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ARTICLE

New records of brachiopods and crinoids from the Silurian (Wenlock) of the southern Urals, Russia

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ABSTRACT

Crinoids and brachiopods are described from the Silurian Uzyan Formation of the Zilair Zone in the southern Urals. The occurrence of the graptolites *Coronograptus praedeubeli* suggests a late Homerian (Wenlock) age for the strata. A new disparid crinoid, *Cicerocrinus gracilis* Donovan sp. nov., is the oldest known member of this genus. It has a long, flexible and homeomorphic column, and a tall bryozoan palaeontology terminology (IBr^2) (second primibrachial) axillary. All species of *Cicerocrinus* described previously have been limited to the Ludlow of the British Isles, Sweden and Estonia, and the Pridoli of Estonia. The poorly preserved brachiopod fauna is represented by small atrypid (*Atrypa*? sp.) and dalmanellid brachiopods (*Levenea*? sp.). The reported assemblage generally inhabited deep-water environments.

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Crinoidea; *Cicerocrinus*; Brachiopoda; atrypids; dalmanellids; Zilair; southern Urals; Russia

Introduction

When Roderick Impey Murchison (1792–1871) travelled to Russia for the first time in 1840, it was not with any anticipation of what would be the most significant contribution of this tour. That is, it was his definition of the Permian System that was of truly international importance (Holliday in press). Rather, he was initially intent on determining the wider extent of the Silurian and Devonian systems, major stratigraphic entities defined by Murchison and by Adam Sedgwick (1785–1873) and Murchison, respectively. Murchison was rightly called the "King of Siluria" (Morton 2004) and, in Russia, he successfully extended his "empire" far to the east.

The present paper describes new discoveries of crinoids and brachiopods from the Russian part of the Silurian "empire", in the succession of the southern Urals (Fig. 1). Crinoids and brachiopods are relatively well known from the Silurian of the southern Urals; however, there are just a few publications (e.g., Tyazheva & Zshavoronkova 1972; Militsyna 1980) dealing with their systematic palaeontology. Crinoids, reported from a few Silurian localities, are based mainly on disarticulated elements of the stem and include the following taxa: *Bystrowicrinus* (col.) Yeltysheva, *Crotalocrinites* Austin & Austin, *Egiasarovicrinus* (col.) Schewtschenko, *Syndetocrinus* Kirk and *Turuchanocrinus* (col.) Stukalina (Militsyna 1980; Stukalina 2000). Note that Webster & Webster (2014, p. 2671) considered *Turuchanocrinus* (col.) to be a nomen nudum. Brachiopods are mainly represented by pentamerids (*Conchidium, Pentamerus* and *Subriana*) (Ozhiganov 1955; Krauze & Maslov 1961). Neither of these fossil groups has previously been reported from the Zilair Zone.

Geological setting and stratigraphy

Silurian sedimentary successions are well known in the southern Urals from both exposures and wells. They were described by Ozhiganov (1955), Klochikhin (1960), Krauze & Maslov (1961), Yakupov et al. (2002) and Artyushkova et al. (2011). The Zilair Zone forms a SW plunging, broad synform of Ordovician to Devonian siliciclastic and carbonate sedimentary rocks (Bastida et al. 1997), which unconformably overlie Neoproterozoic basement. The platform sedimentary rocks are overlain by Upper Devonian flysch, which forms the entire core of the synclinorium (Puchkov 1997). The southern Urals sector of the Zilair Zone is interpreted to represent a continental slope and rise basin setting (Brown et al. 1998). The sequences of the three sections examined in this zone comprise three successive formations, Yuzhno, Uzyan and Sermenevo formations (Fig. 2). The lowermost Yuzhno Bainazarovo Formation is characterised by claystones, siltstones and thin beds of limestones. Mudstones and shales make up the ~500-m-thick Uzyan Formation (Maslov et al. 2008). The overlying Sermenevo Formation is represented by dark grey massive dolostones and black bituminous limestones. Only the Uzyan Formation is discussed further below. Based on its included graptolites and conodonts, the Uzyan Formation is considered to be of late Llandovery to Wenlock age (Yakupov et al. 2002).

