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Pseudagnostus rugosus Ergaliev, 1980: a key agnostoid species for intercontinental correlation of upper Furongian (Cambrian) strata

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Abstract – *Pseudagnostus rugosus* Ergaliev, 1980 is described from the Furongian *Ctenopyge tumida* Zone at Gislövshammar, Scania, southern Sweden. This is the first record of this distinctive agnostoid in Scandinavia. The species is known previously from Malyi Karatau, Kazakhstan, and northwestern Hunan and western Zhejiang, South China, and provides a newly recognized link between middle–upper Furongian successions in Baltica, Kazakhstan and South China. The occurrences of *P. rugosus* allow a correlation between the *C. tumida* Zone of Baltica, the lower *Eolotagnostus scrobicularis–Jegorovaia* Zone of Kazakhstan and the lower *Lotagnostus americanus* Zone of South China.

Keywords: agnostoids, *Pseudagnostus*, correlation, biostratigraphy, Furongian, Sweden.

1. Introduction

During the past decades, it has become apparent that many agnostoid genera and species have a nearly cosmopolitan distribution and provide the most precise tools available for intercontinental correlations in the upper half of the Cambrian (e.g. Robison *et al*. 1977; Robison, 1984; Peng & Robison, 2000; Geyer & Shergold, 2000; Ahlberg, 2003). The subdivision of this interval into stages will consequently be largely based on the first appearance datum (FAD) of intercontinentally distributed agnostoids (e.g. Babcock *et al*. 2005; Babcock & Peng, 2007).

The middle Cambrian (provisional Series 3) faunas of Baltica are relatively diverse and generally dominated by agnostoids and polymerid trilobites including, for instance, paradoxidids, solenopleurids, conocoryphids and anomocarids. At the base of the Furongian, the middle Cambrian faunas are replaced by taxonomically restricted ones, generally dominated by largely endemic species of the family Olenidae (Eriksson & Terfelt, 2007; Ahlberg *et al*. 2009). Non-olenid polymerids are generally rare, confined to a few intervals, and represented by genera characteristic of Furongian successions elsewhere in the world (Terfelt & Ahlgren, 2007; Terfelt, Ahlberg & Eriksson, 2010). Global correlation of the Furongian olenid biofacies of Scandinavia is difficult and relies largely on tie points provided by a few agnostoids (Ahlberg & Ahlgren, 1996; Ahlberg, 2003).

Here we report the occurrence in Scandinavia of *Pseudagnostus rugosus* Ergaliev, 1980, recorded from the middle–upper Furongian *Ctenopyge tumida* Zone. Its potential for intercontinental correlation is evaluated herein.

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2. Intercontinental correlation

The non-olenid, 'exotic' polymerid trilobites in the Baltic trilobite realm have a fairly wide geographical distribution and they have potential for broad intercontinental correlations (Ahlberg, 2003; Terfelt & Ahlgren, 2007). Agnostoids provide, however, a firm basis for correlation with successions outside Baltica. Out of the 14 agnostoid taxa recorded from the Furongian in Scandinavia (including the species described herein), seven are excellent biostratigraphical indices or have potential for intercontinental correlation (Ahlberg, 2003; this study). *Agnostus* (*Homagnostus*) *obesus* (Belt, 1867) is a common species ranging from the *Olenus gibbosus* Zone through the *Parabolina brevispina* Zone (*sensu* Terfelt *et al*. 2008) in Scandinavia (e.g. Westergård, 1944, 1947; Terfelt *et al*. 2008). This species has also been recorded from England (Rushton, 1983), Newfoundland (Martin & Dean, 1988), Siberia (e.g. Lazarenko *et al*. 2008), Kazakhstan (Ergaliev & Ergaliev, 2008), Korea (Choi, Lee & Sheen, 2004; Choi & Kim, 2006) and North America (Pratt, 1992; Stitt & Perfetta, 2000). The value of this species for correlation is, however, limited due to its long range and lack of clear diagnostic features. A single pygidium of *Pseudagnostus leptoplastorum* Westergård, 1944 has been recorded from the *Leptoplastus raphidophorus* Zone at Andrarum, southern Sweden (Westergård, 1944). This species was recently recorded from the *Acutatagnostus acutatus–Erixanium* Zone in the Kyrshabakty section, Malyi Karatau, Kazakhstan (Ergaliev & Ergaliev, 2008), thus suggesting a broad correlation between the lower *Leptoplastus*-yielding strata in Scandinavia and the *A. acutatus–Erixanium* Zone in Kazakhstan (Fig. 2).

