Global Geology, 28(1): 1-10 (2025)

doi: 10.3969/j. issn. 1673-9736. 2025. 01. 01
Article ID: 1673-9736 (2025) 01-0001-10

Revision of the Strophomenida (Brachiopoda) in the Lower Devonian of central Jilin Province, China

LI Ning[1,2*] and YU Lili[3]

1. College of Earth Sciences, Jilin University, Changchun 130061, China;
2. International Center of Future Science, Dinosaur Evolution Research Center, Jilin University, Changchun 130061, China;
3. No.104 Co., Ltd. of Inner Mongolia Coal Geological Exploration, Chifeng 024005, Inner Mongolia Autonomous Region, China

Abstract: A genus within the family Douvillinidae of the order Strophomenida from the Erdaogou Member of the Xibiehe Formation in the Early Devonian of central Jilin has been re-examined, with consideration given to the 56 specimens collected and described by Liu and Huang (1977). Based on its distinct external ornamentation and internal characteristics, it has been classified as *Cymostrophia* (*Protocymostrophia*). It is concluded that the three specices described by Liu and Huang (1977), *Idioglyptus alatus*, *I. semicircularis*, *I. subquadratus*, as well as the *Mesodouvillina jilinensis* Su, 1980 should be considered synonyms and be named *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li.
Keywords: *Cymostrophia* (*Protocymostrophia*); Strophomenida; Erdaogou Member; central Jilin; Early Devonian

Introduction

The Early Devonian represents one of the periods when brachiopods were remarkable abundance. In the Xibiehe Formation in central Jilin Province, an extremely rich assemblage of brachiopod fossils has been discovered. However, so far only one genus belonging to the order Strophomenida has been reported.

The brachiopod fauna in the Xibiehe Formation of this region was initially reported by Liu and Huang (1977). They established many new species. Specifically, in the upper sandy-shale member of the Erdaogou Member (referred to as the Xiaosuihe Member in this paper) four new Strophomenida species were described: *Idioglyptus alatus*, *I. semicircularis*, *I. subquadratus* and *I. erdaogouensis*. Moreover, the quantity of these fossils is quite remarkable. Liu and Huang (1977) suggested that the age of this brachiopod fauna was the Late Silurian. Subsequently, Su (1980, 1992) described a total of 16 species belonging to 15 genera of brachiopods from the Erdaogou Formation, includig both the underlying limestone member and the overlying sandy-shale member. Among them, the fossils of the order Strophomenida were identified as *Mesodouvilina jilinensis* Su. These specimens were also collected from the sandy-shale of the upper Erdaogou Member, consistent with the collection location of Liu and Huang (1977). However, no in-depth discussion on the specific age was presented.

Through multiple field investigations, the author has collected a large number of brachiopod fossils

Received 4 February 2025, accepted 11 February 2025
Supported by the National Natural Science Foundation of China Nos.41702011 and 41372019.
*Coresponding author (E-mail:lining@jlu.edu.cn)

within the limestone member of the Erdaogou Member. A total of 650 specimens have been gathered. A total of 14 species, belonging to 12 genera brachiopods have been identified. Although the species of Strophomenida are not abundant, their internal structures are better preserved than those studied by Liu and Huang (1977) and Su (1980, 1992). These fossils provide invaluable materials for further in-depth research. In this study, they are classified under *Cymostrophia* (*Protocymostrophia*).

The genus *Cymostrophia* was proposed by Caster in 1939, designating *Leptaena stephani* Barrande, 1849 as its type species. It is currently classified into two subgenus, *C.* (*Cymostrophia*) and *C*. (*Protocymostrophia*) (Cocks & Rong, 2000). *Cymostrophia* is widely distributed in the Early Devonian strata (Talent *et al*., 2001) in areas such as Salair and Altai in western Siberia (Khalfin, 1955; Khalfin, 1960; Kulkov, 1963; Gratsianova, 1967; Alekseeva *et al*., 1970; Bublychenko, 1974; Gratsianova, 1975), North America and Canada (Caster, 1939; Hervey, 1944; Jones, 1982), Australia (Parfrey, 1989; Brock & Talent, 1993), as well as Guangxi and Guizhou (Wang 1956; Hou & Xian, 1975; Xian & Jiang, 1978), Altay in Xinjiang (Zhang *et al*., 1983), Gansu (Zhang & Fu, 1983) in China.

The findings of this study are based on the 22 specimens collected by the research team, combined with the 56 specimens previously described as *Idioglyptus* by Liu and Huang (1977) . Through a comprehensive comparison with other species within the genus *Cymostrophia,* it is determined that this represents a new species, which is named as *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li herein. This newly identified species is considered to be synonymous with *Idioglyptus alatus* Liu, *I. semicircularis* Liu, *I. subquadratus* Liu and *Mesodouvillina jilinensis* Su.

1 Geographical and stratigraphy

The fossil location is near the Erdaogou of Dasuihe Town, Yongji County, 18 km west of Jilin City in the central Jilin Province (Fig.1a). The Late Silurian-Early Devonian strata in this area are part of the Xibiehe Formation (Li, 1997). The Xibiehe Formation is widely distributed in the Darhan Muminggan-central Jilin Province-eastern Harbin regions. In central Jilin Province, it is exposed in Zhangjiatun, Xiaosuihe and Erdaogou in Yongji County.