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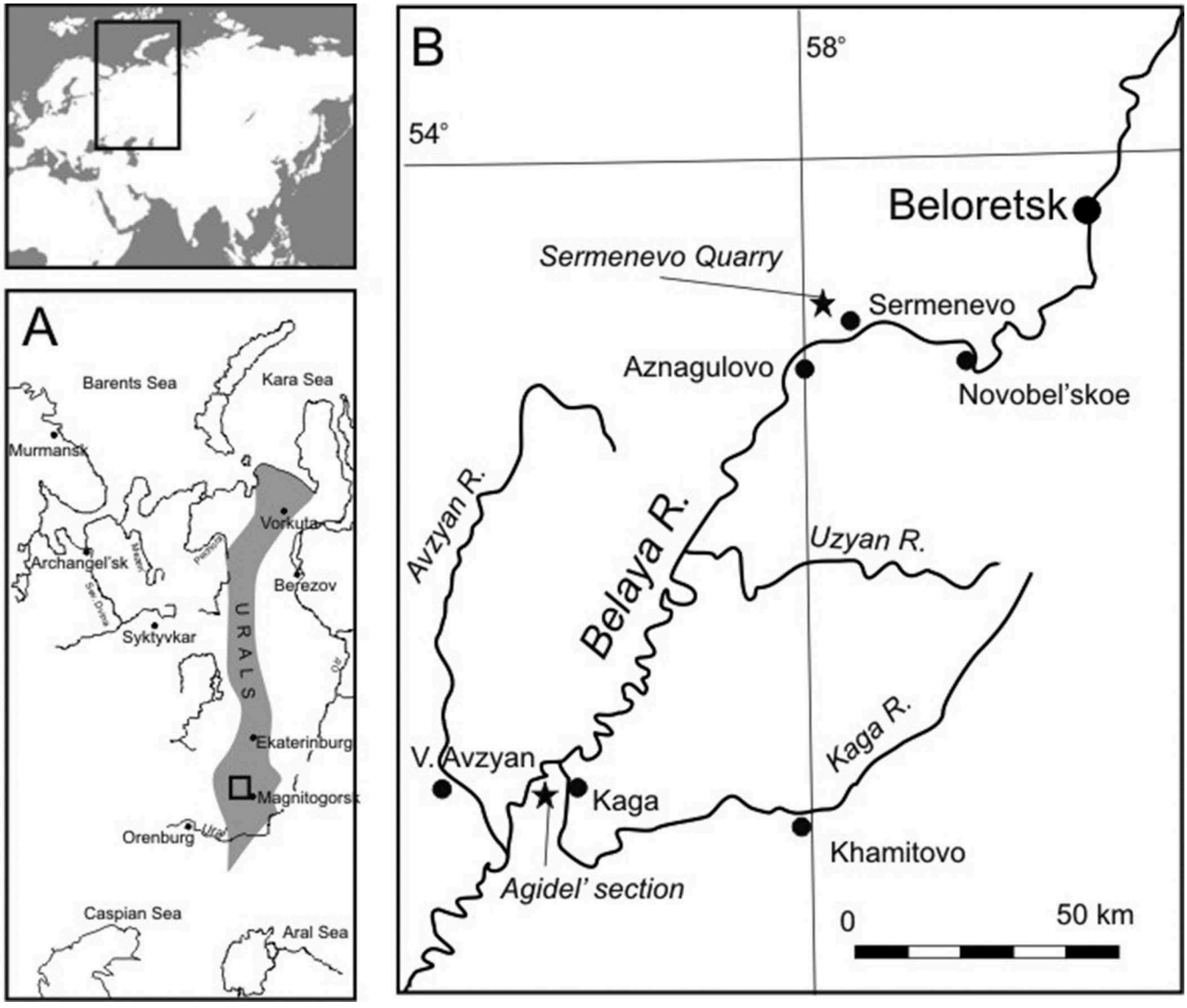

Figure 1. A sketch geography of Russia showing the Urals and the location of the studied area (the Sermenevo Quarry near the village of Sermenevo, and the Agidel' section near the village of Kaga) referred to in the text.

Materials

The studied palaeontological specimens were collected at two localities (Fig. 1): the Sermenevo Quarry, and the Agidel' section. At Agidel', in the valley of the Belaya River, 5 km NW of the village of Kaga, the dark grey to grey, well-laminated shales and interbeds of siltstones, make up an ~160 m of the Uzyan Formation (Figs. 3, 4). Shales at about ~145 m from the base of the section yield rare Homerian graptolites *Colonograptus* cf. *ludensis* . In contrast to the shales, siltstones contain crinoid columnals and small atrypid brachiopods (Fig. 6B, C). To date these are the first fossil discoveries in this section.

At the Sermenevo Quarry, located 3 km NW of the village of Sermenevo (Fig. 1), a ~ 10-m-thick succession of unmetamorphosed dark grey to green and brownish carbonaceous-silty mudstones (shales) is exposed (Figs. 3, 5). Rocks yield poorly preserved graptolites, brachiopods (Fig. 6A), crinoids (Figs. 7, 8), orthoceratid cephalopods, gastropods and bryozoans. The graptolites *Colonograptus* ex gr *deubeli*, *C. praedeubeli*, *Lobograptus idoneus* (Koren' et al. 1996) and *Pristiograptus dubius* have been identified, indicating the *C. deubeli* – *C. praedeubeli* Biozone (Koren' et al. 1996) of the upper Homerian stage of the Wenlock Series. It should be noted that Paalits et al. (1998), while examining the same quarry, mistakenly referred to this interval as the Sermenevo Formation. Subsequently, Yakupov et al. (2002) placed the Paalits et al. (1998) data, obtained from this interval within the upper part of the Uzyan Formation.

