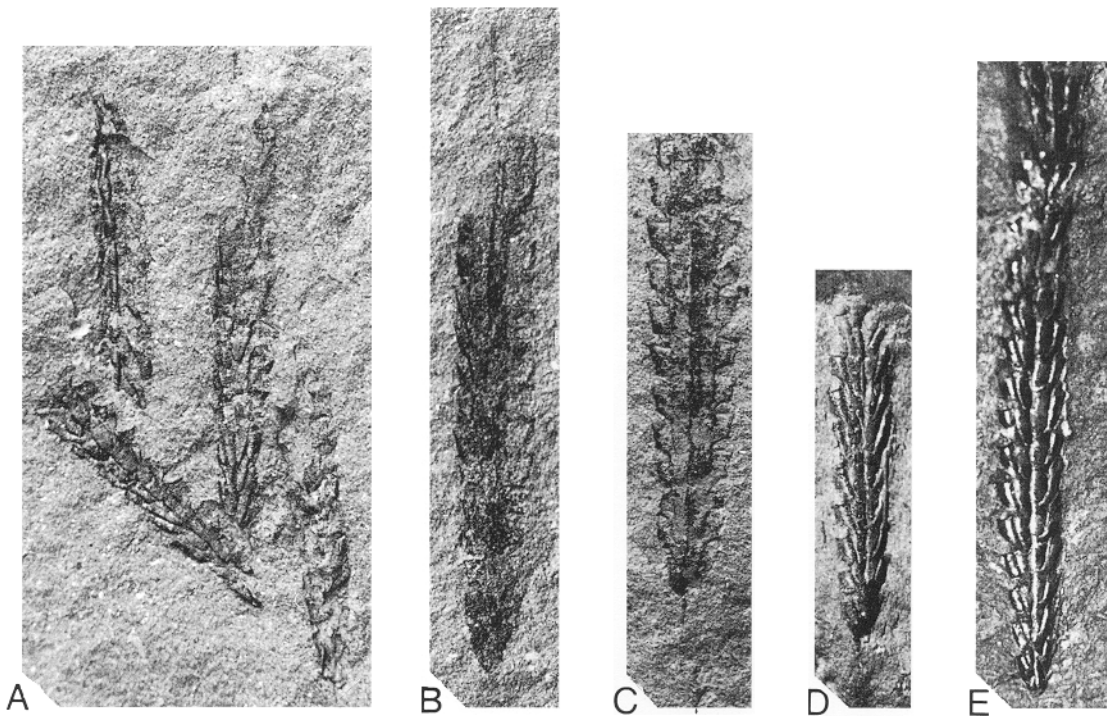
Remarks. Elles and Wood (1907) are regarded here as the authors of *N. persculptus*; Salter (1865) neither figured nor described this species (see discussion in Williams 1983 and Zalasiewicz and Tunnicliff 1994).

The Bohemian material of '*G.*' *bohemicus* agrees well with the Welsh material illustrated herein, and with the British and Scandinavian specimens of *N. persculptus* described by Williams (1983) and Bjerreskov (1975) respectively, as well as the material described by Koren' *et al.* (1980) from Kazakhstan, by Koren' and Sobolevskaya (1983) from Siberia, and by VandenBerg *et al.* (1984) from Australia (Table 1). The distal end of Bohemian rhabdosomes is, however, more commonly uniserial. This latter tendency has been illustrated by Williams (1983) in *Normalograptus venustus venustus* (Legrand), by Lin and Chen (1984) in '*Glyptograptus*' *lungmaensis* Sun and



TEXT-FIG. 3. Bohemian specimens of *Normalograptus persculptus*. A, PŠ 648a; flattened specimen, with periderm. B, PŠ 278/2; preserved in very low relief, with periderm. C, L 14651, holotype of '*Glyptograptus bohemicus*'; flattened, partly limonitized film. D, PŠ 278/1; very low relief external mould with some periderm. E, L 14650; preserved in low relief, distally as an external mould. F, PŠ 130; preserved in low relief, with periderm. G-H, PŠ 662a (two rhabdosomes on one slab); preserved in low to moderate relief. Localities: A, Velká Ohrada; B-E, Jinonice-Nová Ves; F, Řepy; G-H, Pankrác. All $\times 8$.

'*Climacograptus*' *wangjiawanensis* Mu and Lin, by Ge (1984) in '*Diplograptus*' *maturatus* Mu and Ni, and commonly in the rhabdosomes referred to '*G.*' *bohemicus* in China. A specimen of *N. persculptus* with four uniserial distal thecae is present in our collections from Rhayader, Wales. The presence of a uniserial distal portion, perhaps the result of some astogenetic mutation, cannot be used as a morphological criterion for separating '*G.*' *bohemicus* from *N. persculptus*.

