

A new aviculopectinid bivalve from the Early Carboniferous of Guizhou, China

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Six silicified left valves including one nearly complete were obtained from acid residues of two samples collected from the Early Carboniferous Muhua Formation in Guizhou Province, China. The Chinese specimens have reticulate ornament and a large asymmetrical aviculopectinid-type resilifer and are much like *Girtypecten* from Permian rocks in the United States. However, the Chinese material shows only unicostate radial ornament, whereas *Girtypecten* is multicostate. Thus, a new taxon *Girtypecten* (*Sinopecten*) *newelli* subgen. et sp. nov. is proposed. The conodont assemblage occurring with *G. (Sinopecten) newelli* dates the new scallop as Tournaisian (the conodont Lower *Siphonodella crenulata* Zone); this is the oldest known occurrence of *Girtypecten*.

Key words: Bivalvia, Aviculopectinidae, *Girtypecten*, *Sinopecten*, Carboniferous, China.

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Introduction

Pectinoids (scallops) are a remarkable group of bivalve mollusks that appeared in the Ludlow (Silurian) and have successfully continued to the present time. They have been of considerable interest to paleontologists because of their diversity and wide geographic distribution. Our new discovery of several fossil scallops from the Early Carboniferous Muhua Formation of Guizhou, China will increase significantly our knowledge of the early diversification of the Aviculopectinoidea. The studied material is the by-product of a search for silicified brachiopods. Several pectinoid valves were found in the residue after limestone was dissolved in acetic acid. They are from two samples (GB and GT; see Fig. 1) collected from a 1.5 m thick dark gray brecciated limestone near the top of the Muhua Formation exposed at the south edge of a small pond on the west side of Gedongguan Village of Muhua, Guizhou, China (Fig. 1). The material includes one nearly complete and three incomplete left valves from GT, and two incomplete left valves from GB. The Muhua section is well known because it was proposed as one of the candidates for the Devonian–Carboniferous boundary stratotype (Ziegler and Sandberg 1984; Hou et al. 1985; Ziegler et al. 1988). The sampling site (GPS coordinator 106°24.205' E, 25°48.256' N) is ca. 190 m northwest of the M2 site and ca. 350 m north of the MH site. Both represent the lower part of the Muhua Formation, the source of three recently described peculiar brachiopod genera (Sun, Baliński, et al. 2004; Sun, Ma, et al. 2004; Baliński

and Sun 2005). The exposed thickness of the Muhua Formation around Gedongguan Village varies from one to ten meters. It is composed of gray to black thin- to medium-bedded argillaceous limestone with occasional lenses of gray to dark gray detrital and black oolitic limestone which in addition to the scallops contains abundant silicified brachiopods, corals, fish remains, and ostracods. The associated conodont assemblage is dominated by elements of *Pseudopolygnathus*; in addition one specimen of *Siphonodella cooperi* was recovered from GT. The lack of *Gnathodus delicatus* in the conodont assemblage suggest that the two samples represent an interval not younger than the conodont Lower *Siphonodella crenulata* Zone.

Girtypecten was regarded as a Permian scallop genus (Newell 1938, 1969; Newell and Boyd 1995). Newell (1938: 77) noted that the Visean (Early Carboniferous) species *Avicula tessellata* Phillips, 1836 (Phillips 1836: 211, pl. 6: 6; see also Hind 1903: 63, pl. 9: 8–11), bears resemblance to *Girtypecten*; however, Newell doubted that it should be assigned to the genus *Girtypecten*. Other Carboniferous species recently assigned to *Girtypecten* include *G. qijiagouensis* Yang, 1983 (Yang 1983: 411, pl. 151: 1, 8, 17; early Late Carboniferous, Xinjiang, China), *G. sp.* (Yang 1983: 411, fig. 3; early Late Carboniferous, Luosuan, Xinjiang, China), and *G.?* cf. *wasserfallensis* (Paul, 1937) (Richter and Amler 1994: 117, pl. 2: 7–11; Early Carboniferous, Bergisches Land).

However, these taxa look similar to Carboniferous species of *Pterinopecten* apart from their atypical reticulated or-