The Xibiehe Formation consists of the Zhangjiatun, Erdaogou and Xiaosuihe lithologic members (Wang *et al*., 2013) and is a lithological assemblage of sandstone, limestone, mudstone, siltstone and bioherms. The Zhangjiatun Member (formerly the Zhangjiatun Formation), the lower member of the Xibiehe Formation, is composed of purple gravel-bearing tuffaceous siltstone, celadon gravel-bearing siltstone, pelitic fine sandstone, and variegation conglomerate and gravel-bearing gritstone in the bottom, with a thickness of 380 m. The Erdaogou Member (formerly the limestone member of the Erdaogou Formation), the middle member of the Xibiehe Formation, is made up of grey bioclastic limestone with yellow-green silty mudstone and mudstone, with a thickness of 102 m. The Xiaosuihe Member (formerly the sandstone-shale member of the Erdaogou Formation) is composed of mainly silty mudstone, siltstone, and debris-arkose, with mudstone and limestone lens, with a thickness of 330 m. It was named the Xiaosuihe Formation by Zheng (1989) and subsequently cited by Peng *et al*. (1990), Guo *et al*. (1992) and Liao *et al*. (1995).

However, for a long time, there has been a significant disagreement about the vertical stratigraphic relationship between the Erdaogou Member and the Xiaosuihe Member, specifically between the limestone member and the sandstone-shale member. One perspective holds that the Xiaosuihe Member is in the lower part of the Erdaogou Formation (Wang and Li, 1986; Peng *et al*., 1990; Guo *et al*., 1992; Liao *et al*., 1995), considering the strata overturned. Conversely, some researchers hold the opposite view, believing that the limestone is above and the sandstone-shale is below (Guo, 1962; Liu and Huang, 1977; Li *et al*., 1997; Wang *et al*., 2013), and the stratigraphic se-

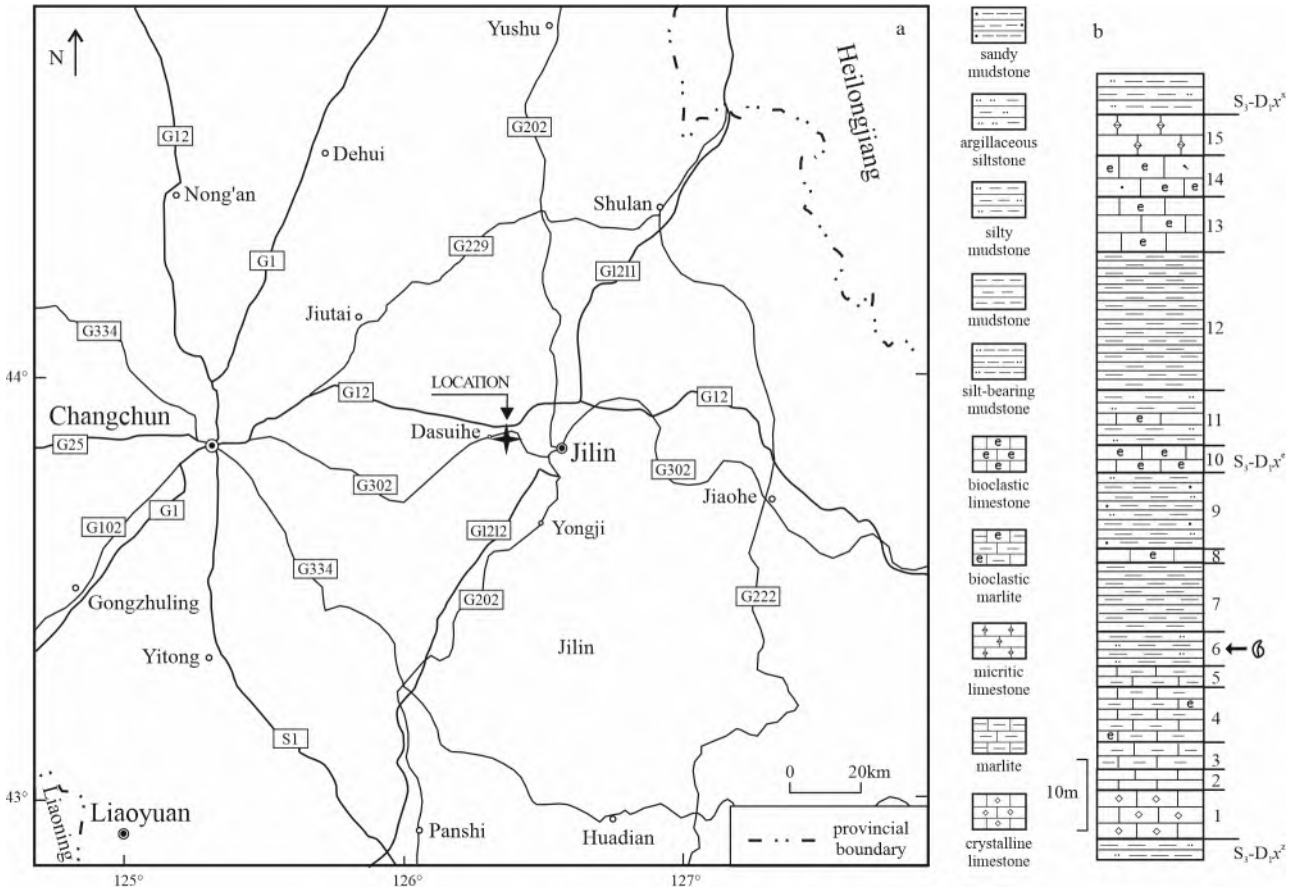


Fig.1 Location of the Erdaogou Member of Xibiehe Formation in central Jilin (a) and stratigraphic column showing the fossil horizons (arrow) sampled long the Erdaogou section (b)

quence is normal. In this paper, we adhere to the latter view, that is, the Xiaosuihe member overlies the Erdaogou member.