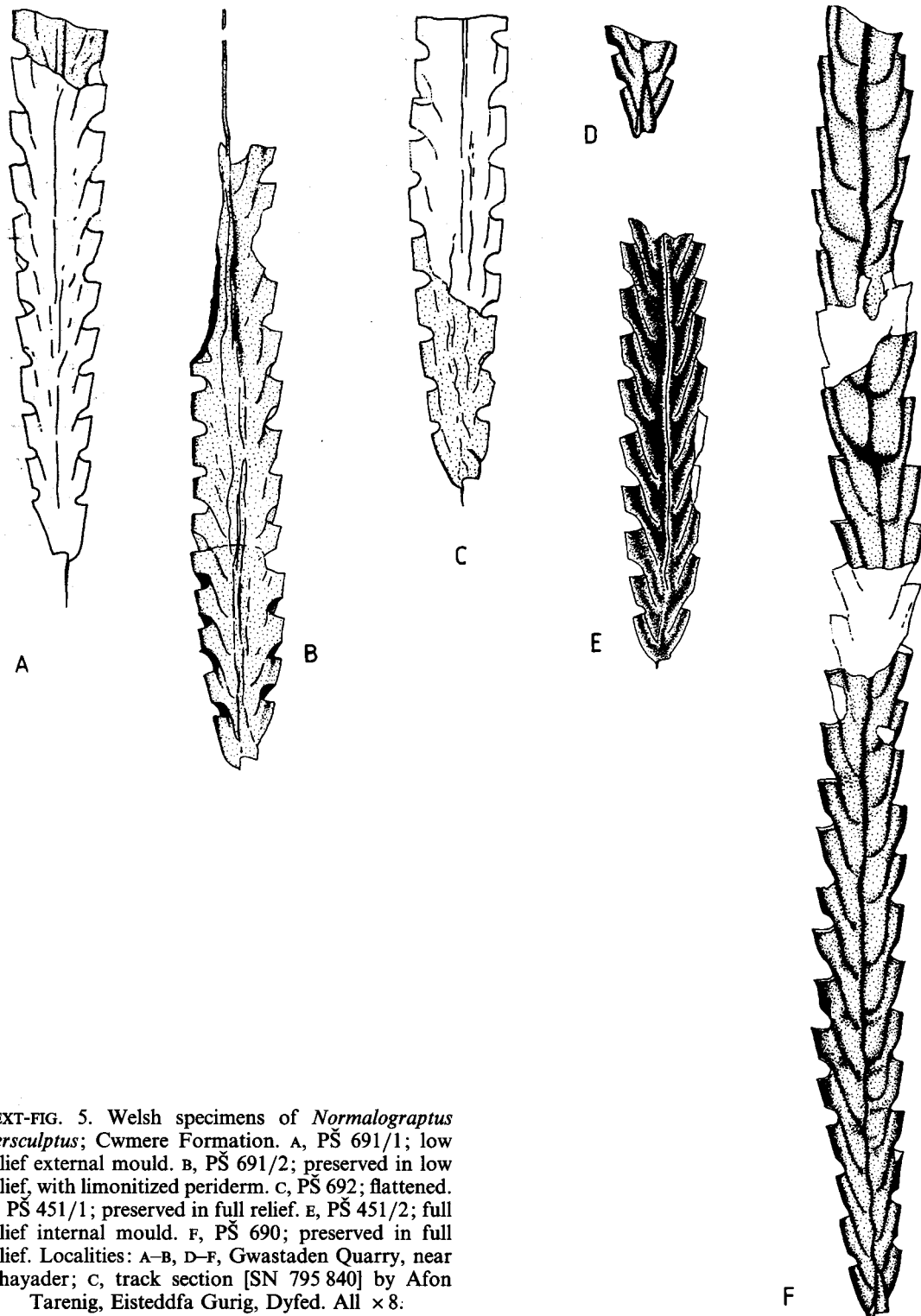


TEXT-FIG. 4. *Normalograptus persculptus* (Elles and Wood, 1907). A, PŠ 662a; four specimens preserved in low to moderate relief, with periderm. B, L 14651, holotype of '*G.*' *bohemicus*; flattened, partly limonitized film. C, PŠ 278/2; preserved in very low relief, with periderm. D, PŠ 451/2; full relief, internal mould. E, PŠ 690; full relief, internal mould. Localities: A, Pankrác, Bohemia; B-C, Jinonice-Nová Ves, Bohemia; D-E, Cwmere Formation, Gwastaden Quarry [SN 970 656], near Rhayader, Powys, Wales. All $\times 5$.