Glyptagnostus reticulatus (Angelin, 1851), *Aspidagnostus lunulosus* (Kryskov *in* Borovikov

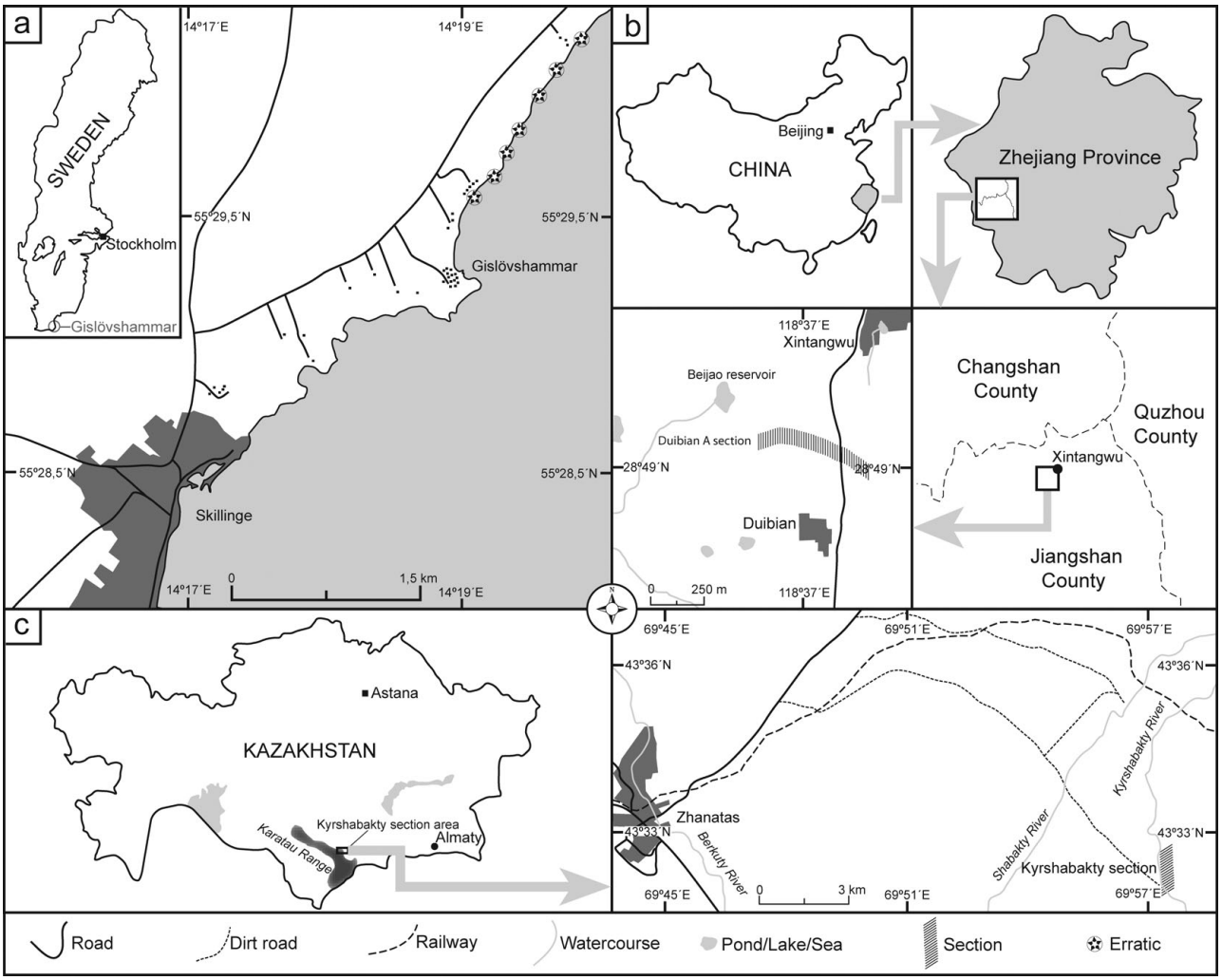

Figure 1. Maps showing key localities from which *Pseudagnostus rugosus* has been recovered. (b) and (c) modified from Peng *et al*. (2009) and Ergaliev & Ergaliev (2008) respectively.