The specimens discussed and studied in this paper were collected from the Erdaogou section in Dasuihe Town, central Jilin. More precisely, these specimens were obtained from the sixth bed of the second member, the Erdaogou Member of the Upper Silurian- Lower Devonian Xibiehe Formation (Fig.1b).

2 Material

The specimens discussed and studied in this paper were collected from the Erdaogou section in Dasuihe Town, central Jilin, mostly from the sixth bed of the Erdaogou member of the Upper Silurian-Lower Devonian Xibiehe Formation. All type species have catalog numbers beginning with S_3-D_1x^e are housed in the College of Earth Sciences, Jilin University. All type species have storage numbers beginning JXE-B.

Furthermore, the 56 specimens collected and described by Liu and Huang (1977) were rediscovered and re-observed. These specimens were collected in sandstone-shale member of Erdaogou Formation (equivalent to the current Xiaosuihe Member of the Xibiehe Formation). Currently, all these specimens are housed in the College of Earth Sciences, Jilin University.

3 Systematic paleontology

Order STROPHOMENIDA Opik, 1934

Family DOUVILLINIDAE Caster, 1939

Subfamily PROTODOUVILLININAE Harper & Boucot, 1978

Gunus *Cymostrophia* Caster, 1939

(=*Corrugatella* Khalfin, 1948)

1939. *Cymostrophia*, Caster, p.39
1953. *Cymostrophia*, Williams, p.39
1965. *Cymostrophia*, Williams, p.395
1967. *Cymostrophia*, Havlicek, p.126
1978. *Cymostrophia*, Harper & Boucot, p.129
2000. *Cymostrophia*, Cocks & Rong, p.268

Type species: *Leptaena stephani* Barrande, 1848, p. 230. Konieprus Limeston in Konieprus, Czech Republic

Diagnosis: Variable outline; variably convex profile, geniculate ventral valve; dorsal valve initially flat, geniculate anteriorly; distinctive ornament of rugae interrupted by primary costellae; relatively large, suboval ventral muscle field bounded by low ridges posterolaterally only; ventral myophragm developed; small, erect cardinal process lobes; dorsal muscle field bounded posterolaterally by low ridges; one pair of low dorsal side septa, small median ridge in valve center.

Genus composition: 2 subgenus—*C*. (*Cymostrophia*) Caster, 1939; *C*. (*Protocymostrophia*) Harper & Boucot, 1978.

Discussion: When Caster established *Cymostrophia* in 1939, it was initially classified within the subfamily Stropheodontinae (Caster, 1939) of the family Stropheodontidae (Caster, 1939). Subsequently, Harper & Boucot (1978) transferred it to the subfamily Protodouvillininae (Harper & Boucot, 1978) of the family Douvillinidae (Caster, 1939). Both the Stropheodontidae and Douvillinidae families feature a strong ventral muscle field bounded by muscle-bounding ridges. However, in the Stropheodontidae, this bounding ridge is commonly absent anteriorly. In contrast, compared with the Stropheodontidae, the Douvillinidae lacks dental plates and dorsal side septa.

The subgenus *Protocymostrophia* was initially assigned to the *Mesodouvillina* as *Mesodouvillina* (*Protocymostrophia*) by Harper and Boucot in 1978. However, *Mesodouvillina* is currently classified within the Amphistrophiidae family. In this family, the ventral valve muscle field is semi-elliptical in outline, laterally bounded by curved muscle-bounding ridges, and lacks dorsal side septa. *Cymostrophia* belongs to the Douvillinidae family. The ventral muscle field in Douvillinidae is variable, ranging from subcircular to bilobed, with distinct impressions. It is usually laterally and anteriorly bounded by ridges and also has dorsal side septa. These characteristics are more consistent with those of *Cymostrophia*.

Distributions: Silurian(Ludlow)–Devonian (Givetian), Cosmopolitan.

Subgenus *Protocymostrophia* Harper & Boucot, 1978
(=*Mesodouvillina* (*Protocymostrophia*) Harper & Boucot, 1978, p.127)

2000. *Cymostrophia* (*Protocymostrophia*) Cocks & Rong, p.268

Type species: *Strophomena ivanensis* Barrande, 1879, pl. 52, Fig.IV 1–4, 9–12. Kotys Limestone, Lochkovian, Svaty Jan pod Skalou, Bohemia, Czech Republic

Diagnosis: It is similar to *C. (Cymostrophia)* but having suboval rather or transverse outline, gently concavoconvex profile, less pronounced interrupted rugae in ornament.

Discussion: *Mesodouvillina* exhibits the greatest similarity in concavoconvex geniculate profile with prominent curved geniculate trail. However, this genus possesses distinct features. It has denticles along half to two-thirds of hinge line; the muscle-bounding ridges are straight or slightly curved, forming a subtriangular ventral muscle field, that is open anteriorly, and dorsal side septa are usually absent. These features do not match those of the type species of the subgenus *Protocymostrophia*. Notably, the distinctive ornament of rugae interrupted by primary costellae, typical of *C*. (*Protocymostrophia*), is absent in *Mesodouvillina*.