Remarks on brachiopods

No taxonomic description is given for the herein reported brachiopods due to the poor preservation of specimens. Brachiopods, collected in both the Agidel' section and the Sermenevo Quarry (Sites 1 and 2), are represented by just three, variably exfoliated valves prepared from the hard, slate matrix together with a number of shell fragments. The fauna is characterised by a relatively small atrypid

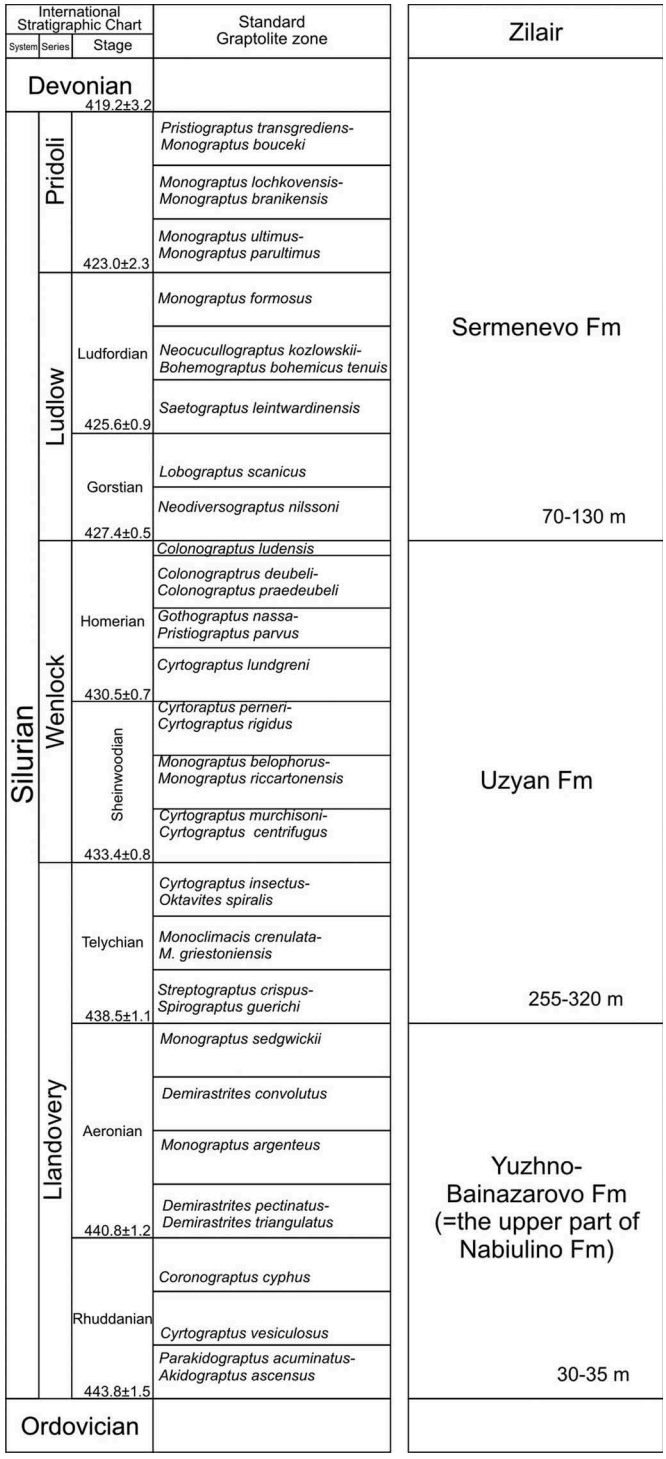

Figure 2. Stratigraphic chart for the Zilair Zone of the southern Urals (from Yakupov et al. 2002).

