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Late Devonian (Famennian) phacopid trilobites from western Mongolia

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This is a contribution to a special series on “*The Central Asian Orogenic Belt (CAOB) during Late Devonian: new insights from southern Mongolia*”.

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Palaeobiogeography, Biodiversity hotspot

Abstract. The early Famennian phacopid trilobites *Feistops mongoliensis* gen. nov. sp. nov., *Feistops khovdensis* gen. nov. sp. nov., ?*Feistops* sp. A and ?*Houseops olonbulagensis* sp. nov., are recorded and illustrated from the western Mongolia Hushoot Shiveetiin gol section from the Baruunhuurai Terrane of the Central Asian Orogenic Belt (CAOB). In this section, exposing large parts of cyclic Famennian shallow-water siliciclastic shelf deposits, *Feistops mongoliensis* gen. nov. sp. nov., *Feistops khovdensis* gen. nov. sp. nov., ?*Feistops* sp. A and ?*Houseops olonbulagensis* sp. nov. are the first known and described **representatives** of trilobites from Late Devonian deposits of western Mongolia. Their affinities with **known other sighted species of the same age** are discussed.

1. Introduction

A major goal in macroevolution is to understand patterns of diversity fluctuations in organisms. Among organisms, according to their **taxonomic**, **morphological** and **behavioral** diversity, trilobites constitute a model to study such diversity evolution (Crônier 2010). Trilobites were relatively abundant and diverse in marine habitats in the mid-Paleozoic, a time of dynamic long-term climate change (Algeo and Scheckler 1998; Stein et al. 2007; Becker et al. 2016) triggering significant biodiversity changes and major biotic crisis (Sepkoski 1996; Racki 2005; Bond and Graspy 2017). In particular, the Late Devonian period is important for the development of the phacopid trilobites because the main groups of reduced-eyed or blind phacopids arose at that time, especially in deeper offshore cephalopod limestones, after a severe diversity restriction triggering one of the highest extinction rates in the Late Palaeozoic (Lerosey-Aubril and Feist 2012; Crônier et al. 2013; Crônier and François 2014). The **trilobite record** remains scarce in shallow near-shore environments due to relatively few studies dealing with shallow-water sections. Recently, Feist (2019) made a challenge to update and

revise both known and new post-event early Famennian phacopids, with respect to their systematic definition and their biostratigraphical assignment within the conodont zonation. He recognized a rather important post-event recovery and diversification of phacopids during the early Famennian (Early *triangularis* through Early *marginifera* conodont **biozones**) with 11 genera and 38 species *versus* only 6 genera and 12 species during the Frasnian.

In shallow near-shore environments, if previous works on organisms that expand from shallow-water habitats such as echinoderms, bryozoans, and ostracods (Waters et al. 2003; Waters and Webster 2009; Ernst 2013; Waters et al. this issue; Nazik et al. this issue) point out that the central Asian Orogenic Belt and neighboring areas acted as a diversity hotspot during the Famennian, nothing has been identified for trilobites. Such **a** diversity hotspot may be related to specific palaeoenvironmental settings (Waters et al. 2003; **Waters and Webster 2009**; Ernst 2013; Waters et al. this issue; Nazik et al. this issue). Moreover, Ariunchimeg et al. (2014) through their marine macrofossil overview from the Baruunhuurai Terrane documented a high diversity and abundant organisms throughout the Frasnian/Famennian interval, and **illustrated** some phacopid trilobite remains.

To evaluate the hypotheses that specific palaeoenvironmental settings or areas could be validated as refugia or radiation centers for trilobite faunas, both during and in the aftermath of global Late Devonian extinction events, a systematic trilobite study has been performed from a shallow-water section. In particular, a focus was on an under-explored area in western Mongolia in order to better expand our knowledge regarding the Devonian trilobite biodiversity and its related events.

Hitherto, only the northern Canning Basin in Western Australia **on the southeastern margin of Gondwana** offered a diverse fauna of early Famennian oculated phacopids from reef-slope environments (Feist et al. 2009). This fauna expanding from shallow-water habitats support the idea of this specific palaeoenvironmental setting as refugia and the origin of post-event

phacopids from shallow water environments is demonstrated for the first time (Feist et al. 2009).

The present paper contributes to the systematic study of the Upper Devonian phacopids. The discovery of new occurrences assigned to *Feistops mongoliensis* gen. nov. sp. nov., *Feistops khovdensis* gen. nov. sp. nov., ?*Feistops* sp. A and ?*Houseops olonbulagensis* sp. nov. from western Mongolia provides the opportunity to get a better understanding of these forms and their palaeoenvironmental setting. These phacopines lend a particular dimension to the Upper Devonian trilobite fauna; they are among the youngest representatives of phacopines, and those with the high number of ocular lenses (Crônier et al. 2011). No members of other trilobite families have been found associated with the studied phacopids at this stage of the investigations.

2. Geological setting and material

The Central Asian Orogenic Belt (CAOB) associated with the closure of a part of the Palaeo-Asian Ocean prior to the end of the Carboniferous, covers a huge area that extends between the Siberian platform and the Cathaysian terranes (Fig. 1A). CAOB includes a complex amalgamation of intra-oceanic island arcs and continental margin arc terranes including Palaeozoic deposits of western Mongolia as part of this complex tectonic framework (Xiao et al. 2010; Xiao and Santosh 2014; Li et al. 2017; Yang et al. 2019).

Figure 1

The mid-Palaeozoic deposits well developed in the Baruunhurai Terrane are located in the southwestern part of Mongolia; the Baruunhurai Terrane being subdivided in three or four subterrane (Badarch et al. 1998; Dergunov 2001; Safonova et al. 2017; Ariunchimeg et al. 2014). The Devonian material originates from a section located in the Olonbulag Subterrane (Fig. 1B) and belonging to the Samnuuruul Formation. The Hushoot Shiveetiin gol section

has a total thickness of approximately 150 m and is divided in an eastern and in a western section (Ariuntogos et al. this issue). The section (Fig. 2) is characterized by shallow-shelf mixed siliciclastic/carbonate facies with distinct fossiliferous horizons and frequently intercalated volcanoclastic rocks (Bolshakova et al. 2003; Kido et al. 2013; Ariunchimeg et al. 2014; Suttner et al. 2019; Ariuntogos et al. this issue). Sedimentary analysis indicates variable facies settings ranging from shallow-intertidal to open marine (for detailed facies analysis we refer to Ariuntogos et al. this issue). The section is of Famennian to Early Mississippian age and ranges from the *Palmatolepis minuta minuta* conodont Biozone to at least the *Palmatolepis rugosa trachytera* conodont Biozone (zonation follows Hartenfels 2011 and Spalletta et al. 2017).