Although the external shape, thin body cavity and unequally parvicostellate ornament of *C*. (*Protocymostrophia*) bear resemblance to those of *Malurostrophia* Campbell and Talent, there are compelling

reasons to suggest that the relationship between these genera is more remote than such similarities might indicate. When Campbell and Talent established *Malurostrophia* in 1967, they emphasized its distinct characteristic: the valve margins sharply geniculate and ventrally directed, except for a prominent dorsally directed tongue in the anterior margin, similar to that of the Maluridae, resulting in a gently resupinate profile, Additionally, they also differ in the adductor scars in the ventral valve. The pedicle valve of *Malurostrophia* has an anterioly bilobed rhomboidal diductor field and strong muscle-bounding ridges, and its ornamentation lacks interrupted rugae.

In the classification system proposed by Williams (1965), these two subgenera were designated as *C*. (*Cymostrophia*) and *C*. (*Idioglyptus*). The genus *Idioglyptus* was originally described from the Middle Silurian West Point Formation in the Port Daniel region, Chaleur Bay, Gaspé Peninsula, Quebec, Canada. The exteriors of type specimens have an ornament of interrupted rugae like to that of *Cymostrophia*. However, the interiors remain unknown. Consequently, the genus *Idioglyptus* has been regarded as a nomen dubium (Cocks & Rong, 2000). In view of this, the classification of the species from the Erdaogou area in central Jilin as *Idioglyptus* by Liu and Huang (1977) is invalidated.

The two subgenera differ in profile and rugae ornamentation. *C*. (*Protocymostrophia*) has a gently concavoconvex profile and less pronounced interrupted rugae in its ornamentation. These rugae occur in body cavity, are strong and dense at the posterior part, and gradually weaken and disappear as they extend forward. Among the currently reported species of *Cymostrophia*, very few have been calassified into subgenra. Based on the differences, it can be inferred that species such as *C. stephani* (Barrande) , *C. patersoni* (Hall), *C. grata* Kulkov, *C. alfa* Kulkov, *C. yolkini* , *C. radiosa* Gratsianova, *C. sinuata* Gratsianova, *C. gibbosa* Gratsianova , *C. puanensis* Xian, *C. yolkini* Gratsianova, *C. bellarugosa* Talent are more closely related to *C*. (*Cymostrophia*). While some like *C. yolkini* Gratsianova, *C. quatrata* Wang, *C. qinglingensis* Zhang, *C.* (*P.*) *gobiensis* Mendbajar may belong to *C*. (*Protocymostrophia*) .

It is necessary to discuss the two specimens described by Zhang *et al*. in 1983, which were classified as *C. stephani*. Among them, one from the Lower Devonian has relatively weak rugae and is more similar to this subgenus. The other, from the Middle Devonian strata, has very prominent rugae and should be assigned to *C*. (*Cymostrophia*).

Distribution: Silurian (Ludlow)–Devonian (Eifelian)*:* cosmopolitan.

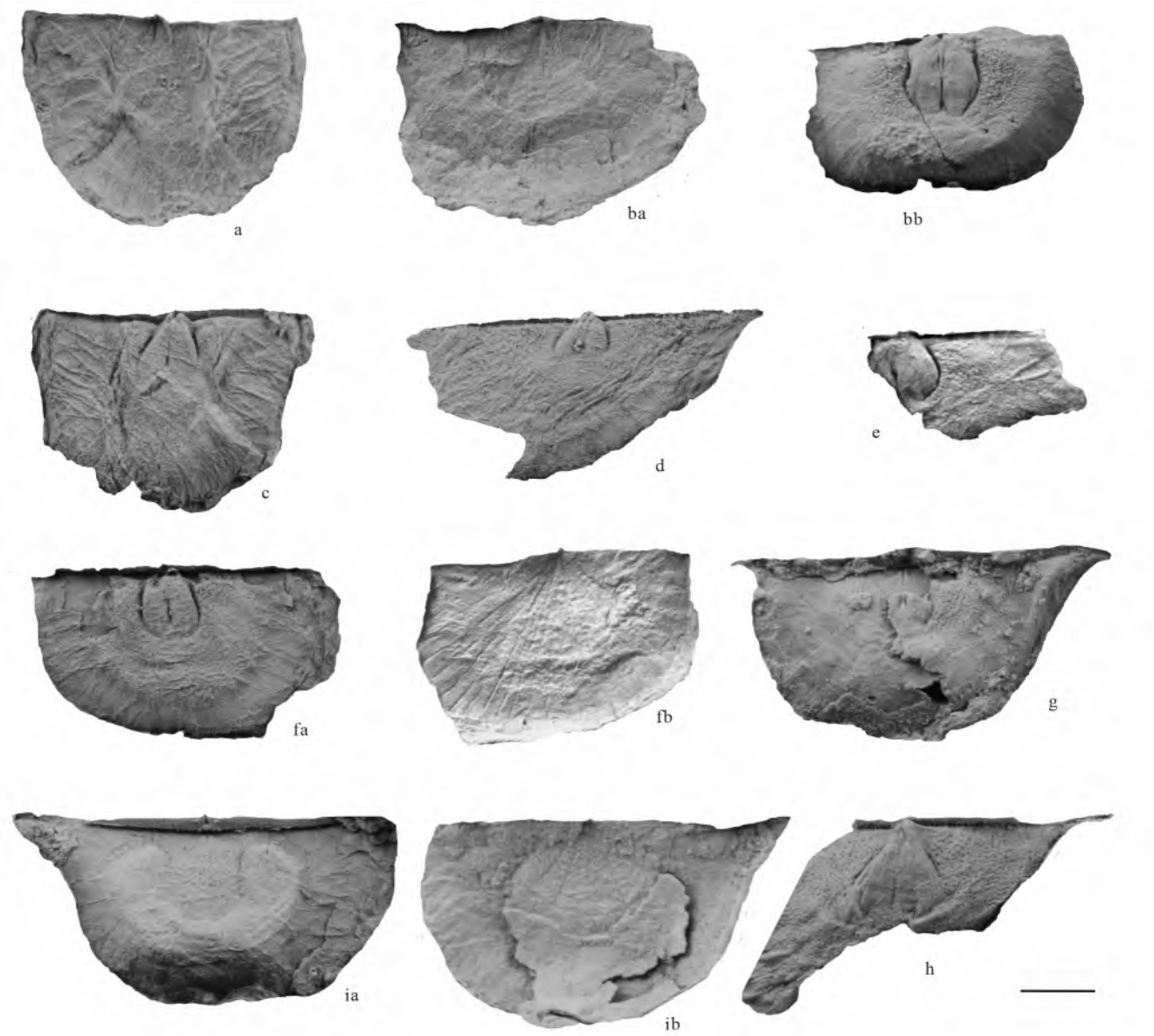
Cymostrophia (*Protocymostrophia*) *alatus* (Liu) Li comb. nov.