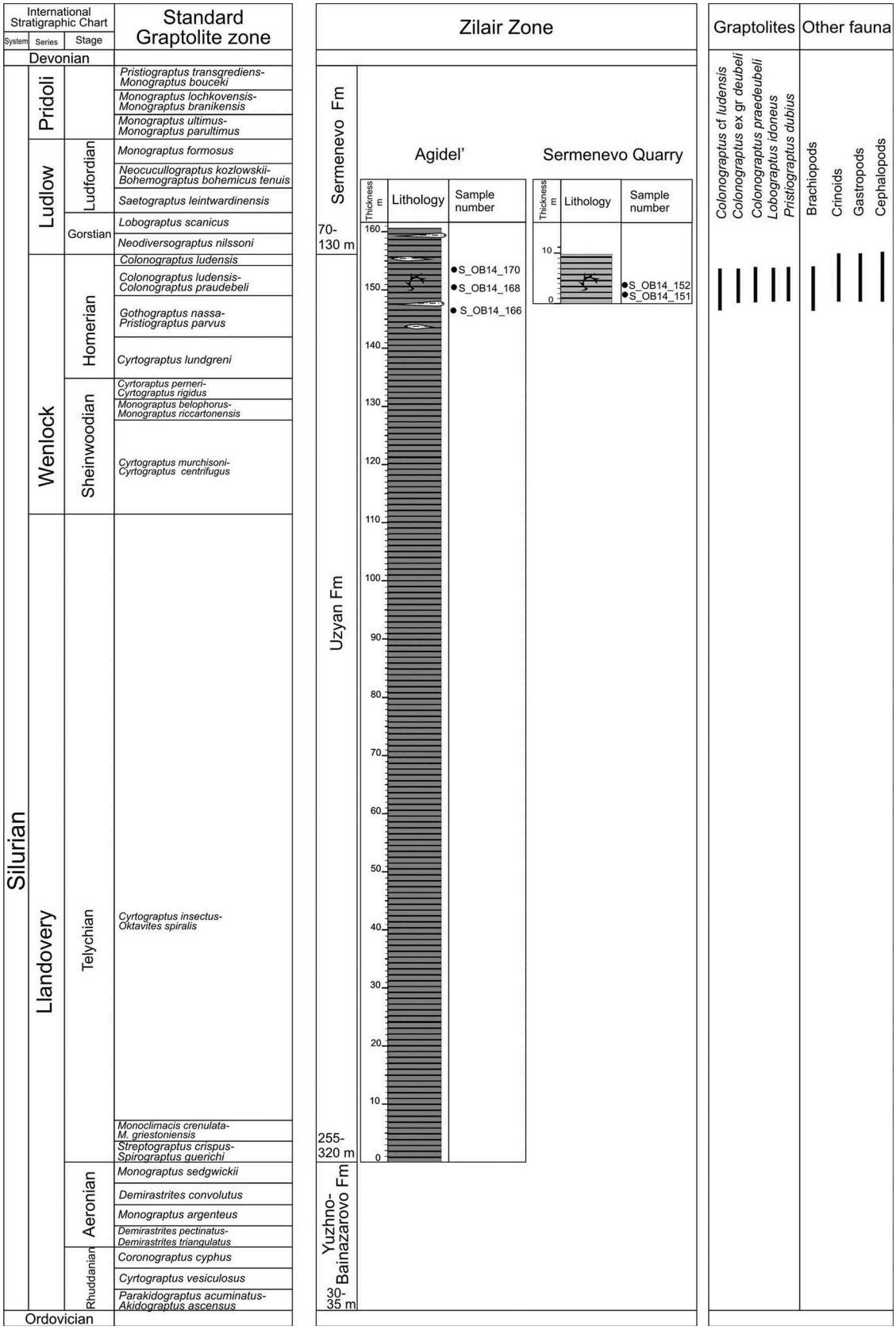

Figure 3. Stratigraphy, correlation and fauna of the Agidel' and Sermenevo sections referred to in the text. The black dots show the location of samples.

Figure 4. Dark-coloured shale unit of the Uzyan Formation, showing slaty cleavage, Agidel' section, Belaya River.

Figure 5. Dark grey mudstones, Uzyan Formation, Sermenevo Quarry, near the village of Sermenevo. Hammer for scale.

brachiopod (Fig. 6B, C). Two near-complete dorsal valves are convex with a slight fold, coarse ribs and a well-developed anterior frill; there is a marked sublamellose concentric sculpture and several spine bases are preserved. The general morphology and ornament is similar to *Atrypa sensu stricto*, which ranges from the Llandovery to Lower Devonian. It is referred to *Atrypa*? sp. herein.

The small dalmanellid brachiopod (Fig. 6A) is similarly poorly preserved, but the dorsal valve is nearly complete. The valve is small, moderately convex, with a weak dorsal sulcus. The ornament is costellate; ribs arise by simple bifurcation, with a moderately strong concentric sculpture. The shape, dorsal sulcus and simple branching of relatively fine costae and costellae is similar to those of *Levenea*, an isorthin ranging from the Llandovery to Middle Devonian, generally inhabiting deeper-water environments. This specimen is referred to *Levenea*? sp.

Systematic palaeontology

Remarks. The specimens described herein are deposited at the Museum of Evolution, Uppsala University, Uppsala, Sweden (prefix PMU). Terminology of the crinoid stem follows Moore et al. (1968), Moore (1978a)) and Ubaghs (1978). The structure of the systematic description follows Fearnhead (2008).