Figure 2

The collected trilobite material assigned to the Phacopidae family is the result of a field campaign in 2018. Phacopids include disarticulated molting remains as well as partially enrolled specimens. Phacopid remains are more or less well-preserved with some distortion due to some abrasion features as a result of sediment transport. The trilobite content with their geographic and stratigraphic locations is listed in Figure 3. The material described and figured herein is stored at the Mongolian University of Sciences and Technology, Ulaanbaatar, Mongolia under repository numbers MUST-RCSR-TRI.-0001 to 0016.

Figure 3

3. Systematic palaeontology (by C. Crônier)

The illustrated specimens were coated with ammonium chloride before photographed using a digital camera Nikon. The morphological terminology follows Chlupáč (1977) and Crônier et al. (2011).

Order Phacopida Salter, 1864

Superfamily Phacopoidea Hawle and Corda, 1847

Family Phacopidae Hawle and Corda, 1847

Subfamily Phacopinae Hawle and Corda, 1847

Genus *Feistops* gen. nov.

Type species. *Feistops mongoliensis* gen. nov. sp. nov.

Species included. Type species: Famennian (*Palmatolepis crepida* to *Palmatolepis glabra pectinata* conodont biozones), western Mongolia; *Feistops khovdensis* gen. nov. sp. nov.: Famennian (*Palmatolepis rhomboidea* conodont Biozone), western Mongolia.

Species tentatively assigned. ?*Feistops* sp. A: Famennian (*Palmatolepis rhomboidea* conodont Biozone), western Mongolia.

Etymology. For Raimund Feist (Montpellier, France), in honor of all his work on Late Devonian trilobites.

Diagnosis. Glabella lowered with a narrow base, subangular anterolateral angles and deep axial furrows; S2 and S3 absent; wide and inflated median portion of L1 relative to its total width; wide L0 with no defined lateral lobes; reniform visual complex with 15-16 vertical lens files and maximum five or six lenses per file; postocular genal field length equals length of posterior border; subocular librigenal field narrow at the front of the eye, becoming larger and concave backwards; no marginulation. Pygidium rather wide with a narrow pygidial axis,

composed of six-seven clear rings plus terminal piece; pygidial pleural field with five-six well-defined ribs; deep pleural furrows; indistinct interpleural furrow. Tubercles on cephalon.

Stratigraphical range.. Early Famennian.

Occurrence.. Western Mongolia.

Remarks.. The configuration of cephalic and pygidial features assign the new taxon to the Phacopidae. However, the following set of features combined observed in the type species, i.e., the lowered glabella with anterior cephalic border forwardly extending beyond anterior outline of glabella, the reniform visual complex close to the posterior border, and the configuration of the curved cephalic doublure long (sag.) and rather deep, not seen in any other early Famennian phacopids, justify its assignment to the new genus. Only the large-eyed phacopine *Magreanops monachus* van Viersen and Vanherle, 2018 from the middle Frasnian of Belgium that shows a number of similar dorsal cephalic traits differs in having a longer (sag.) eye (see next 'comparison' section).

Feistops mongoliensis gen. nov. sp. nov.

Fig. 4.1-13

Etymology.. After the area of western Mongolia.

Holotype.. Cephalon, MUST-RCSR-TRI.-0001 (Fig. 4.1-5).

Paratype.. Pygidium, MUST-RCSR-TRI.-0002 (Fig. 4.6).

Type locality.. Hushoot Shiveetiin gol section, the Baruunhuurai Terrane, Olonbulag **Subterrane**, western Mongolia.

Type stratum.. Samnuuruul Formation, Famennian (**thin-bedded marly limestone**), *Palmatolepis glabra pectinata* conodont Biozone, Late Devonian.

Material.. Holotype, one small fragmented cephalon, and one fragmented and mostly exfoliated pygidium from HS-C-5 (4d); one fragmented cephalon and one fragmented pygidium from HS-F10 (*Palmatolepis glabra pectinata* conodont **Biozone**). Possibly one poorly preserved thorax from HS-C-13 and one pygidium from HS-F15 (*Palmatolepis crepida* conodont **Biozone**).

Diagnosis.. Cephalon narrow; glabella bounded by moderately divergent axial furrows; L1 with few tubercles; reniform visual complex with 15 vertical lens files and maximum five lenses per file; inter-lensar sclera thickened dorsally and more lightly ventrally; inflated palpebral lobe; palpebral furrow distinct and convex (abax.). Pygidium rather wide with a narrow pygidial axis, composed of six-seven clear rings plus terminal piece; pygidial pleural field with five-six well-defined ribs; deep pleural furrows; indistinct interpleural furrow. Medium-sized to fine tubercles distinct and moderately dense on cephalon.

Description.. *Cephalon*: Narrow, length/width ratio about 0.66. *Dorsal view*: Glabellar ratio of width at L1/maximum width of frontal lobe about 0.46, narrow at base. Glabella lowered bounded by relatively deep axial furrows that are moderately divergent (66°). Frontal outline parabolic anteriorly. Frontal lobe hardly overhanging a deep preglabellar furrow. S2 and S3

indistinct. S1 continuous and hardly curved in its middle part, subparallel to S0, and becoming deeper in its distal portions. L1 shorter (sag.) than L0 (more than half length of L0) and with a wide (tr.) median portion relative to its total width. Median portion of L1 inflated, with tubercles. L1 with subcircular/subquadrate lateral lobes separated from its median part by a weak exsagittal furrow. S0 distinct and almost transverse/ hardly curved in its middle portion. L0 wide (tr.) with lateral lobes not defined. Reniform visual surface with 15 dorso-ventral files of lenses (only 12 for the small cephalon) and a maximum of 5 lenses per file, with smaller lenses in the anterior part. Inter-lensar sclera thickened dorsally and more lightly ventrally. Palpebral furrow distinct and strongly convex (abax.). Exsagittal length of the postocular genal field equal length (exsag.) of the posterior border. *Lateral view*: Glabella sloping obliquely and then dorsoventrally in its anterior part. Outline of L1 curved. L0 as high as glabella at its maximum convexity. Anterior border relatively short, forming a border projected forward and sloping posteroventrally. Marginulation no visible. Posterior border furrow deep and narrow. Lateral border furrow moderately narrow and shallow at the front of the eye, becoming shallower towards back. Subocular librigenal field very narrow at the front of the eye, becoming larger and concave backwards with no subocular pad. Posterolateral border furrow shallow (continuous on the internal mold) and posterolateral border widening at the genal angle. *Frontal view*: Glabellar outline semicircular becoming oblique laterally (divergence of 57°). Palpebral area inflated and as high as the inflated palpebral lobe. *Ventral view*: Vincular furrow relatively deep and wide (sag.), broadly and evenly curved. Posterior band of the cephalic doublure long (sag.), with a hypostomal suture slightly convex backward medially. *Pygidium*: mostly exfoliated. Rather wide with a length/width ratio about 47% (excluding the half ring), and its maximum width (tr.) in front of its midlength (sag.) in dorsal view. Posterior outline roughly broadly rounded. Pygidial axis very long (sag.) and rather narrow (tr.), weakly tapered, with rather incomplete terminal closure. Seven distinct rings in