Figs.2 a-h

1977. *Idioglyptus alatus*, Liu, p.63, pl.V, figs.1-12
1977. *Idioglyptus semicircularis*, Liu, p.63, pl.V, figs.13-18
1977. *Idioglyptus subquadratus*, Liu, p.64, pl.V, figs.19-21
1980. *Mesodouvillina jilinensis*, Liu, p.283, pl.120, figs.36-39
1992. *Mesodouvillina jilinensis*, Su, p.203, pl.62, figs.22-26

Material: Twenty two specimens: six ventral internal molds, eight ventral external molds, two dorsal interior valves , six dorsal internal molds.

Description: Shell is small to medium size (ranging from 11 to 14 mm in length, and 21 to 24 mm in width). It has semicircular outline, is slightly transverse and attains its maximum width at the alae at the hingeline. The hingeline is straight and there are denticles present for approximately one-thirds of its length on both sides of the small umbo. The cardinal extremities are apical. Gently concavoconvex profile, thin body cavity. Variably convex profile, geniculate ventral valve. The dorsal valve is initially flat or slight concave, geniculate anteriorly. These specimens perhaps with prominent curved geniculate trail, which is not preseved well in most specimens. So, the figures in Fig.2 are all the views of the body cavity. The valves are covered by unequally parvicostellate,