Class Crinoidea Miller 1821
Subclass Disparida Moore & Laudon 1943
Order Pisocrinida Ausich & Copper 2010
Family Pisocrinidae Angelin 1878
Genus *Cicerocrinus* Sollas 1900
1900 *Lagarocrinus* Jaekel, pp. 480–481.

Type species. *Cicerocrinus elegans* Sollas, 1900, by monotypy (Moore et al. 1978b, p. T536); probably from the Upper Ludlow of the British Isles, precise locality unknown (Ramsbottom 1958, p. 111).

Other nominal species. In addition to the type species, Webster (2003) and Webster and Webster (2014) recognised the following additional species of *Cicerocrinus: Cicerocrinus anglicus* (Jaekel 1900) (Silurian, Ludlow, Wales); *C. osiliensis* (Jaekel 1900) (Late Silurian, Estonia); *C. scanicus* (Jaekel 1900) (Late Silurian, Sweden and Estonia).

Diagnosis. (Revised after Moore et al. 1978b, p. T536.) Cup high and conical, with upright elongate basals. Basals 5, unequal in size; AE and BC smaller than other three basals and with truncated, rather than acute, distal edge. Radials also unequal in size; C and E radials small, triangular and not in contact with basals; B ray with small triangular superradial and large inferradial which is shifted obliquely to the left and situated directly above the BC basal; D and A radials are large, simple, in contact with basals, and together with the B inferradial comprise most of the theca (see Sollas 1900; Fig. 3; reproduced in Donovan et al. 2009; text-fig. 10, with explanatory caption). Anal X small, on upper right shoulder of D radial. Arms branch on second primibrachial in all rays, each arm with two main rami or with an additional division high above the cup. Secundibrachials bear stout unbranched ramules on alternate sides of every second brachial.

Remarks. The oldest pisocrinid known, *Eocicerocrinus sevastopuloi* Donovan, 1989, from the Ashgill (Katian; Upper Ordovician) of the Laurentian of south-west Scotland (see also Donovan & Clark 2015), is the only other pisocrinid genus with branched arms. All other pisocrinids – *Calycanthocrinus* Follman, *Parapisocrinus* Mu, *Pisocrinus* de Koninck and *Triacrinus* Münster – have unbranched arms; the arms are unknown in *Jaekelicrinus* Yakovlev (Moore et al. 1978b; pp. T533-T537; Donovan 1989; p. 69).