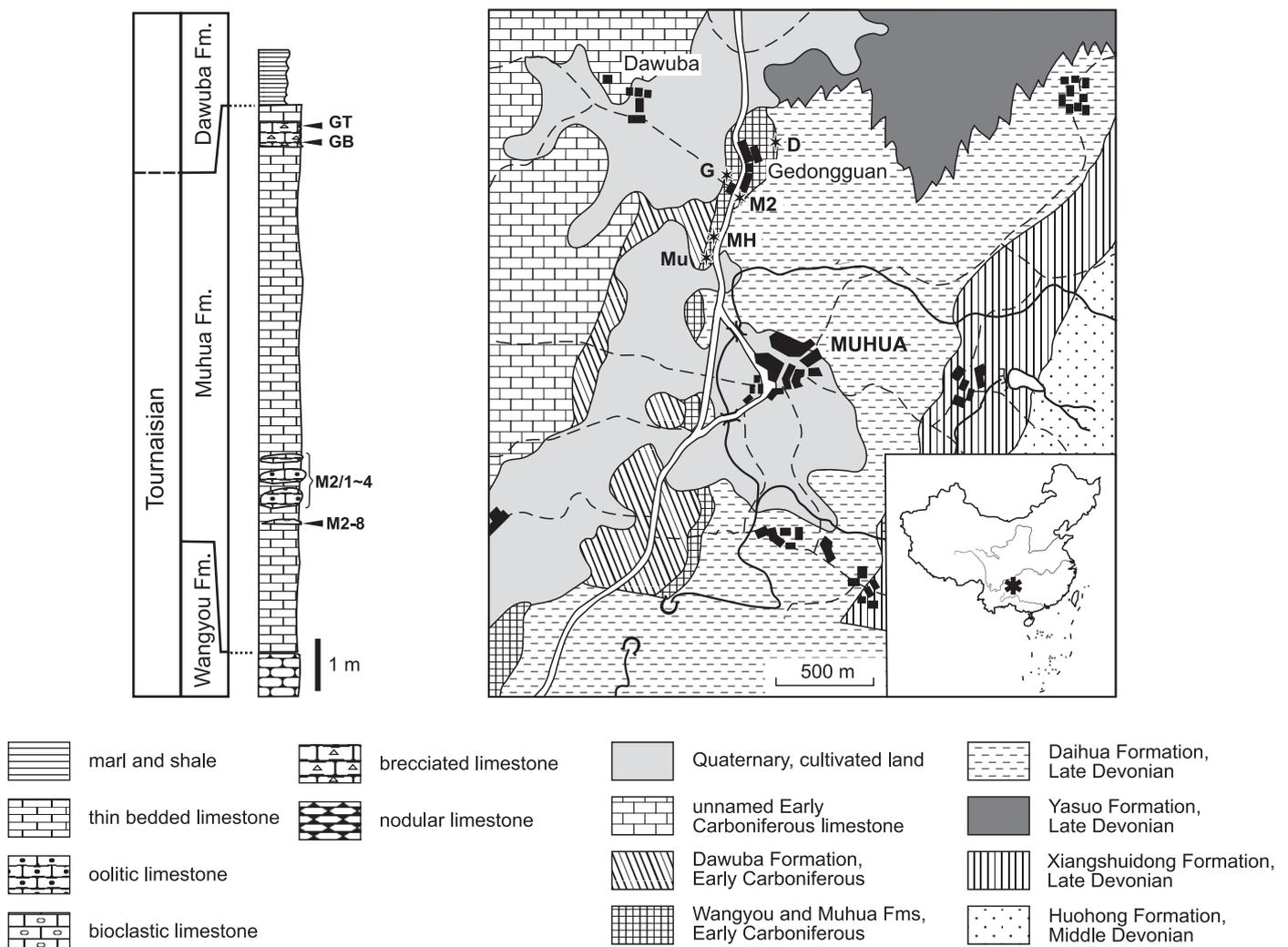


Fig. 1. Lithologic sequence of the Tournaisian Muhua Formation at the M2 (M2/1–4 and M2–8) and G (GB and GT) sampling sites, and the geological map around Muhua, Guizhou Province, Southwest China. The map modified from Baliński (1999).

namentation. Therefore we are still not convinced that these Carboniferous species belong to *Girtypecten*, until more is known about their ligament nature. Similarly, an Australian taxon listed by Roberts (1963: 4) as *?Girtypecten* sp. from the Tournaisian of Lewinsbrook, New South Wales, was never described nor illustrated and its taxonomic status must remain questionable. On the other hand, our material can be assigned with certainty to *Girtypecten*, because it has both typical aviculopectinid-type ligament and typical reticulated ornamentation. Our finding extends the geographic and stratigraphic range of the genus. The new species described here is characterized by unicostate ornamentation with a reticulated grid of widely spaced radial and commarginal ribs, thus differing from the multicostate *Girtypecten* described by Newell and Boyd (1995: 41). The latter has ranks of new costae added by implantation during growth.

Institutional abbreviation.—PKUM, Geological Museum of Peking University, Beijing, China.

Systematic paleontology

Order Pectinoidea Rafinesque, 1815

Superfamily Aviculopectinoidea Meek and Hayden, 1864

Family Aviculopectinidae Meek and Hayden, 1864

(= Etheripectinidae Newell and Boyd, 1995; non Aviculopectinidae Newell and Boyd, 1995)

Genus *Girtypecten* Newell, 1938 [emended]

Type species: *Aviculopecten sublaqueatus* Girty, 1908; original designation by Newell (1938: 77).