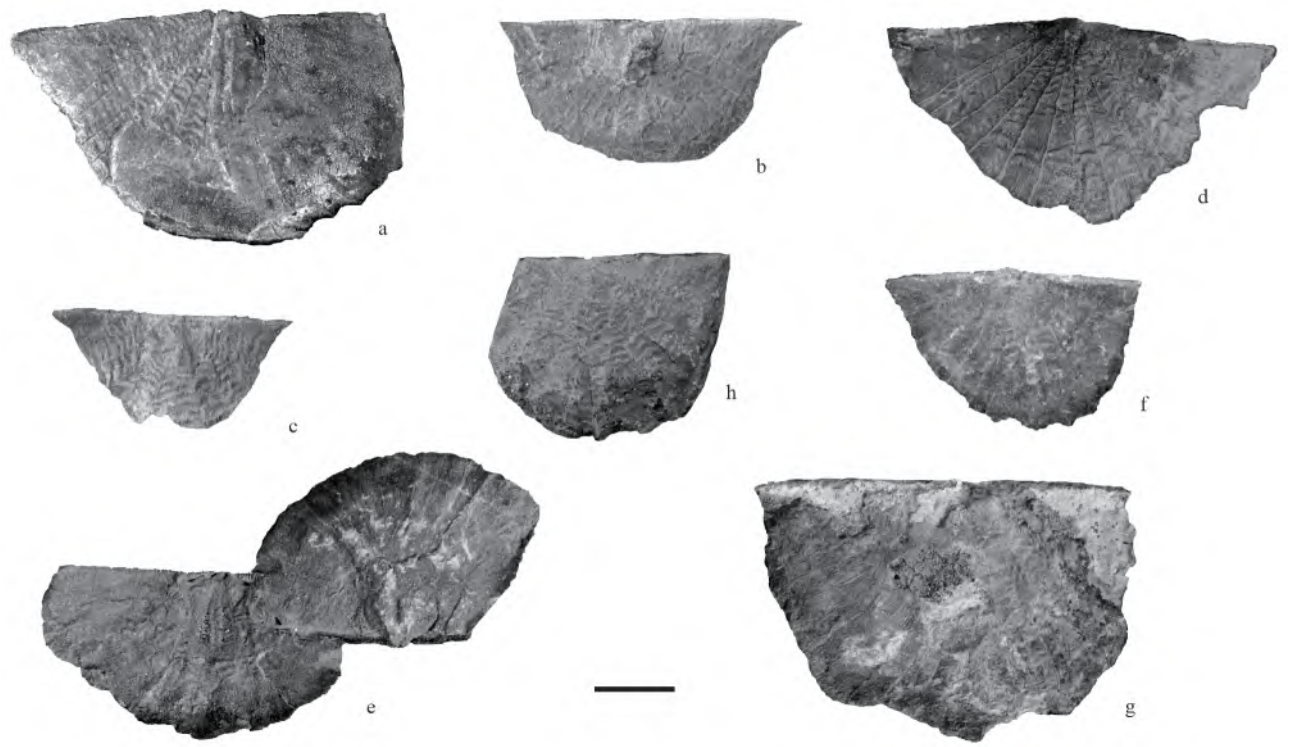


a. ventral external mold JXE-B53; ba-bb. ventral external and internal molds, JXE-B054a, JXE-B054b; c-e. ventral internal molds, JXE-B055, JXE-B56, JXE-B57; fa-fb. ventral internal and external molds, JXE-B58a, JXE-B58b. g. dorsal external mold, JXE-B59. h. dorsal internal mold, JXE-B60. ia-ib, dorsal and ventral external molds, JXE-B61a, JXE-B61b. Scale bar: 5 mm.

Fig.2 ***Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li comb. nov.**

primary costellae are distinct and increase in number in an inserted manner at different position on the valve. Some are inserted at a distance of 5 mm from the umbo, and some are inserted 5 mm behind the geniculation. The width between two primary costellae is approximately 2 mm or less than 2mm, and there are 8–10 secondarystripes costellae. Concentric ragae developed on the body cavity and were disrupted by the primary costellae. The ragae are gradually weaken and disappear near the geniculation.

Interior of the ventral valve, small almond-shaped or boval muscle field was bounded by prominent ridges posterolaterally. The surrounding ridges curve towards the middle anterior margin of scarfield and gradually weaken. The median septal ridge develops in the anterior or middle of muscles scar. Sometimes



a-d. *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li (=*Idioglyptus alatus* Liu, 1977), a. ventral and ventral internal views; b-c. ventral view; d. ventral external mold; e-g. *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li (=*Idioglyptus semicircularis* Liu, 1977), e. ventral and dorsal internal views; f. ventral view; g. dorsal external mold; h. *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li (=*Idioglyptus subquadratus* Liu, 1977), dorsal external mold. Scale bar: 5 mm.

Fig.3 *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li (after Liu & Huang, 1977)

ventral myophragm developed at the anterior margin of the muscles scar. Adductor scar is narrow.

Inside the dorsal valve, cardinal process lobes are bilobe. A pair of socket-plate diverges from the cardinal process, forming an angle of approximately 60° with the bounding ridges of the muscle scar. Dorsal muscle field is rhombic and bounded posterolaterally by ridges. The median septal ridge is not very prominent and sometimes extends to the mid-length of the valve. There is one pair of low dorsal side septa.

Comparison and discussion: Compared with the type species *Strophomena ivanensis* Barrande, the shell of this species is relatively smaller and more transversely expanded. This is also an external characteristic that distinguishes this species from other species within the genus.

This species can be somewhat similar to *Cymostrophia* (*P.*) *gobiensis* Mendbajar from the Early Devonian strata of the Borzya terrane in eastern Mongolia. The difference lies in the fact that the muscle scar of the latter is larger, and the surrounded by ridges only laterally.

Cymostrophia quatrata Wang from the Yujiang Formation in Liujing, Guangxi, China, has a square shape of external morphology, compared to the specimens in this study. The convexity of the ventral valve is more intense, and the entire hinge line is attached with denticles, which differentiates it from this genus. Additionally, there is *C. qinglingensis* Zhang distributed in the northwestern region of China. The distribution of its shell wrinkles conforms to the characteristics of this subspecies. Compared with this species, the shell is larger, approximately 2 to 5 times that of this species. *Cymostrophia yolkini* Gratsianova 1967 from the Altai region is somewhat similar in shell size and shape to this species, both having relatively small shells. However, although its concentric

ragae are slightly prominent than those of this species and develop throughout the furface of body cavity, but they are not as dense as those of *Cymostrophia* (*Cymostrophia*). Further taxonomic classification requires more fossil materials.

This study focuses on comparing the specimens collected and described by Liu and Huang (1977). Fig.3 presents some of them, which were classified as *Idioglyptus*. Similar to the fossils collected this research, the margins of these specimens are incompletely preserved. However, a notable difference is that these specimens predominantly show external views, with relatively poor preservation of internal structures. These specimens constitute a relatively large proportion and display a wider size range. The smallest measures 6 mm in length and 12 mm in width, while the largest is 20 mm long and 34 mm wide. In contrast, the fossils collected in this study are relatively consistent in size, with lengths ranging from 11 to 13 mm, and they account for a relatively small proportion within the biota. Nevertheless, these specimens are extremely similar to ours in terms of individual external shape, ornamentation, and internal structure. Both have a thin body cavity and unequally parvicostellate, concentric ragae developed on the posterior, which are disrupted by the primary costellae. The denticles do not extend to one-third of the hingeline (Fig.2a, Fig.3e). They both have small almond-shaped or boval muscle field, bounded by prominent ridges posterolaterally (Fig.2b-f, Fig.3a, e). Moreover, the genus *Idioglyptus* adopted by Liu and Huang is no longer applicable. It is concluded that it is reasonable to re-classify the specimens of *I. alatus*, *I. semicircularis*, *I. subquadratus* (Liu and Huang, 1977) into *C.* (*Protocymostrophia*) .