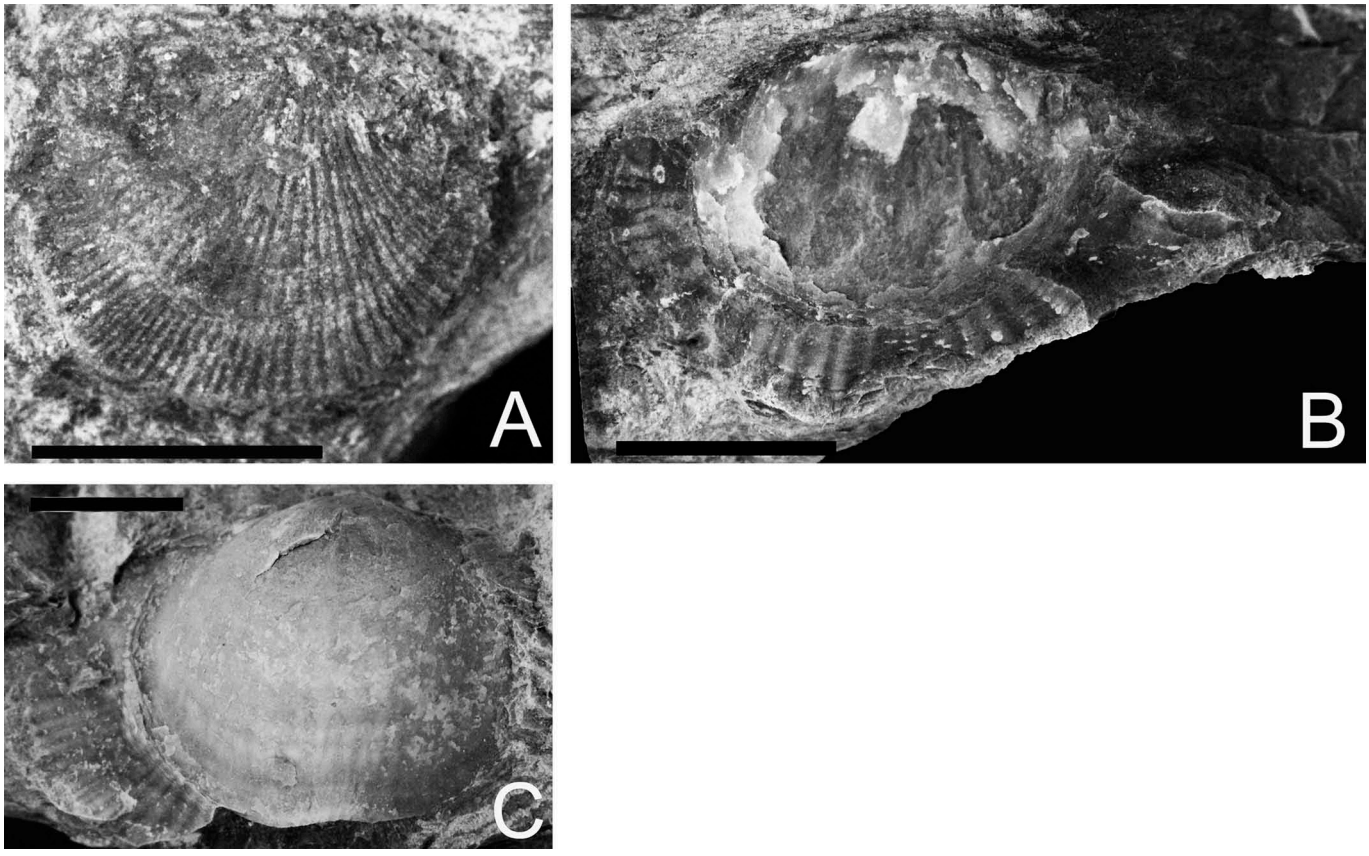

Figure 6. Brachiopods from the Uzyan Formation of the southern Urals. **A** Dalmanellid *Levenea*? sp. **B** and **C** Atrypid *Atrypa*? sp. All scale bars represent 10 mm.

Range. Silurian, Wenlock, southern Urals (herein); Ludlow, northern Europe, British Isles, Sweden, Estonia (Webster 2003); Pridoli, Estonia (Ausich et al. 2012, 2015).

Cicerocrinus gracilis Donovan sp. nov.
Figures 7, 8

Etymology. Latin *gracilis*, meaning "slender", in reference to the long and slender column of this species.

Type material. Holotype, PMU 28754a, PMU 28747a and PMU 28745b, PMU 28746a (Fig. 7C, 8), part and counterpart (PMU 28746b is also a counterpart to PMU 28746a, but this surface bears paratypes only). Other paratypes, PMU 28 748, PMU 28 749, PMU 28 750, PMU 28 751, PMU 28 752, PMU 28 753, PMU 28754a, PMU 28754b (part and counterpart), PMU 28 755 and PMU 28 756 (Fig. 8).

Type locality. Sermenevo Quarry, 3 km NW of the village of Sermenevo, Beloretsk Region, Bashkortostan, Russia.

Diagnosis. A species of *Cicerocrinus* with a particularly long, flexible, homeomorphic column and a tall IBr_2 axillary brachial.

Description. Attachment structure unknown. Column circular to rounded pentagonal in section, long, gracile and flexible (Fig. 7). Articulation symplectial, marginal, comprised of short, unbranched crenulae; circular areola; lumen central, moderately broad, circular(?) (Fig. 7H). Column homeomorphic (or, possibly, weakly heteromorphic; differences in height of columnals are subtle). Columnals with convex, unsculptured latera. Cup incomplete and crushed, basals not seen, but apparently tall and gently conical or cylindrical, unsculptured. On specimen PMU 28747b (Fig. 8B), E radial small, triangular, resting on shoulders of adjacent, larger, polygonal D and A radials; plating on specimen PMU 28747a less easily decipherable (Fig. 8A). Arms partly disarticulated, incomplete, unsculptured, uniserial, apinnulate, branching isotomously at IBr_2. IBr_1 low, trapezoidal, broadest at base. IBr_2 over twice the height of IBr_1, axillary, aboral latera gently concave. Secundibrachials more slender, cylindrical in aboral view, higher than wide, first ramules supported by $IIBr_{2-3}$. Ramules more slender than secundibrachs. Brachials U-shaped in section; adoral groove V-shaped in section.

Remarks. *Cicerocrinus gracilis* sp. nov. is the oldest known member of this genus. All species described previously have been limited to the Ludlow and Pridoli. *Cicerocrinus gracilis* is easily distinguished from the type species, *C. elegans* Sollas, and *C. osiliensis* (Jaekel), both of which bear low, broad, axillary IBr_2 (compare Fig. 8B with Sollas 1900, Fig. 3; Jaekel 1900, Fig. 2; respectively). The holotype and only specimen of *Cicerocrinus anglicus* is lost and was never figured, and Jaekel's description (1900; pp. 486–487; Donovan et al. 2009; p. 31) is inadequate for comparison. *Cicerocrinus scanicus* (Jaekel) differs from *C. gracilis* in its robust arrangement of ramules (compare Jaekel 1900; Fig. 3 with Fig. 8 herein).