the pygidial axis. Pygidial pleural field with five-six distinct ribs delimited by deep pleural furrows. Interpleural furrows indistinct. Pseudo-articulating half rings very weakly suggested by expanded inter-rings furrows. *Sculpture*: Cephalon covered with medium-sized to fine tubercles of rather heterogeneous size, moderately dense on entire composite lobe. Few small pits added to tubercles on the palpebral lobe. Posterior band of the cephalic doublure and pygidium showing no evidence of sculpture.

Comparison.. The holotype is relatively well-preserved and almost complete. There is a slight collapse of the left anterior part of the glabella, but the glabella remains lowered. The left lateral border is damaged, which induced visually an asymmetry. However, the characters observed and discussed in the description seem to be present. The small associated cephalon is unfortunately poorly preserved and prevent us to complete the description. Nevertheless, *Feistops* gen. nov. differs from all other known sighted genera of the same age worldwide.

Feistops mongoliensis gen. nov. sp. nov. differs from *Nephranops* Richter and Richter, 1926 from the middle *triangularis* to early *crepida*, i.e., *Palmatolepis crepida* conodont Biozone according to Spalletta et al. 2017, that is characterized by a low kidney-shaped palpebral lobes with a visual surface generally without lenses or only with residual lenses. *Feistops mongoliensis* shares with *Nephranops* a pygidium with a narrow and long axis composed of 7–9 rings, not reaching the posterior margin.

Feistops mongoliensis differs from *Pulvinocephalus* Feist, 2019 from early *triangularis* to early *marginifera*, i.e., *Palmatolepis marginifera marginifera* conodont Biozone according to Spalletta et al. 2017, that is characterized by a reduced-eyed visual surface or blind and with an anterior cephalic border forwardly extending beyond the anterior outline of glabella.

Feistops mongoliensis differs from *Cryphops* Richter and Richter, 1926 from middle to late *crepida*, i.e., *Palmatolepis glabra prima* conodont Biozone according to Spalletta et al.

2017, that is characterized by an elliptical visual surface with 7-11 lenses, a very broad (sag.) and slightly vaulted pre-vincular doublure inclined posteroventrally, a deep and long (sag.) vincular furrow bordered by sharp edges and without post-vincular doublure.

Feistops mongoliensis differs from *Babinops* Feist and Becker, 1997 from late *crepida* to *rhomboidea* that is characterized by genal spine or reducing to pointed genal angle, and a cephalic doublure without vincular furrow. This obsolescence of the vincular furrow is also observed in the contemporaneous phacopidelline taxa *Ductina* Richter and Richter, 1931 and *Dienstina* Richter and Richter, 1931. However, *Feistops mongoliensis* shares with *Babinops minor* Feist et al., 2009 a low convex glabella not overhanging anterior border, a short postocular distance, kidney-shaped palpebral lobes and a similar visual surface in size: 16 dorsoventral lens files in *Babinops minor* against 15 in *Feistops mongoliensis*, a maximum of five lenses in each file in both taxa, and maximum total number of lenses 61 in *Babinops minor* against 50 in *Feistops mongoliensis*.

Feistops mongoliensis shares with *Houseops* Feist et al., 2009 from late *triangularis* to late *crepida*, i.e., *Palmatolepis glabra prima* conodont Biozone according to Spalletta et al. 2017, a relatively subdued transverse cephalic profile, not impressed S2 and S3 glabellar furrows, and a relatively flat glabella. *Feistops mongoliensis* differs from *Houseops* that is characterized by smaller eyes distant from the posterior margin, weak palpebral furrows, flat palpebral lobes, a flat and short post-vincular area, and an ornamentation consisting of thin and sparse tubercles.

?*Houseops nalivkini* (Maksimova, 1955) from the early Famennian (possibly *triangularis* to *marginifera*) of the Southern Urals has been tentatively assigned to *Houseops* by Feist et al., 2009 mainly on account of the retracted anterior outline of its low glabella and the narrow and posteriorly pointed pygidial axis. Because of these characters, *Feistops mongoliensis* resembles ?*H. nalivkini*. However *Feistops mongoliensis* differs from ?*H. nalivkini* by its not

inflated abaxially postocular area, a narrower (tr.) cephalon, its more recurved anterolateral corners of the glabella, and its coarser tuberculation.

The new species shows some morphological features of *?Houseops tamtertensis* described by Crônier, 2013 in Crônier et al., 2013 from the Famennian (*rhomboidea*) of Algeria such as a narrow cephalon with coarse conical tubercles, similar anterolateral corners of the glabella. However *?Houseops tamtertensis* differs from *Feistops mongoliensis* by its lowered glabella with a wide base and a frontal outline slightly tapered, a visual complex with only 13 dorso-ventral lens files and maximum 3 lenses per file, and a palpebral furrow almost transverse.

The new species resembles *Phacops granulatus* (Münster, 1840) from the Famennian of Europe (Germany, Silesia, Poland, Moravia, Austria, England, Spain, Portugal) and North Africa (Algeria, Morocco), but also encountered in Urals, Kazakhstan, China, and Iran on account of its narrow cephalon, a visual surface with 15 vertical files and both palpebral area and palpebral lobe about same level in height. However, *Phacops granulatus* differs in having a broader (tr.) and inflated glabella pointed anteriorly, a palpebral furrow less convex (abax.), a longer exsagittal length of the postocular genal field and dense homogeneous tubercles on glabella.

The new species shares a glabella and cheeks little inflated, a lack of ornamentation on the cephalic doublure with *Phacops tafilaltensis* Crônier and Clarkson, 2001. However, *Phacops tafilaltensis* differs in having a broader (tr.) cephalon, and a visual surface much longer (18 vertical files, 4–5 lenses per file).