Considering the significant differences between the specimens in this study and other species within the genus *Cymostrophia* (*Protocymostrophia*), a new species *C.* (*P.*) *alatus* is established, with the species name derived from *Idioglyptus alatus* Liu 1977. Additionaly, the differences among *I. alatus*, *I. semicircularis*, and *I. subquadratus* described by Liu and Huang (1977) are extremely subtle, mainly manifested in size variations and the sharpness or bluntness of the cardinal extremities. Through specimens observation, the author found that the specimens named *I. semicircularis* may have incompletely preserved wing-shaped cardinal extremities. The aspect ratios of these specimens were also statistically analyzed, all of which range from 0.55 and 0.62. Therefore, it can be reasonably concluded that they should be classified as the same species, *C.* (*Protocymostrophia*) *alatus* (Liu) Li.

Su (1980, 1992) described the Strophomenida fossils from Erdaogou as *Mesodouvillina jilinensis*. The differences between the two genera have been previously discussed. Evidently, the specimens described by Su are significantly different from the characteristics of *Mesodouvillina*. These specimens originate from the same stratigraphic horizon as those of Liu and Huang (1977), and there is a highprobability that they belong to the same genus and species. Thus, in this article, they are revised as *Cymostrophia* (*Protocymostrophia*) *alatus* (Liu) Li.

Acknowledgments

The author is deeply indebted to the late Professor Wang Chengwen. During his lifetime, he not only led the author and the research team in the collection of fossils but also offered invaluable guidance in the field of fossil research. His profound insights and unwavering dedication have been a constant source of inspiration and have laid a solid foundation for the present study. Moreover, the authors also wishes to thank Li Ting and Wang Zhihui, who accompanied in the fossil collection. Thanks to Yang Hantao, College of Earth Sciences, Jilin University for his provision of the fossil specimens originally described by Liu and Huang in 1977.

Author contributions

LI Ning: conceptualization and design of the entire research, led the field collection, sorting and fossil identification of samples, composed the original draft, took pictures of fossils,

revised and edited the paper according to the review comments. YU Lili: provided the reference materials, drew illustrations, reviewed the content, language expression and logical structure and took charge of editing the references.

Conflict of interest statement

The authors declare that they have no competing interests.

References

Alekseeva R E, Afanasjeva G A, Schischkina GR, 2001. Lower and middle Devonian branchiopods of the Far East of Russia and Mongolia: Strophomenids and Chonetids. *Nauka*. 1-131. (in Russian)

Alekseeva R E, Gratsianova R T, Elkin E A, *et al*. 1970. Stratigraphy and brachiopods of the Lower Devonian of northeastern Salair. Moscow: Scientific Press, 1-187. (in Russian)

Brock G A, Talent J A. 1993. Emsian (Early Devonian) brachiopods from the Ukalunda Beds and Douglas Ceek, north Queenslan. *Memoirs of Association of Australasian Palaeontologists,* **15**: 225-248.

Bublychenko N L. 1974. Brachiopods of the Middle and Upper Devonian of the Ore Altai. Kazakh: Nauk Publishing House, 1-168. (in Russian)

Campbell K S W. Talent J A. 1967. Malurostrophia, a new genus of Stropheodotid brachiopod from the Devonian of Australia. *Proceedings of Royal Society of Victoria*, **80**(2):309-330.

Caster,K.E., 1939. A Devonian Fauna from Colombia. *Bulletins of American Paleontology*, **24**(83): 102-318.

Cocks L R M, Rong J Y. 2000. Strophomenida // Treatise on invertebrate paleontology Part H Brachiopoda Vol.2. Lawrence: Geology Society America, 216-349.

Fu L P. 1982. Brachiopoda, Cambrian-Silurian//Atlas of Palaeo ntology of Northwest Region: Shaanxi, Gansu and Ningxia provinces,Vol.1,Precambrian-Early Palaeozoic.Beijing:Geo logical Publishing House, 95-179. (in Chinese)

Gratsianova R T. 1967. Brachiopods and stratigraphy of the Lower Devonian of the Mountainous Altai. Moscow: Scientific Press, 1-176. (in Russian)

Gratsianova R T. 1975. Early and Middle Devonian Brachiopods of the Altai-Sayan Region, Strophomennidina. Moscow: Scientific Press, 1-106. (in Russian)

Guo H J. 1962. Slurian trilobites of the Erdaogou Group in Jilin. *Acta Palaeontologica Sinica*, **10**(3): 369-385. (in Chinese)

Guo S Z, Su Y Z , Chi Y Y, *et al*. 1992. Paleozoic biostratigraphy and lithofacies-paleogeography of Eastern Jilin and Heilongjiang provinces, China//Nan R S, Guo S Z. (eds.). Palaeozoic biostratigraphy and palaeogeography of Nei Mongol—Northeast China geosynclinal region. Beijing: Geological Publishing House, 71-146. (in Chinese)

Harper, C W Jr, Boucot A J. 1978. The Stropheodontacea, parts I–III. *Palaeontographica (Abt. A),* **161**: 55–175.