& Kryskov, 1963) and *Pseudagnostus cyclopyge* (Tullberg, 1880) are three distinctive and geographically widespread agnostoid species known from the lower Furongian in Scandinavia (Ahlberg, 2003). The cosmopolitan *G. reticulatus* appears near the FAD of *Olenus gibbosus* and ranges up into the *Olenus wahlenbergi* Zone, suggesting that the base of the *O. gibbosus* Zone correlates with the base of the Paibian Stage and the Furongian Series (Eriksson & Terfelt, 2007). This correlation is further strengthened by the presence of *A. lunulosus* in the *O. gibbosus* Zone. *Pseudagnostus cyclopyge* (Tullberg, 1880) is fairly common in the *Parabolina brevispina* Zone (basal provisional Stage 9) in southern Sweden. This species has also been recorded from the upper Steptoean Regional Stage in northwest Canada (Pratt, 1992) and in the middle Sakian Regional Stage in southern Kazakhstan (Ergaliev & Ergaliev, 2008). Thus, *P. cyclopyge* has a wide palaeogeographical distribution, allowing a broad correlation into Laurentia and the Karatau-Naryn microplate (Kazakhstan).

In Scandinavia, agnostoids are absent in the middle Furongian (between the *Leptoplastus crassicornis* and *Ctenopyge similis* zones; upper part of provisional Stage 9), but occur sporadically in younger strata (e.g. Ahlberg & Ahlgren, 1996; Terfelt *et al*. 2005). *Lotagnostus americanus* (Billings, 1860) is an easily recognizable and widely distributed agnostoid, and the base of provisional Cambrian Stage 10 is expected to be drawn at the FAD of this species (Peng & Babcock, 2005; Babcock *et al*. 2005; Babcock & Peng, 2007). In Scandinavia, *L. americanus* (previously referred to as *L. trisectus*) appears in the *Ctenopyge spectabilis* Zone and ranges up into the *Ctenopyge linnarssoni* Zone.

Another important species is *Pseudagnostus rugosus* Ergaliev, 1980, which has recently been recovered from the *Ctenopyge tumida* Zone at Gislövshammar in Scania, Sweden (Fig. 1a). This species was known previously from Malyi Karatau, Kazakhstan (Fig. 1c), and western Zhejiang (Fig. 1b) and northwestern Hunan, South China, and provides a newly recognized link between upper Furongian successions in Baltica, Kazakhstan and South China. In Kazakhstan, *P. rugosus* ranges from the base of, and approximately half way through, the *Eolotagnostus scrobicularis–Jegorovaia* Zone (Fig. 2) and is associated with a