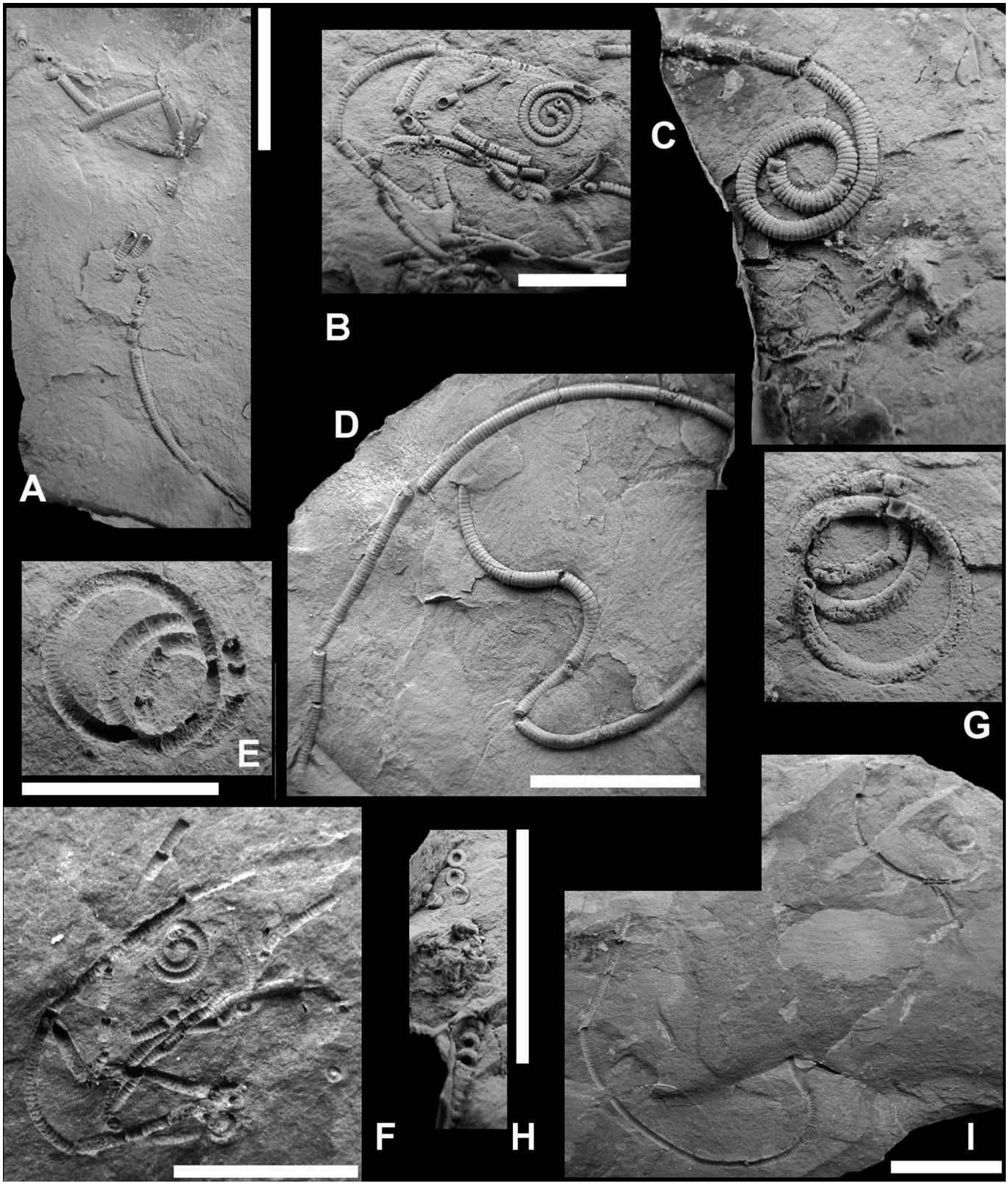

Figure 7. *Cicerocrinus gracilis* Donovan sp. nov. All paratypes unless stated otherwise. **A** PMU 28 748, long, partly disarticulated pluricolumnal. **B** F PMU 28746a and PMU 28746b, respectively, part and counterpart, curved and coiled pluricolumnals. **C** PMU 28745a, cup (holotype) angled to lower left next to a paratype, planar coiled pluricolumnal. **D** PMU 28 752, long, sinuously curved pluricolumnal. **E** G PMU 28 749, coiled pluricolumnal. **H** PMU 28 750, disarticulated columnals. **I** PMU 28 751, long curved pluricolumnals. **A-D, G, H** These are latex casts; other specimens are natural moulds. All specimens coated with ammonium chloride. All scale bars represent 10 mm.