The new species also resembles *Rabienops wedekindi* (Richter and Richter, 1926) from the late Famennian because of its narrow cephalon and fine homogeneous tubercles on glabella. However, *Rabienops wedekindi* differs in having a broader (tr.) glabella and a shorter visual surface with only 13 vertical lens files with four maximum lenses per file.

By comparison with trilobite faunas from closely areas such as the Xinjiang, Northwest China where the genus *Omegops* [Struve, 1976](#) has been encountered in the late Famennian ([Xiang 1981](#); [Yuan and Xiang 1998](#)), *Feistops mongoliensis* differs from *Omegops mobilis* ([Xiang, 1981](#)) or *O. ?cornelius* ([Richter and Richter, 1933](#)) that are characterized by a reduced intercalating ring as a narrow flat band, a distinct postocular pad, a marginulate lateral border, and coarse tubercles on glabella. *Feistops mongoliensis* shares with *Omegops* a visual surface with 15-16 dorso-ventral files.

The new species resembles *Magreanops monachus* [van Viersen and Vanherle, 2018](#) from the Frasnian of Belgium because of its lowered glabella with a narrow base, its lack of S2 and S3, its wide L0 and its shape and distribution of glabellar tubercles. Nevertheless, *Magreanops monachus* differs in having a longer (sag.) eye (18 dorso-ventral files with a maximum of 8-9 lenses per file in *M. monachus* versus 15 dorso-ventral files with a maximum of 5 lenses per file in *Feistops mongoliensis*), no subocular area, and a glabellar outline semicircular becoming oblique laterally with a divergence of 27° in frontal view (57° in *Feistops mongoliensis*). Due to the similar dorsal cephalic features, *Feistops* could be a potential descendant of *Magreanops*.

Feistops khovdensis gen. nov. sp. nov.

Fig. 5.1-3, 10-11

Holotype. Cephalon, MUST-RCSR-TRI.-0006 (Fig. 5.1-3).

Paratype. Cephalothorax, MUST-RCSR-TRI.-0007 (Fig. 5.10-11).

Type locality.. Hushoot Shiveetiin gol section, the Baruunhuurai Terrane, Olonbulag **Subterrane**, western Mongolia.

Type stratum.. Samnuuruul Formation, Famennian (**thin-bedded limestone**), *Palmatolepis rhomboidea* conodont Biozone, Late Devonian.

Material.. One cephalon **MUST-RCSR-TRI.-0006** and a fragmented cephalothorax **MUST-RCSR-TRI.-0007** (Fig. 5.1-3, 10-11).

Diagnosis.. Cephalon very wide; glabella bounded by high divergent axial furrows; slightly inflated median portion of L1 with few subdued tubercles; reniform visual complex with 15-16 vertical lens files and maximum six lenses per file; thin inter-lensar sclera; subdued palpebral lobe; palpebral furrow weak and convex (abax.). Subdued and dense fine-sized tubercles on cephalon.

Description.. *Cephalon*: Wide, length/width ratio about 0.50. *Dorsal view*: Glabellar ratio of width at L1/maximum width of frontal lobe about 0.44, narrow at base. Glabella lowered bounded by relatively deep axial furrows that are highly divergent (73°). Frontal outline broadly parabolic anteriorly. Frontal lobe hardly overhanging a distinct preglabellar furrow. S2 and S3 indistinct. S1 continuous and hardly curved in its middle part, subparallel to S0, and becoming deeper in its distal portions. L1 shorter (sag.) than L0 (half-length of L0) and with a wide (tr.) median portion relative to its total width. Median portion of L1 slightly inflated, with few tubercles. L1 with subcircular lateral lobes separated from its median part by a distinct exsagittal furrow. S0 distinct and almost transverse/ hardly curved in its middle portion. L0 relatively wide (tr.) with lateral lobes not defined. Reniform visual surface with

15-16 dorso-ventral files of lenses and a maximum of 6 lenses per file. Inter-lensar sclera thin. Palpebral furrow weak and convex (abax.). Exsagittal length of the postocular genal field equal length (exsag.) of the posterior border. *Lateral view*: Glabella sloping dorsoventrally in its anterior part. Outline of L1 curved. L0 as high as glabella at its maximum convexity. Anterior border relatively short, forming a border projected forward and sloping posteroventrally. Marginulation no visible. Posterior border furrow deep and narrow. Lateral border furrow wide and shallow backwards. Subocular librigenal field narrow at the front of the eye, becoming larger and concave backwards with no subocular pad. Posterolateral border furrow almost effaced and posterolateral border widening at the genal angle. *Frontal view*: Glabellar outline semicircular becoming oblique laterally (divergence of 80°). Palpebral area inflated and higher than the subdued palpebral lobe. *Ventral view*: not available. *Thorax*: Axial rings convex without defined lateral lobes. Axial furrows distinct. Anterior pleural band narrower (exsag.) than the posterior pleural band. Pleural furrows narrow and deep. *Sculpture*: Cephalon covered with fine subdued tubercles of rather homogeneous size, dense on entire composite lobe. Thoracic rings showing similar sculpture. There is no evidence of sculpture on the lateral border (mostly eroded or damaged).

Comparison.. The new species is represented by a complete and relatively well-preserved cephalon but probably exposed to a dorso-ventral distortion (inducing an elevation of lateral border and leading to a wider cephalon than reality) and a fragmented cephalothorax providing us an almost complete description, except for pygidium. *Feistops khovdensis* gen. nov. sp. nov. shares with *Feistops mongoliensis* gen. nov. sp. nov.: a subdued glabella with a narrow base and subangular anterolateral angles, similar axial furrows in shape (i.e., slightly sigmoidal) and depth (deep between S1 and front of palpebral furrow), a wide and inflated median portion (tr.) of L1 relative to its total width (tr.), no S2 and S3, no marginulation, an

almost effaced lateral border furrow, and a postocular genal field length equal length of its posterior border. *Feistops khovdensis* differs from *Feistops mongoliensis* by its wider cephalon, subdued tubercles on composite lobe, higher divergent axial furrows, a shorter (tr.) occipital ring relative to its total cephalic width (tr.), weaker palpebral furrows, and a subdued palpebral lobe more reniform in dorsal view. The ventral view not accessible prevent us to describe and to compare the anterior cephalic border and the cephalic doublure.