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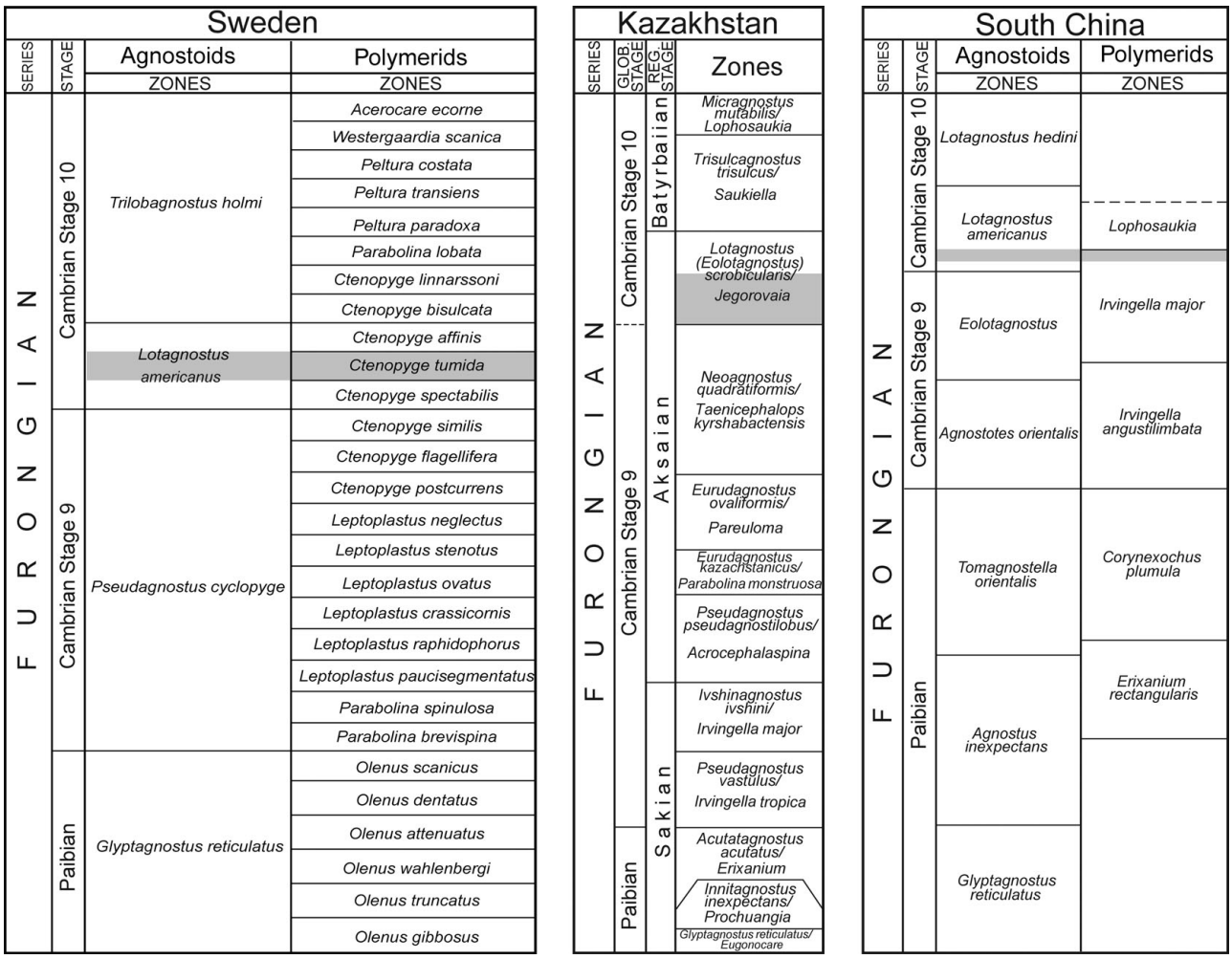

Figure 2. Biostratigraphical subdivision of the Furongian of Scandinavia (modified from Terfelt *et al*. 2008), Kazakhstan (modified from Ergaliev & Ergaliev, 2008 and Ergaliev *et al*. 2008) and Zhejiang, South China (modified from Peng *et al*. 2009). Shaded intervals show stratigraphical occurrences of *Pseudagnostus rugosus* and levels of correlation.

trilobite assemblage characterized by olenids (*Westergaardites* Troedsson, 1937, *Plicatolina* Shaw, 1951, *Parabolinites* Henningsmoen, 1957, *Chekiangaspis* Lu *in* Chien, 1961) and several species of *Rhaptagnostus* Whitehouse, 1936 (Ergaliev & Ergaliev, 2008, table 5; Ergaliev *et al*. 2009, figs 5, 8). In western Zhejiang, China, *P. rugosus* ranges through the upper lower part of the *Lotagnostus americanus* Zone (Fig. 2) and is associated with the zonal index species (Lu & Lin, 1983, 1984). Peng (1992) figured a single pygidium from considerably older strata (*Lotagnostus* (*Eolotagnostus*) *decorus*/*Kaolishaniella* Zone) in the Cili-Taoyuan area, northwestern Hunan, South China. This is an anomalous occurrence not observed elsewhere, and the stratigraphical position needs to be confirmed. Hitherto, *L. americanus* has been the best tool available for intercontinental correlation of middle–upper Furongian strata. This species is fairly long-ranging, spanning five trilobite zones in Scandinavia. *Pseudagnostus rugosus* is, however, known from the *Ctenopyge tumida* Zone only and has a considerably shorter range. In China and Kazakhstan it appears to have a shorter range than the zonal indices. The record of *P. rugosus* in Scandinavia allows for a more precise correlation between the *C. tumida* Zone of Baltica, the lower *Eolotagnostus scrobicularis–Jegorovaia* Zone of Kazakhstan and the lower *Lotagnostus americanus* Zone of South China.

3. Systematic palaeontology

Morphological terminology follows Robison (1982), Shergold, Laurie & Sun (1990) and Whittington & Kelly *in* Kaesler (1997). All described and illustrated specimens (LO) are housed at the Department of Geology, Lund University, Sweden.