Zalasiewicz and Tunncliffe (1994) assigned Hutt's (1974) specimens from the English Lake District to *N.?* *parvulus* (H. Lapworth). This species is significantly narrower than *N. persculptus* and post-dates it stratigraphically (see Zalasiewicz and Tunncliffe 1994 for details).

HIRNANTIAN GRAPTOLITE BIOZONATION

Jaeger (1977) figured '*G.*' *bohemicus* from the uppermost part of the Dobra Sandstone in Saxony (Germany). His material came from a level which corresponds approximately with the *bohemicus*-bearing beds in Bohemia. Most reports of the species, however, are from China, where it is usually assigned to *Diplograptus*. In China a *bohemicus* Biozone is widely recognized below the *persculptus* Biozone, being regarded as a stratigraphical equivalent of the *extraordinarius* Biozone (Li *et al.* 1983; Mu *et al.* 1983; Wang *et al.* 1984; Mu 1988). The index species is accompanied by faunas including *Paraorthograptus typicus* Mu, *Climacograptus supernus* Elles and Wood and *Normalograptus extraordinarius* (Sobolevskaya). The Chinese *bohemicus* Biozone is commonly separated from the succeeding *persculptus* Biozone by beds containing a rich, shelly *Hirnantia* fauna. According to Mu (1988), these beds correspond with the time of maximum Hirnantian glacio-eustatic regression and clearly precede the post-glacial transgressive sequence of the *persculptus*



TEXT-FIG. 5. Welsh specimens of *Normalograptus persculptus*; Cwmere Formation. A, PŠ 691/1; low relief external mould. B, PŠ 691/2; preserved in low relief, with limonitized periderm. C, PŠ 692; flattened. D, PŠ 451/1; preserved in full relief. E, PŠ 451/2; full relief internal mould. F, PŠ 690; preserved in full relief. Localities: A–B, D–F, Gwastaden Quarry, near Rhayader; C, track section [SN 795 840] by Afon Tarenig, Eisteddfa Gurig, Dyfed. All $\times 8$.

TABLE 1. Measurements of dorso-ventral width, rhabdosome length, thecal count and thecal overlap in *Normalograptus persculptus*. Specimens are preserved flattened (F), in low to moderate relief (M) or full relief (R).

material, described by	preservation	width					length max.	thecal count		thecal overlap
		prox.	5th thecal pair	5 mm from prox.	10 mm from prox.	dist. max.		/prox. 5 mm	/dist. 10 mm	
<i>persculptus</i> Elles and Wood (1907)	M-R	1.0	/	/	/	2.0-2.5	> 30	/	8-10	1/2
<i>persculptus</i> Williams (1983)	M-R	1.0	/	1.5-1.7	/	2.0-2.7	30	5.5	9	/
<i>persculptus</i> this paper (mid-Wales)	R	0.85-0.95	1.45	/	1.7-1.8	1.95	37	5-6	8.5-10	1/2
	F	0.95-1.15	1.55-1.75	/	1.8-1.95	2.2				
<i>persculptus</i> Bjerreskov (1975)	R	1.0	1.5	/	/	1.6	20	5	9.5-10	1/2
	F					2.0				
<i>persculptus</i> Koren and Sobolevskaya (1983)	F	1.05-1.25	1.7-1.8	1.85-2.0	1.9-2.2	2.25	45	5-5.5	9.5-10	1/2-1/3
<i>persculptus</i> forma B Koren et al. (1980)	M	1.0-1.1	1.5-1.7	1.6-1.75	1.75-2.0	2.0	35	5-6	9-10	1/2
	F				(2.5)	2.5				
'bohemicus' this paper (Bohemia)	M	0.8	1.45-1.6	/	1.6-1.7	2.35	28	5.5-5.8	10-10.5	1/2
	F	1.1-1.3	1.6-1.95	/	1.9-2.3					
'bohemicus' Mu and Lin (1984)	F	1.0-1.2	/	1.7	2.0	2.0	27	5.5	10	1/2
'bohemicus' Ge (1984)	F	1.4 (1.15-1.25)	1.6-1.7	1.8	2.2-2.3	2.3	20	5	8	1/2
'bohemicus' Li (1984)	F	1.0-1.2	/	1.8-2.0	2.1-2.2	2.2	>13	5-5.5	/	1/2-2/3
'bohemicus' Chen and Lin (1984)	F	1.0-1.2	/	2.0-2.1	2.0-2.1	2.2	27	/	10-11	1/2
<i>persculptus</i> Chen and Lin (1984)	F	1.0-1.5	/	1.5	1.7	2.1	22	/	10-11	1/2-2/3

Biozone. In Arctic Canada Melchin *et al.* (1991) found specimens of '*G.* *bohemicus*' just above beds which yielded *Paraorthograptus pacificus* (Ruedemann). The Bohemian specimens of '*G.* *bohemicus*' are almost certainly younger than those assigned to this taxon from Chinese and Canadian sequences.