Feistops khovdensis shares with *Houseops* a relatively subdued transverse cephalic profile, not impressed S2 and S3 glabellar furrows, a relatively flat glabella, weak palpebral furrows, flat palpebral lobes; and especially with *Houseops* sp. A an ornamentation with fine and dense tubercles on the composite lobe. However, *Feistops khovdensis* differs from *Houseops* especially by a genus diagnostic feature, i.e., smaller eyes distant from the posterior margin. Otherwise, *Feistops khovdensis* differs from ?*H. nalivekini* by its not inflated abaxially postocular area, a posterolateral border furrow almost effaced and its more recurved anterolateral corners of the glabella.

?*Feistops* sp. A

Fig. 5.15-16

Material.. One fragmented cephalon plus one left cheek, MUST-RCSR-TRI.-0008 (Fig. 5.15-16) from Hushoot Shiveetiin gol section, the Baruunhuurai Terrane, Olonbulag Subterrane, western Mongolia; Samnuuruul Formation, Famennian, *Palmatolepis rhomboidea* conodont Biozone, Late Devonian.

Description.. *Cephalon*: wide, length/width ratio about 0.58. *Dorsal view*: Glabellar ratio of width at L1/maximum width of frontal lobe about 0.44, narrow at base. Glabella lowered

bounded by relatively deep axial furrows that are moderately divergent (65°). Frontal outline pointed anteriorly. Frontal lobe hardly overhanging the preglabellar furrow with angular anterolateral corners. S2 and S3 indistinct, maybe indicated by a break in the sculpture. S1 continuous and hardly curved in its middle part, subparallel to S0, and becoming deeper in its distal portions. L1 shorter (sag.) than L0 (more than half length of L0) and with a wide (tr.) median portion relative to its total width. Median portion of L1 inflated, with tubercles. L1 with subcircular, lightly inflated lateral lobes separated from its median part by a distinct exsagittal furrow. S0 distinct and almost transverse/ hardly curved in its middle portion. L0 wide (tr.) with lateral lobes not defined. Reniform visual surface (damaged) apparently lowered, with a maximum of 5 lenses per file. Inter-lensar sclera slightly thickened only dorsally. Palpebral furrow deep and convex (abax.). No subocular pad but a depressed subocular area. Exsagittal length of the postocular genal field almost equal the length (exsag.) of the posterior border. Postocular area strongly inflated even distally with granulation. Cheek swollen. *Lateral view*: Glabella lowered sloping obliquely in its anterior part. Outline of L1 curved. L0 as high as glabella at its maximum convexity. Marginulation no visible. Posterior border furrow very deep and narrow. Lateral border furrow wide and shallow. Posterolateral border furrow shallow and posterolateral border widening at the genal angle. *Frontal view*: not available. *Sculpture*: Cephalon covered with medium-sized to fine conical tubercles of rather homogeneous size, dense on entire composite lobe.

Comparison.. ?*Feistops* sp. A shares with *Feistops mongoliensis*: a subdued glabella with a narrow base, axial furrows moderately divergent and similar in depth (deep between S1 and front of palpebral furrow), a wide and inflated median portion (tr.) with tubercles of L1 relative to its total width (tr.), a wide (tr.) of L0 relative to its total width, no S2 and S3, no marginulation, a postero-lateral border furrow distinct and continuous, an almost effaced

lateral border furrow, and a postocular genal field length equal length of its posterior border.

?*Feistops* sp. A differs from *Feistops mongoliensis* by its wider cephalon, its frontal outline pointed anteriorly, denser tubercles rather homogeneous in size on composite lobe, and a postocular genal field strongly swollen. The ventral view not accessible prevent us to describe and to compare the anterior cephalic border and the cephalic doublure.

These specimens show some morphological features of ?*Houseops tamtertensis* such as a cephalon with coarse and dense conical tubercles, a lowered glabella pointed anteriorly. However ?*Houseops tamtertensis* differs from ?*Feistops* sp. A by its lowered glabella with a wide base, a visual complex with only 13 dorso-ventral lens files and maximum 3 lenses per file, and a palpebral furrow almost transverse.

?*Feistops* sp. A resembles ?*H. nalivekini* on account of the retracted anterior outline of its lowered glabella with subangular anterolateral corners, the inflated abaxially postocular area. However ?*Feistops* sp. A differs from ?*H. nalivekini* by a narrower (tr.) cephalon and its coarser tuberculation.

Genus *Houseops* Feist et al., 2009

Type species. *Houseops canningensis* Feist et al., 2009: Upper Devonian, Canning Basin, Australia.

Species assigned. *Houseops canningensis* Feist, 2009 in Feist et al., 2009: Famennian (late *crepida*, i.e., *Palmatolepis glabra prima* conodont **Biozone** according to Spalletta et al. 2017), Western Australia; *H. beckeri* Feist, 2009 in Feist et al., 2009: Famennian (late *triangularis*, i.e., *Palmatolepis minuta minuta* conodont **Biozone** according to Spalletta et al. 2017), Western Australia; *H. sp. A* Feist, 2009 in Feist et al., 2009: Famennian (late *triangularis*, i.e.,

Palmatolepis minuta minuta conodont **Biozone** according to [Spalletta et al. 2017](#)), Western Australia; *H. miserrimus miserrimus* ([Drevermann, 1901](#)): Famennian (? late *crepida*, i.e., *Palmatolepis glabra prima* conodont **Biozone** according to [Spalletta et al. 2017](#)), Germany; *H. miserrimus wiedensis* ([Lütke, 1968](#)): Famennian (late *crepida*, i.e., *Palmatolepis glabra prima* conodont **Biozone** according to [Spalletta et al. 2017](#)), Germany.

Species tentatively assigned.. ?*H. pronini* [Maksimova, 1955](#): Frasnian or **basal** Famennian?, Urals; ?*H. nalivkini* ([Maksimova, 1955](#)): Famennian (possibly *triangularis* to *marginifera*), Urals; ?*H. ocellatus* ([Perna, 1915](#)), Famennian (possibly *triangularis* to *marginifera*), Urals; ?*H. tamtertensis* ([Crônier, 2013 in Crônier et al., 2013](#)), Famennian (possibly *triangularis* to *marginifera*), Algeria; ?*H. olonbulagensis* sp. nov.: Famennian, western Mongolia.

?Houseops olonbulagensis sp. nov.

Fig. 6.1-9

Etymology.. After the Olonbulag Subterrane of western Mongolia.

Holotype.. Cephalothorax **MUST-RCSR-TRI.-0009** (Fig. 6.7-8).

Paratypes.. Two fragmented exoskeletons **MUST-RCSR-TRI.-00010-11**(Fig. 6.1-6).