Order AGNOSTIDA Salter, 1864
Family AGNOSTIDAE M'Coy, 1849
Subfamily PSEUDAGNOSTINAE Whitehouse, 1936
Genus *Pseudagnostus* Jaekel, 1909

Type species. *Agnostus cyclopyge* Tullberg, 1880 (p. 26, pl. 2, fig. 15a, c) from the Furongian *Parabolina brevispina* Zone at Andrarum, Scania, southern Sweden; by original designation.

Remarks. Shergold (1977) reviewed the concept and classification of *Pseudagnostus* and recognized three

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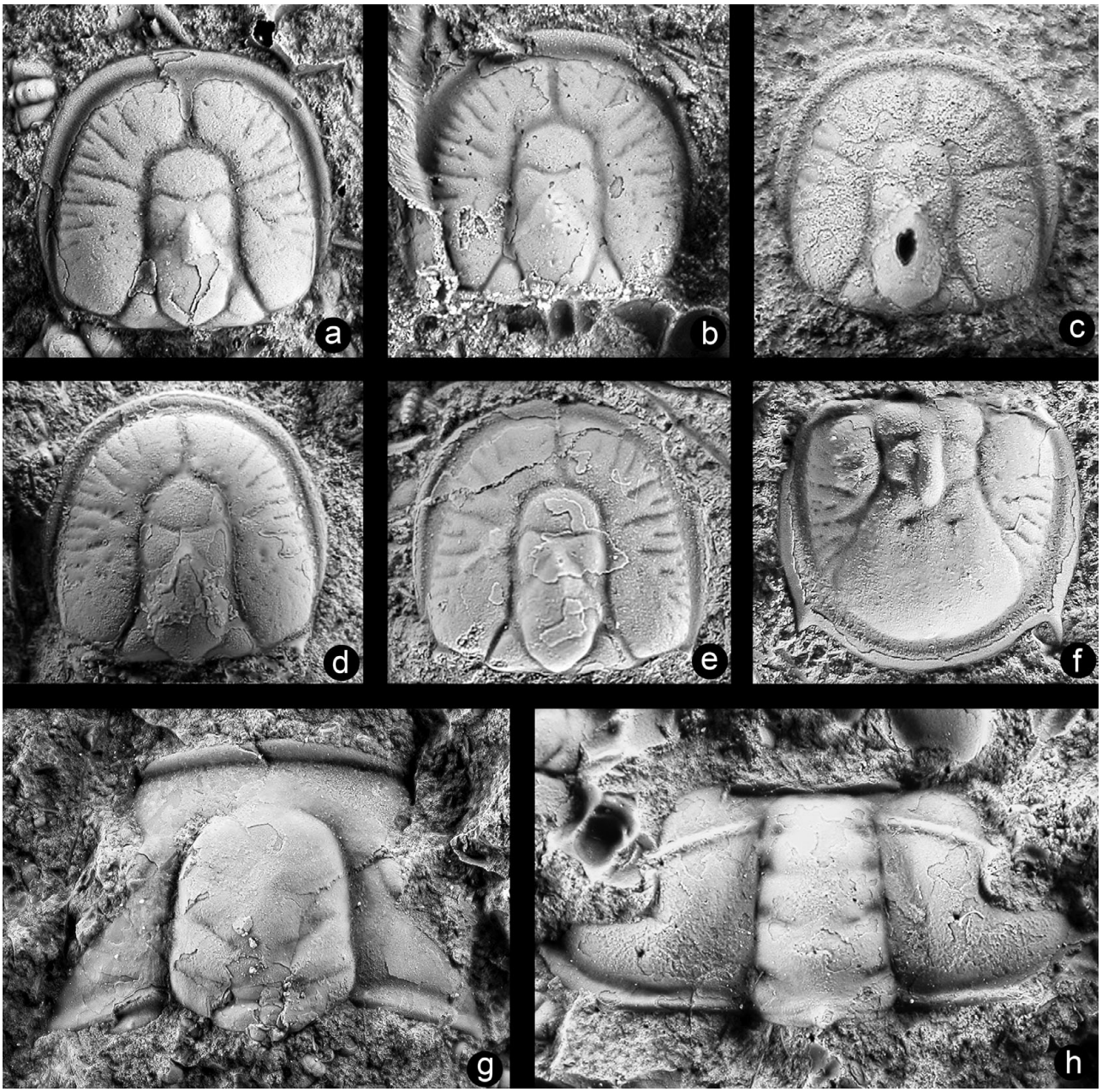