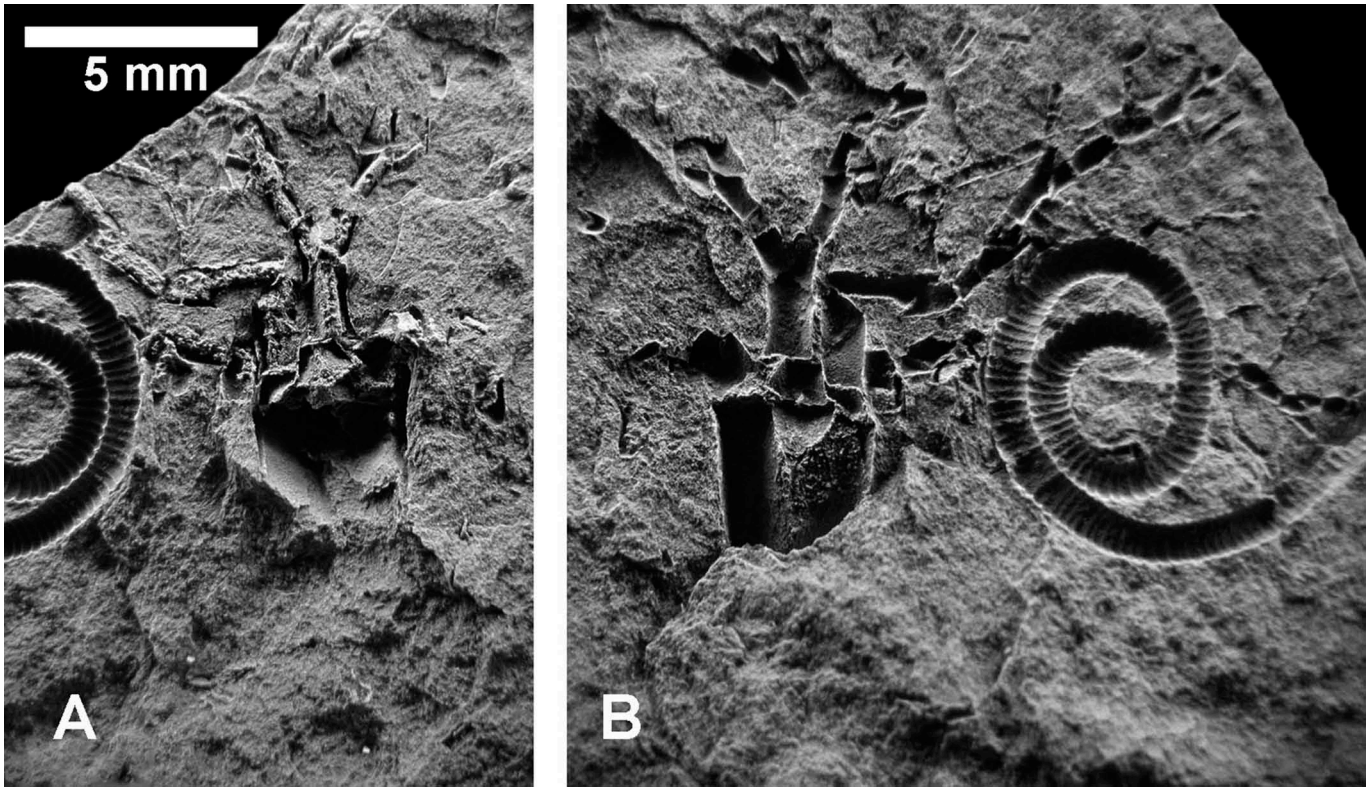

Figure 8. *Cicerocrinus gracilis* Donovan sp. nov., holotype. **A** Cup and arms (adoral surface). **B** Cup and arms (aboral surface). Triangular E-ray radial at top centre of cup supporting low, trapezoid IBr1 and relatively tall IBr2. Specimens coated with ammonium chloride.

The long and contorted column of *C. gracilis* is noteworthy. The slender, coiled pluricolumnals almost certainly collapsed after death rather than form a distal planar coiled attachment (Baumiller & Ausich 1996). The long pluricolumnals indicate that *C. gracilis* was adapted to maintain the crown high above the sediment surface to harvest food from water that was free of sediment.

Summary

A new collection of crinoids and brachiopods from the Silurian of southern Urals are reported and described herein. Taxa from the upper part of the Uzyan Formation (Wenlock) are represented by atrypid (*Atrypa*? sp.) and dalmanellid brachiopods (*Levenea*? sp.), and the pisocrinid crinoid *Cicerocrinus*. The latter material is significant recording a new disparid crinoid, *Cicerocrinus gracilis* Donovan sp. nov., which is the oldest known member of this genus, previously limited to the Ludlow of Sweden, Estonia and the British Isles, and the Pridoli of Estonia.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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