Type locality.. Hushoot Shiveetiin gol section, the Baruunhuurai Terrane, Olonbulag **Subterrane**, western Mongolia.

Type stratum.. Samnuuruul Formation, Famennian (greenish shale), *Palmatolepis glabra pectinata* conodont Biozone, Late Devonian.

Material.. Holotype MUST-RCSR-TRI.-0009, one fragmented enrolled exoskeleton MUST-RCSR-TRI.-0010 and one fragmented unrolled exoskeleton MUST-RCSR-TRI.-0011 from HS-F10 (*Palmatolepis glabra pectinata* conodont Biozone); one thoracopygon associated to one pygidium MUST-RCSR-TRI.-0012 from HS-C-5 (*Palmatolepis glabra pectinata* conodont Biozone).

Diagnosis.. Cephalon wide; glabella bounded by low divergent axial furrows; L1 with subquadrate lateral lobes, not strongly inflated; visual complex with at least 13 dorso-ventral files of lenses and a maximum of 5 lenses per file; thin inter-lensar sclera; palpebral furrow weak and convex (abax.); exsagittal length of the postocular genal field almost equal length (exsag.) of the posterior border. Moderately dense medium-sized tubercles on glabella.

Description.. *Cephalon*: Wide, length/width ratio about 0.57. *Dorsal view*: Glabellar ratio of width at L1/maximum width of frontal lobe about 0.49, narrow at base. Glabella lowered bounded by relatively deep axial furrows that are low divergent (55°). Frontal outline parabolic anteriorly. Frontal lobe hardly overhanging a deep preglabellar furrow. S2 and S3 indistinct on the internal mold. S1 damaged in its middle part, deep in its distal portions. L1 shorter (sag.) than L0 (more than half length of L0) and with a wide (tr.) median portion relative to its total width. Median portion of L1 inflated, without tubercles presumably. L1 with subquadrate lateral lobes, not strongly inflated, separated from its median part by a weak exsagittal furrow. S0 distinct and almost transverse/ hardly curved in its middle portion. L0 rather wide (tr.) with lateral lobes not defined. Reniform visual surface with at least 13 dorso-

ventral files of lenses and a maximum of 5 lenses per file. Inter-lensar sclera thin presumably. Palpebral furrow weak and convex (abax.). Exsagittal length of the postocular genal field almost equal length (exsag.) of the posterior border. *Lateral view*: Glabella sloping obliquely dorsoventrally in its anterior part. Outline of L1 rather strongly curved. L0 as high as glabella at its maximum convexity. Anterior border relatively short, forming a border projected forward and sloping posteroventrally. Marginulation apparently present on the posterolateral border. Posterior border furrow deep and narrow. Lateral border furrow no visible (damaged) at the front of the eye, shallow backwards. Subocular librigenal field no visible (damaged) at the front of the eye, becoming larger and concave backwards with no subocular pad. Posterolateral border furrow shallow and continuous and posterolateral border widening at the genal angle. *Frontal view*: Glabellar outline semicircular becoming oblique laterally (divergence of 50°). Palpebral area inflated and as high as palpebral lobe. *Ventral view*: Vincular furrow relatively deep and wide (sag.), broadly and evenly curved. Posterior band of the cephalic doublure long (sag.), with a hypostomal suture apparently transverse medially. *Thorax*: Slightly tapered with **apparently** 10 thoracic axial rings (untypically). Maximum axial width (tr.) ratio of the last ring / first ring about 86%. Axial rings convex without defined lateral lobes. Axial furrows distinct. Anterior pleural band narrower (exsag.) than the posterior pleural band. Pleural furrows narrow and distinct. *Pygidium*: mostly exfoliated. Wide with a length/width ratio about 38% (excluding the half ring), and its maximum width (tr.) in front of its midlength (sag.) in dorsal view. Posterior outline roughly broadly rounded. Pygidial axis long (sag.) and rather narrow (tr.), tapered, with rather complete terminal closure. Pygidial axis showing a slight constriction from the fourth axial ring. Seven distinct rings in the pygidial axis. Pygidial pleural field with five distinct ribs delimited by deep pleural furrows. Interpleural furrows indistinct. Pseudo-articulating half rings very weakly suggested by expanded inter-rings furrows. *Sculpture*: Internal mold of glabella covered with medium-sized

tubercles of rather homogeneous size, moderately dense on entire composite lobe, and pits. Posterolateral border with pits. Cheek, postocular area, posterior border, lateral preoccipital lobe, posterior band of the cephalic doublure, thorax and pygidium showing no evidence of sculpture.

Comparison.. The holotype is partially exfoliated and fragmented that prevent us to get a complete description. We are not confident with this assignation but *?Houseops olonbulagensis* and *Houseops* (Fig. 6b) seem to share similar sagittal sections. However, it is not impossible with more material that the few studied specimens may belong to a new genus. Nevertheless, the two associated fragmented exoskeletons allow to approach an almost complete description. *?Houseops olonbulagensis* sp. nov. differs from *Feistops mongoliensis* gen. nov. sp. nov. in having a wide cephalic outline, coarser pustular and dense tubercles only on the composite lobe, and a pygidial axis less long and more tapered.

?Houseops olonbulagensis sp. nov. shares with from *?Houseops nalivkini* (Maksimova, 1955) from the early Famennian of the Southern Urals a wide cephalon and apparently an inflated genal field but differs by its shallow posterolateral border furrow, its less swollen postero-lateral border, and its coarser tuberculation.

?Houseops olonbulagensis sp. nov. shares with *Omegops mobilis* (Xiang, 1981) or *O. ?cornelius* (Richter and Richter, 1933) from the late Famennian of the Northwest China coarse tubercles on glabella and a marginulate lateral border. However, *Omegops mobilis* or *O. ?cornelius* differ from *?Houseops olonbulagensis* sp. nov. by their reduced intercalating ring as a narrow flat band and their distinct postocular pad.

Undetermined phacopids

Fig. 5.4-6, 7-9, 12-13, 14

Material.. Two isolated pygidia **MUST-RCSR-TRI.-0013-14** from HS-C-1 (Fig. **5.4-6**, 14) and one mostly exfoliated pygidium **MUST-RCSR-TRI.-0015** from HS-C-1_crino layer (Fig. **5.12-13**): **Hushoot Shiveetiin gol section, the Baruunhuurai Terrane, Olonbulag Subterrane, western Mongolia; Samnuuruul Formation, Famennian, *Palmatolepis rhomboidea* conodont Biozone, Late Devonian**. These pygidia can be assigned to *Feistops khovdensis* gen. nov. sp. nov. or *?Feistops* sp. A but no complete exoskeleton prevents a specific assignation. An additional exfoliated pygidium **MUST-RCSR-TRI.-0016** from HS-C-3 (Fig. **5.7-9**) and a pygidium counterpart from HS-F7 can be assigned to these taxa.