Figure 3. *Pseudagnostus rugosus* and selected polymerid trilobites from the *Ctenopyge tumida* Zone, Gislövshammar, Scania, southern Sweden. (a–f) *Pseudagnostus rugosus*. (a) Cephalon, ×11.5, LO10556. (b) Cephalon, ×13.0, LO10555. (c) Cephalon, ×13.5, LO10554. (d) Cephalon, ×10.0, LO10558. (e) Cephalon, ×10.5, LO10557. (f) Pygidium, ×14.0, LO10561. (g) *Parabolinites laticaudus*, cranidium, ×5.5, LO10566. (h) *Ctenopyge tumida*, cranidium, ×12.0, LO10567.

subgenera: *Pseudagnostus*, *Pseudagnostina* Palmer, 1962 and *Sulcatagnostus* Kobayashi, 1937. Peng & Robison (2000) discussed the morphological plasticity within the genus, and provisionally suppressed *Pseudagnostina* and *Sulcatagnostus* as junior subjective synonyms of *Pseudagnostus*. This view is followed herein (cf. Choi, Lee & Sheen, 2004).

Pseudagnostus rugosus Ergaliev, 1980
Figures 3a–f, 4a–f, Table 1

1980 *Pseudagnostus* (*Sulcatagnostus*) *rugosus* sp. nov.; Ergaliev, p. 112, pl. 17, figs 3, 4.
1983 *Pseudagnostus rugosus*; Ju *in* Qiu *et al*., p. 39, pl. 13, fig. 11.
1984 *Pseudagnostus* (*Sulcatagnostus*) *rugosus* Ergaliev; Lu & Lin, pp. 57–8, pl. 3, figs 4–6.
1989 *Pseudagnostus* (*Sulcatagnostus*) *rugosus* Ergaliev; Lu & Lin, pp. 119–20, pl. 14, figs. 12, 13.
1992 *Pseudagnostus* (*Pseudagnostus*) *rugosus* (Ergaliev, 1980); Peng, p. 26, fig. 12G.
2003 *Lotagnostus* cf. *trisectus* (Salter, 1864); Ahlberg, fig. 3H.
2005 *Pseudagnostus rugosus* Ergaliev; Peng *et al*., fig. 6:7, 8.
2008 *Sulcatagnostus rugosus* (Ergaliev, 1989); Ergaliev & Ergaliev, p. 181, pl. 49, figs 9–12 (*non* pl. 48, fig. 4).

Holotype. A nearly complete cephalon illustrated by Ergaliev (1980, pl. 17, fig. 3) and Ergaliev & Ergaliev (2008, pl. 49, fig. 9).

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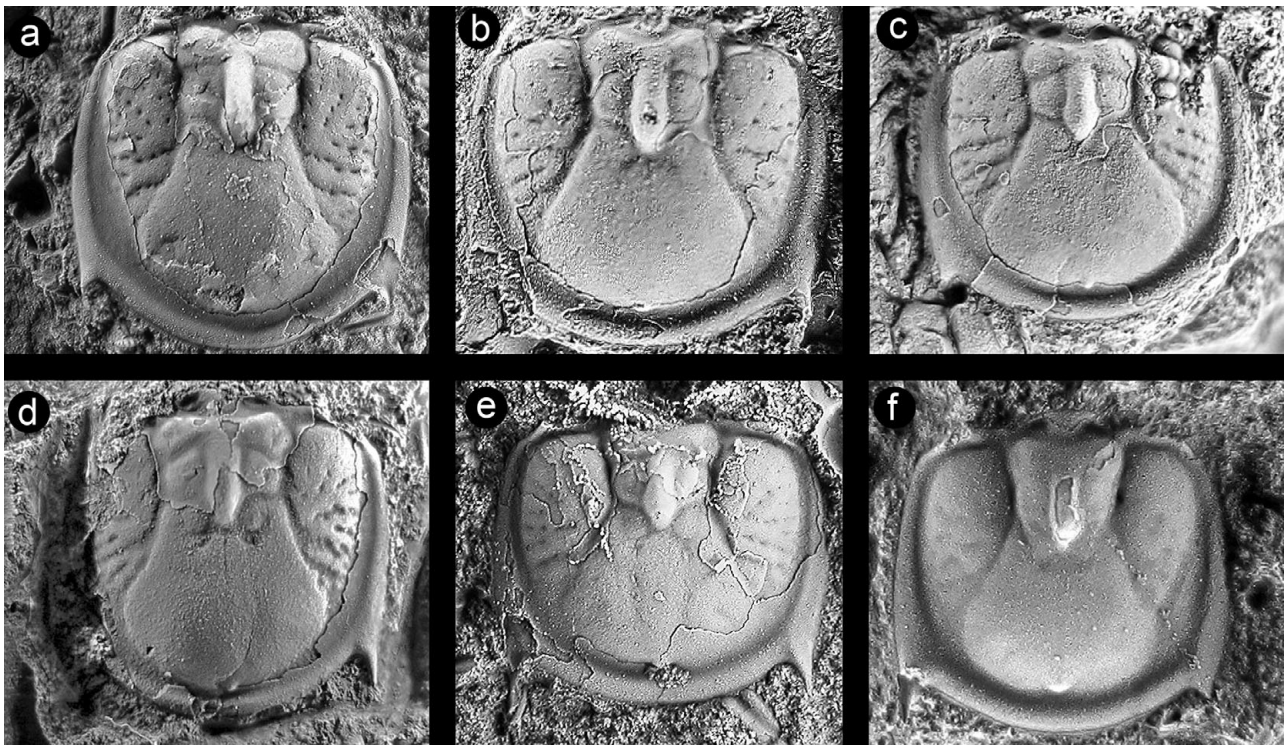