Havlicek V. 1967. Brachiopoda of the suborder Strophomenidina in Czechoslovakia. *Rozpravy Ústredního ústavu Geologického*, 33:1–235.

Hervey W S., Robert R S. 1944. Index fossils of North American, a new work besed on the complete revision and reillustration of Grabau and Shimer's North American index fossils. New York: John Wiley & Sons Inc,1.

Hou H F, Xian S Y. 1975. Lower and Middle Devonian brach iopods from Guangsi and Guizhou// Professional papers in stratigraphy and palaeontology of Chinese Academy of Geological Sciences, 1-85. (in Chinese)

Jones B. 1982. Lower Devonian brachiopods from the "Bird Fiord" Formation of the Vendom Fiord area, Ellesmere Island, Arctic Canada. *Journal of Paleontology*, **56**(6): 1375-1396.

Khalfin L L. 1960. Biostratigraphy of the Paleozoic of the Sayano-Altai Mountainous Region: tran-sactions of the Siberian Research Institute of Geology. *Geophysics and Mineral Resources,* **20**: 422-820. (in Russian)

Khalfin L. L. 1955. Brachiopods of the Lower Devonian of Altai//Atlas of guiding forms of the fossil fauna and flora of Western Siberia. Moscow: Gosgeoltekhizdat, 23-460. (in Russian)

Kulkov N P. 1963. The Brachiopoda of the Lower Devonian Solovikhin strata in the Gorny Altai. Moscow: Publishing House of the Academy of Sciences of the USSR, 1-131. (in Russian)

Li D J. 1997. Stratigraphy (Lithostratic) of Jilin Province. Wuhan: China University of Geosciences Press, 1-324. (in Chinese)

Liao W H, Rong J Y, Hu Z X, *et al*. 1995. Silurian-Devonian biostratigraphy, communities and biogeography in central Jilin. *Journal of Statigraphy*, **19**(4): 241-249. (in Chinese with English abstract)

Liu F, Huang Z X. 1977. Silurian strata and fauna in the central of Jilin Province. *Journal of Changchun College of Geology*, **7**(1): 52-79. (in Chinese)

Parfrey S M. 1989. Early Devonian fossils from the Ukalunda Beds, north-west of Mount Coolon central Queensland.

Queensland Government Mining Journal, **90**(1046): 1-20.

Peng Y J, Xia Z L, Sun J G. 1990. New cognition of the Erdaogou Group in Jilin—a good seletion of boundary-stratotype section. *Jilin Geology*, **9**(1):1-20. (in Chinese with English abstract)

Su Y Z, 1980. Brachiopods (Cambrian-Devonian Part)// Paleontological atlas of Northeast China, Paleozoic Volume 1. Beijing: Geological Publishing House, 294-327. (in Chinese)

Su Y Z, 1992. Brachiopods (Cambrian-Devonian)//Paleontological atlas of Jilin China. Changchun: Jilin Science and Technology Press, 1-726. (in Chinese)

Talent J A, Gratsianova R T, Yolkin E A. 2001. Latest Silurian (Pridoli) to Middle Devonian (Givetian) of the Asia-Australia hemisphere: rationalization of brachiopod taxa and faunal lists, stratigraphic correlation chart. *Courier Forschungsinstitut Senckenberg*, **236**: 1-221.

Wang C W, Li N, Sun Y W, *et al*. 2013. Stratigraphic framework of Late Paleozoic in northeastern China. *Global Geology*, **16**(1):1-18.

Wang C Y, Li D J. 1986. Conodonts from the Ertaogou Formation in central Jilin Province. *Acta Micropalaeontologica Sinica*, **3**(4):421-428. (in Chinese with English abstract)

Wang Y, Jin Y G, Fang D W. 1964. Brachiopod fossils of China II. Beijing: Science Press, 1-354. (in Chinese)

Wang Y, Rong J Y. 1986. Yukiangian Early Emsian, Devonian brachiopods of the Nanning-Liujing dstrict, central Guangxi, souhtern China. Beijing: Science Press, 1-282. (in Chinese)

Wang Y. 1956. Some new Brachiopods from the Yukiang Formation of southern Kwangsi Province. *Act Palaeontogolica Sinica*, **4**(2): 137-162. (in Chinese)

Williams A. 1965. Suborder Strophomenidina öpic, 1934// Moore R. C. (ed.). Treatise on invertebrate paleontology, part H. Brachiopoda Vol 1. Geological Society of America and University of Kansas Press, 231-271.

Xian S Y, Jiang Z L. 1978. Phylum Brachiopoda Dumeril, 1806//Palaeontological atlas of Southwest China, Vol. 1 Cambrian-Devonian. Beijing: Geological Publishing House, 251-337. (in Chinese)

Zhang Y, Fu L P. 1983. Brachiopoda (Devonian)//Palaeontological atlas of Northwestern China (Shanxi-Gansu-Ningxia Part), Paleozoic Part 2. Beijing: Geological Publshing House, 244-425. (in Chinese)

Zhang C, Zhang F M, Zhang Z X, Wang Z. 1983. Brachiopods//Palaeontological atlas of northwestern China (Xinjiang Part), Paleozoic Part 2. Beijing: Geological Publshing House, 262-385. (in Chinese)

Zheng C Z. 1989. New division of the Devonian stratigraphic sequence of Jilin Province. *Journal of Stratigraphy*, **13**(1): 47-51. (in Chinese with English abstract)