Description.. *Pygidium*: Rather wide with a length/width ratio about 49% (excluding the half ring), and its maximum width (tr.) at about its midlength (sag.) in dorsal view. Posterior outline roughly broadly rounded to roughly transverse medially. Pygidial axis long (sag.) and rather narrow (tr.), tapered, with rather incomplete terminal closure. Pygidial axis showing a slight constriction from the fourth axial ring (Fig. 4.5). At least seven distinct rings in the pygidial axis. Pygidial pleural field with five-six distinct ribs delimited by deep pleural furrows. Interpleural furrows indistinct. Pseudo-articulating half rings very weakly suggested by expanded inter-rings furrows. *Sculpture*: Pygidium showing no evidence of sculpture.

4. Discussion and conclusions

The studied material comes from the eastern part of the Hushoot Shiveetiin gol section that ranges stratigraphically from the *Palmatolepis minuta minuta* conodont **Biozone** to at least the *Palmatolepis rugosa trachytera* conodont **Biozone** with hiatuses of several conodont **biozones** ([Ariuntogos et al. this volume](#)). Trilobites were sampled in six levels (levels HS-C1, C3/F7, C5, F10, C13 and F15) which also yielded other fauna such as diverse conodonts and

macrofossils including brachiopods, solitary rugose corals, branching tabulate corals (Suttner et al. 2019; Ariuntogos et al. this volume, Nazik et al. this volume, Waters et al. this volume).

The studied material is most often incomplete, difficult to prepare and often preserved as internal mold. Due to insufficient preservation of the cephala, additional material is required. However, the relatively well-preserved phacopid trilobites are assigned to *Feistops mongoliensis* gen. nov. sp. nov. and ?*Houseops olonbulagensis* sp. nov. from the *crepida* conodont **Biozone**, *Feistops khovdensis* gen. nov. sp. nov. and ?*Feistops* sp. A from the *Palmatolepis rhomboidea* conodont **Biozone**, thus becoming four endemic taxa from western Mongolia because of their cephalic shape and doublure when visible. Moreover, according to conodont biofacies and microfacies analyses (Suttner et al. 2019; Ariuntogos et al. this volume), a slight change in bathymetric conditions seems to occur from a slight shallowing during the late *Palmatolepis crepida* conodont **Biozone** followed by a deepening during the *Palmatolepis rhomboidea* conodont **Biozone** in the Hushoot Shiveetiin gol section.

Interestingly, in order to get a better understanding on the distribution of Late Devonian faunas at the interface of palaeogeography and palaeoecology, a comparison of our trilobite fauna with those from the western Junggar of Xinjiang, Northwest China, from the Hongguleleng Formation (stratotype) will be useful. This as a reference section in comparison to other sections in the CAOB including the studied western Mongolia Hushoot Shiveetiin gol section. Indeed, the Hongguleleng Formation is also Famennian in age, with evidence for the Frasnian/Famennian boundary near the base of the Stratotype section and the Hangenberg event near the top. This Formation is characterized by a very well preserved and diverse marine faunal assemblage with abundant brachiopods, numerous crinoids and blastoids, and phacopid trilobites (Waters et al. 2003; Suttner et al. 2014; Zong and Gong 2017). Phacopids occur from the late *rhomboidea* **Biozone**, i.e., the *Palmatolepis gracilis gracilis* **Biozone**

(Spalletta et al. 2017), to the D/C boundary, but they are most abundant in the late *rhomboidea* conodont **Biozone**, i.e., the *Palmatolepis gracilis gracilis* **Biozone** (Spalletta et al. 2017; Suttner et al. 2014). This interval consists of deeper water facies with maroon and green shales and radiolarian cherts. Unfortunately, no phacopid specimens have been illustrated or described. Moreover, some trilobites (not yet studied but with an equivalent age to the Mongolian phacopids) have been found with a mixed fauna of very small crinoids, brachiopods, corals and bryozoans in the lower part of the section from an interval of very thin-bedded limestone with shale and volcanoclastic rocks within the *crepida* **Biozone** (personal communication JW).

At a global scale, excluding the Americas, Famennian phacopids are characterized by a worldwide distribution (Chlupáč 1975; Crônier and François 2014). However, if the majority of genera is apparently limited to a single cratonic margin, the other few genera are cosmopolitan (Crônier and François 2014). New discoveries in unexploited areas such as the newly studied western Mongolia once again reveals the endemic nature of many genera.

In the early Famennian, the post-Kellwasser event recovery marked a new step especially for phacopid trilobites (Lerosey-Aubril and Feist 2012; Crônier et al. 2013). The evolutionary pattern in phacopids shows a major increase in the specific origination during the late early Famennian (Crônier et al. 2013). A first turnover occurred during the **lower** Famennian with few new genera reported, i.e., *Nephranops* Richter and Richter, 1926 in European deep offshore cephalopod environments and *Pulvinocephalus* Feist, 2019 from the *Palmatolepis triangularis* **Biozone**. Nevertheless, the significant post-Kellwasser recovery occurred during the late early Famennian leading to a second turnover with new blind phacopid genera from deep offshore habitats and eyed-phacopid genera from shallower habitats in the photic zone

(Crônier et al. 2013; Feist 2019). This study provides an update for species and subspecies currently known with regard to their age distribution according to conodont zonation.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Figure 1. **a:** Location of the Central Asian Orogenic Belt (CAOB) on a palinspastic map ([http:// www.palaeos.com](http://www.palaeos.com)) (modified from [Blakey et al. \(2016\)](#), with continent positions and shapes modified from the tectonic data of [Hara et al. \(2010\)](#), [Metcalf \(2011\)](#), and [Xiao et al. \(2010\)](#); trilobite assemblages modified from [Cronier and François \(2014\)](#)). **b:** Geographical location of the Khovd province, southwestern part of Mongolia and location of studied section in the Olonbulag **Subterrane** exhibiting mid-Paleozoic deposits of the Baruunhurai Terrane. Geological map of the investigated area: “a” eastern and “b” western Hushoot Shiveetiin gol section (from [Ariuntogos et al., this issue](#)).

Figure 2. Lithological log, stratigraphical range and trilobite levels of the Hushoot Shiveetiin gol section, western Mongolia. Figure is changed after [Ariuntogos et al., this issue](#).