Figure 4. *Pseudagnostus rugosus* from the *Ctenopyge tumida* Zone, Gislövshammar, Scania, southern Sweden. (a) Pygidium, ×10.0, LO10564. (b) Pygidium, ×13.0, LO10562. (c) Pygidium, ×11.0, LO10563. (d) Pygidium, ×9.5, LO10565. (e) Pygidium, ×13.5, LO10560. (f) Small pygidium, ×16.5, LO10559.

Table 1. Dimensions (in mm) of cephala and pygidia of *Pseudagnostus rugosus*

Specimen	Lc	Lcb	G	N	Wc	Wg
LO10554	3.05	0.20	1.90	0.80	3.15	0.95
LO10555	3.15	0.30	2.15	1.00	3.50	0.95
LO10556	3.75	0.35	2.35	1.15	4.00	1.10
LO10557	4.00	0.30	2.50	1.40	4.30	1.30
LO10558	4.30	0.40	2.85	1.50	4.60	1.35
	Lp1	Lp2	Lpa	Lpb	Wp	Wpa
LO10559	2.55	2.30	2.10	0.20	2.70	1.70
LO10560	–	2.65	2.40	0.25	3.15	2.10
LO10561	3.00	2.80	2.55	0.25	3.10?	2.00
LO10562	–	3.20	2.85	0.35	3.75	2.50
LO10563	3.70	3.40	3.15	0.25	4.25	2.60
LO10564	4.35	4.10	3.70	0.40	4.45	2.65
LO10565	4.45	4.15	3.75	0.30	5.00?	2.60

Measurements were made with a micrometer eyepiece fitted inside a binocular microscope. All dimensions were measured as straight-line distances with an accuracy of about 0.05 mm. Lc – maximum length (sag.) of cephalon; Lcb – length (sag.) of cephalic border (including border furrow); G – length (sag.) of glabella; N – distance (sag.) from rear of glabella to highest point of median node; Wc – maximum width (tr.) of cephalon; Wg – maximum width (tr.) of glabella (excluding basal lobes); Lp1 – maximum length (sag.) of pygidium (including articulating half ring); Lp2 – length (sag.) of pygidium (excluding articulating half ring); Lpa – length (sag.) of pygidial axis (excluding articulating half ring); Lpb – length (sag.) of the posterior pygidial border (including border furrow); Wp – maximum width (tr.) of pygidium; Wpa – maximum width (tr.) of pygidial axis. Estimated measurements are denoted with a question mark.

Material. Thirty-seven cephala and 40 pygidia preserved in dark grey limestone concretions (orsten). All specimens are from locally derived boulders collected by Peter Cederström along the shore 0.6–2.0 km NNE of the hamlet of Gislövshammar in Scania (Skåne), southern Sweden. Most specimens are preserved in three dimensions.