Koren' and Sobolevskaya (1983) placed '*G.* *bohemicus*' into synonymy with *N. persculptus* after conducting a detailed study of the latter taxon from Siberia (Omulevka Uplift) and Kazakhstan (Koren' *et al.* 1980). Our study, primarily of Bohemian and Welsh specimens, confirms this synonymy. By contrast with the Chinese sections, where '*G.* *bohemicus*' and *N. extraordinarius* commonly occur together, in the sections described by Koren' *et al.* (1980) and Koren' and Sobolevskaya (1983) the earliest *N. persculptus* succeed the youngest specimens of *N. extraordinarius* without any overlap of their stratigraphical ranges.

With '*G.* *bohemicus*' being a junior synonym of *N. persculptus* it is clear that there is considerable diachroneity in the first occurrence of this species. In China and Arctic Canada *N. persculptus* appears as early as just above the *pacificus* Biozone, whilst in Siberia, Kazakhstan and Britain it appears above the *extraordinarius* Biozone.

The *bohemicus* Biozone should be omitted from future graptolite biozonal schemes. Where the first *N. persculptus* appears above the graptolite fauna of the *extraordinarius* Biozone (e.g. Great Britain, Kazakhstan, Siberia) the *persculptus* Biozone consists of the interval between the *extraordinarius* and *acuminatus* biozones (Text-fig. 6).

System	Series	Stage	Scotland Dob's Linn Williams (1983, 1988)	Bohemia Barrandian this paper	Kazakhstan Koren' et al. (1980)	NE Russia Omulev Mountains Koren' et al. (1983)	Canadian Arctic Islands Melchin et al. (1991)	Central China Mu (1988)
ORDOVICIAN	Ashgill	Rawtheyan	<i>anceps</i>					
		Himantian	<i>pacificus</i>	<i>laticeps</i>	<i>supernus</i>	<i>supernus</i>	<i>pacificus</i>	<i>uniformis</i>
		<i>complexus</i>				<i>longispinus</i>	<i>fastigatus</i>	<i>szechuanensis</i>
		<i>extraordinarius</i>	?	form A	<i>extraordinarius</i>	' <i>bohemicus</i> '	' <i>bohemicus</i> '	' <i>bohemicus</i> '
		<i>persculptus</i>	<i>persculptus</i>	<i>persculptus</i> form B	<i>persculptus</i>	<i>persculptus</i>	<i>persculptus</i>	<i>persculptus</i>
	<i>acuminatus</i>	- <i>acuminatus</i> <i>ascensus</i>	<i>acuminatus</i>	<i>acuminatus</i>	<i>acuminatus</i>	<i>acuminatus</i> <i>sinizini</i> <i>maderii-lubricus</i>	<i>acuminatus</i>	

TEXT-FIG. 6. Correlation chart summarizing upper Ashgill graptolite biozonations and illustrating the stratigraphical ranges of *Normalograptus persculptus* (solid lines) and *N. extraordinarius* (dashed lines).

In peri-Gondwanan Europe (Bohemia, Saxony, Austrian Carnic Alps, Sardinia) a considerable gap in the graptolite record occurs below the *N. persculptus*-bearing horizon near the top of the Hirnantian. Here, the *extraordinarius* and *pacificus* biozones are entirely (or in Bohemia, almost entirely) represented by strata which are barren of graptolites.

The situation is more complicated in China and the Canadian Arctic where the *bohemicus* Biozone is succeeded by the *persculptus* Biozone. For example, the Chinese *bohemicus* Biozone, containing *N. persculptus* together with a fauna characteristic of the *extraordinarius* Biozone of Britain and the former USSR, could be either (1) assigned to the *extraordinarius* Biozone, despite the presence of *N. persculptus* (applying the assemblage zone concept as used by Elles 1925 and Rickards 1976), or (2) assigned to an expanded *persculptus* Biozone (on the basis that graptolite biozones should be defined by the first appearance of their index species, as suggested by Jaeger 1981, Štorch 1994 and Koren' et al. 1995) directly succeeding the *pacificus* Biozone; the *extraordinarius* Biozone would be relegated to subzonal status and would represent the lower portion of the *persculptus* Biozone. We prefer the latter option.

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