Figure 3. Lithostratigraphic column of the ‘Samnuuruul’ Formation and stratigraphical location of studied phacopid trilobites from Hushoot Shiveetiin gol section.

Figure 4. Phacopid trilobites from the Baruunhurai Terrane, Olonbulag **Subterrane**, western Mongolia. (1-5) *Feistops mongoliensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-C-5, *Palmatolepis glabra pectinata* conodont **Biozone**), Holotype, **MUST-RCSR-TRI.-0001**, cephalon respectively in dorsal, frontal, ventral and lateral views, and detail of the left eye. (6) *Feistops mongoliensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-C-5, *Palmatolepis glabra pectinata* conodont **Biozone**), **MUST-RCSR-TRI.-0002**, fragmented pygidium in dorsal view. (7-8, 12) *Feistops mongoliensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-F10, *Palmatolepis glabra pectinata* conodont **Biozone**), **MUST-RCSR-TRI.-0003**, cephalon respectively in dorsal, lateral views, and detail of the right eye. (9-11) *Feistops mongoliensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-

F10, *Palmatolepis glabra pectinata* conodont **Biozone**), **MUST-RCSR-TRI.-0004**, pygidium respectively in frontal, dorsal and lateral views. (13) *Feistops mongoliensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-F15, *Palmatolepis crepida* conodont **Biozone**), **MUST-RCSR-TRI.-0005**, pygidium in dorsal view. Scale: 3 mm (except 5 and 12: 2 mm). Schematic representation of **a**: a visual surface in *Feistops mongoliensis* gen. nov. sp. nov., Holotype, **MUST-RCSR-TRI.-0001**; **b**: a visual surface in *Feistops mongoliensis* gen. nov. sp. nov., **MUST-RCSR-TRI.-0003**; **c**: a sagittal profile of anterior part of cephalon in *Feistops mongoliensis* gen. nov. sp. nov., Holotype, **MUST-RCSR-TRI.-0001**; **d**: a sagittal profile of anterior part of cephalon in *Houseops* illustrated in [Feist 2019](#). I-VII: horizontal rows; 1-15 (from the front): vertical files. Grey boxes indicate number of lens present.

Figure 5. Phacopid trilobites from the Baruunhuurai Terrane, Olonbulag **Subterrane**, western Mongolia. (1-3) *Feistops khovdensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-C-1, *Palmatolepis rhomboidea* conodont **Biozone**), Holotype, **MUST-RCSR-TRI.-0006**, cephalon respectively in frontal, dorsal, and lateral views. (4-6) Undetermined phacopids, Hushoot Shiveetiin gol section (bed HS-C-1, *Palmatolepis rhomboidea* conodont **Biozone**), **MUST-RCSR-TRI.-0013**, pygidium respectively in frontal, dorsal and lateral views. (7-9) Undetermined phacopids, Hushoot Shiveetiin gol section (bed HS-C-3, *Palmatolepis rhomboidea* conodont **Biozone**), **MUST-RCSR-TRI.-0016**, exfoliated pygidium respectively in frontal, dorsal and lateral views. (10-11) *Feistops khovdensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section (bed HS-C-1, *Palmatolepis rhomboidea* conodont **Biozone**), fragmented cephalothorax, **MUST-RCSR-TRI.-0007**, respectively in lateral and dorsal views. (12-13) Undetermined phacopids, Hushoot Shiveetiin gol section (bed HS-C-1, *Palmatolepis rhomboidea* conodont **Biozone**), **MUST-RCSR-TRI.-0015**, mostly exfoliated pygidium respectively in dorsal and frontal views. (14) Undetermined phacopids, Hushoot Shiveetiin

gol section (bed HS-C-1, *Palmatolepis rhomboidea* conodont **Biozone**), **MUST-RCSR-TRI.-0014**, pygidium in dorsal view. (15-16) *?Feistops* sp. A, Hushoot Shiveetiin gol section (bed HS-C-1, *Palmatolepis rhomboidea* conodont **Biozone**), **MUST-RCSR-TRI.-0008**, one fragmented cephalon in dorsal view and one partial left cheek from another cephalon and detail of its left eye. Scale: 3 mm (except 16: 2 mm).

Schematic representation of **a**: two visual surfaces in *Feistops khovdensis* gen. nov. sp. nov., Hushoot Shiveetiin gol section, Holotype (bed HS-C-1); **b**: a partial visual surface in *?Feistops* sp. A, Hushoot Shiveetiin gol section (bed HS-C-1). I-VII: horizontal rows; 1-15 (from the front): vertical files. Grey boxes indicate number of lens present.

Figure 6. Phacopid trilobites from the Baruunhuurai Terrane, Olonbulag **Subterrane**, western Mongolia. (1-3) *?Houseops olonbulagensis* sp. nov., Hushoot Shiveetiin gol section (bed HS-F10, *Palmatolepis glabra pectinata* conodont **Biozone**), fragmented enrolled exoskeleton, **MUST-RCSR-TRI.-0010**, respectively in lateral and ventral views, and detail of the vincular furrow. (4-6) *?Houseops olonbulagensis* sp. nov., Hushoot Shiveetiin gol section (bed HS-F10, *Palmatolepis glabra pectinata* conodont **Biozone**), fragmented unrolled exoskeleton, **MUST-RCSR-TRI.-0011**, respectively in dorsal views and detail of the right eye. (7-8) *?Houseops olonbulagensis* sp. nov., Hushoot Shiveetiin gol section (bed HS-F10, *Palmatolepis glabra pectinata* conodont **Biozone**), Holotype, **MUST-RCSR-TRI.-0009**, fragmented cephalothorax respectively in lateral and dorsal views. (9) *?Houseops olonbulagensis* sp. nov., Hushoot Shiveetiin gol section (bed HS-C-5, *Palmatolepis glabra pectinata* conodont **Biozone**), one thoracopygon associated to one pygidium in dorsal view, **MUST-RCSR-TRI.-0012**. Scale: 3 mm (except 6: 2 mm).

Schematic representation of **a**: a visual surface in *?Houseops olonbulagensis* sp. nov., Hushoot Shiveetiin gol section, Holotype (bed HS-F10); **b**: sagittal profiles of anterior part of

cephalon in ?*Houseops olonbulagensis* sp. nov. (Holotype), and *Houseops* illustrated in [Feist 2019](#). I-VII: horizontal rows; 1-15 (from the front): vertical files. Grey boxes indicate number of lens present.