Description. Cephalon moderately convex, subovoid to subrectangular in outline, slightly wider than long, and widest along transverse line slightly posterior to F3. Glabella, occupying 62–68 % of total cephalic length, nearly parallel-sided, slightly constricted at mid-length, and broadly rounded anteriorly. Median node prominent, elongated, situated at midpoint of glabella, and extending into acute apex of F2. Rear of glabella obtusely angulated in dorsal view. F3 distinct and sinuous. F2 prominent and with shape of an inverted V. F1 absent. Basal lobes subtriangular, divided and connected medially. Preglabellar median furrow deeply impressed, broad and complete. Acrolobe slightly constricted. Genae distinctly scrobiculate, lacking cross furrows. Anterior and lateral border convex, defined by distinct border furrow, widest antero-laterally, becoming narrower postero-laterally. Sagittally, border and border furrow combined occupy 7–10 % of total cephalic length.

Pygidium subovoid to subrectangular in outline, 1.1–1.3 times wider than long (excluding articulating half-ring), and widest at mid-length. Pygidial axis constricted at F2, reaching posterior border furrow. F1 and F2 well defined. M2 longer (exsag.) than M1. Median tubercle elongated, extending backwards above the anterior portion of posteroaxis. Posteroaxis strongly expanded, defined by straight to slightly concave axial furrows, and nearly twice as long as anteroaxis. Posteroaxis undivided or faintly trilobed (divided into an intranotular and a pair of extranotular parts) with small median node at posterior end. Anterior part of posteroaxis with a pair of rounded scars. Pleural fields with distinct pits, arranged in rows. Posterior and lateral border convex, defined by distinct border furrow, widest postero-laterally, becoming narrower antero-laterally. Prominent posterolateral spines situated

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along transverse line passing slightly anterior to rear end of posteroaxis.

Remarks. The material from Sweden agrees in all essential features with *Pseudagnostus rugosus* described by Ergaliev (1980) and Ergaliev & Ergaliev (2008) from Malyi Karatau, southern Kazakhstan.

Pseudagnostus rugosus closely resembles *P. intermedius* Varlamov, Pak & Rosova, 2005 from the *Agnostotes clavatus–Irvingella perfecta*, *Norilagnostus quadratus–Irvingella cipita* and *Irvingella norilica* zones in the Chopko River section, Norilsk District, northwestern Siberian Platform. *Pseudagnostus intermedius* differs, however, from *P. rugosus* in having a 30% wider anteroaxis, smaller pygidial spines, a more constricted glabella, a wider cephalic border furrow, and a less pronounced anteroglabella. In addition, *P. intermedius* is more effaced.

A cephalon from Västergötland, south-central Sweden, figured by Ahlberg (2003, fig. 3H) as *Lotagnostus* cf. *trisectus*, is here assigned to *P. rugosus*. As in the material from Scania, this cephalon has distinct scrobicules on the genae, a prominent F2 with the shape of an inverted V, and a transglabellar and sinuous F3.

In the material at hand, the smallest pygidia (Fig. 4e, f) have a more broadly rounded posterior margin and a proportionately narrower anteroaxis than larger pygidia.

Occurrence. Lower *Lotagnostus* (*Eolotagnostus*) *scrobicularis–Jegorovaia* Zone, uppermost Aksaian Regional Stage, Kyrshabakty section, Malyi Karatau, Kazakhstan (Ergaliev & Ergaliev, 2008; Figs 1c, 2).

Upper lower *Lotagnostus americanus* agnostoid Zone or uppermost *Irvingella major* polymerid Zone, Siyanshan Formation in the Jiangshan-Changshan-Zhuji area, western Zhejiang Province, South China (Lu & Lin, 1983, 1984, 1989; Peng *et al*. 2005; Figs 1b, 2).

Lotagnostus (*Eolotagnostus*) *decorus*/*Kaolishaniella* Zone, Bitiao Formation, Shenjiawan section, Cili-Taoyuan area, northwestern Hunan, South China (Peng, 1992).

Middle *Lotagnostus americanus* agnostoid Zone or *Ctenopyge tumida* polymerid Zone NNE of Gislövshammar, southeastern Scania, Sweden (Figs 1a, 2). Associated with *C. tumida* Westergård, 1922 (Fig. 3h), *Parabolinites laticaudus* (Westergård, 1922) (Fig. 3g) and *Sphaerophthalmus alatus* (Boeck, 1838). In Sweden, *P. rugosus* is also known from coeval strata at Hällekis in Västergötland (a cephalon referred to as *Lotagnostus* cf. *trisectus* by Ahlberg, 2003, fig. 3H).

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