Emended diagnosis.—Shell subcircular, prosocline or acline, left valve more convex than right, auricles elongate, sometimes acuminate, well differentiated from disc; disc surface marked only with simple, coarse, widely spaced primary costae (unicostate) or having ranks of new costae added by

intercalation during growth (multicostate). Costae and similarly spaced commarginal ridges cross each other and produce a reticulated ornamentation of squares and rectangles; left valve often with costal spines rising from the ridge intersections, distally pointed, circular in cross section with an innerside (ventral) or outerside (dorsal) groove; right valve spineless. Alivincular ligament with posteriorly or anteriorly elongate asymmetrical resilifer.

Discussion.—Newell and Boyd (1995) employed terms such as multicostate, unicostate, and uniplicate in describing radial ornamentation in pectinoid bivalves and utilized these characters for their diagnoses and classification. They brought multicostate into the definition of the genus *Girtypecten* Newell, 1938 as an important character, but they did not mention the existence of unicostate species, such as *Girtypecten spinosus* Chen, 1962. Therefore, it is necessary to emend the diagnosis of *Girtypecten* to accommodate both multicostate and unicostate species. A new subgenus *Girtypecten (Sinopecten)* is here proposed for the unicostate species of *Girtypecten*, while *Girtypecten (Girtypecten)* is appropriate for multicostate species such as the one described by Newell and Boyd (1995: 41).

The genus *Acanthopecten* is also characterized by distally pointed spines, which, however, are located between ribs and are externally concave, unlike the pyramidal costal spines of *Girtypecten*.

Subgenus *Girtypecten (Girtypecten)* Newell, 1938

Type species: *Aviculopecten sublaqueatus* Girty, 1908; original designation by Newell (1938: 77); Guadalupian (Middle Permian), Texas.

Species included: *Pseudomonotis fimbriata* Gemmellaro, 1896 (Gemmellaro 1896: 204, pl. 23: 16–19; Permian Sosio beds, Sicily, Italy); *Girtypecten beipeiensis* Liu, 1976 (Liu 1976: 183, pl. 14: 1; Changhsingian, Late Permian, Sichuan, China); *Girtypecten* cf. *spinosus* Chen, 1962 (Zhang et al. 1977: 510, pl. 197: 5; Late Permian, Guangxi, China; the closest species of this multicostate form seems to be *G. qinghaiensis* Lu, 1979 rather than *G. spinosus*, because the latter is an unicostate species); *Girtypecten qinghaiensis* Lu, 1979 (in Zhang et al. 1979: 227, pl. 58: 1; Middle Permian, Qinghai, China); *Girtypecten sublaqueatus* (Girty, 1908) (see Newell and Boyd 1995: 41, fig. 30: 1–7; Upper Wolfcampian–Upper Guadalupian, West Texas and Wyoming).

Stratigraphic and geographic range: Upper Wolfcampian–Changhsingian; Italy, China, and USA.

Diagnosis.—Multicostate *Girtypecten* with left valve often having pyramidal costal spines rising from the ridge intersections, distally pointed, with a ventral groove along the innerside; resilifer asymmetrical, posteriorly elongate.

Subgenus *Girtypecten (Sinopecten)* nov.

Type species: *Girtypecten (Sinopecten) newelli* sp. nov.; Tournaisian (Early Carboniferous), Guizhou, China.

Derivation of the name: Prefix *Sino* from Latin *Sinae*, oriental people mentioned by Ptolemy, and now generally applied to things pertaining to China and the Chinese; and the stem of *Pecten*, from the name of a Cenozoic scallop, and now widely applied to forming scallop names.

Species included: *Acanthopecten chitralensis* Reed, 1925 (Reed 1925: 56, pl. 10: 4, Early Permian, India and Pakistan); *Girtypecten spinosus* Chen, 1962 (Chen 1962: 194, pl. 1: 2a, b; Wuchiapingian, Late Permian, Guizhou, China); *Girtypecten* cf. *spinosus* (Lu, in Zhang et al. 1979: 228, pl. 58: 5; Maokouan, Middle Permian, Qinghai, China); *Girtypecten* cf. *spinosus* (Yin 1982: 354, pl. 30: 9; Changhsingian, Late Permian, Sichuan, China); *Girtypecten carboniferus* Zhang, 1987 (Zhang 1987: 277, pl. 1: 7, 8, 10, 15, 16; early Mapingian, Late Carboniferous, Guangxi, China).

Stratigraphic and geographic range: Tournaisian–Changhsingian; India, Pakistan, and China.

Diagnosis.—Unicostate *Girtypecten* with left valve often having pyramidal costal spines rising from the ridge intersections, distally pointed, with a dorsal groove along the outerside; resilifer asymmetrical, anteriorly elongate. Besides the unicostate ornamentation, the new subgenus differs from *Girtypecten (Girtypecten)* in having resilifer positioned before the beak and costal spines with dorsal groove.

Description.—Shell suborbicular, nearly acline or slightly prosocline; auricles elongate, well differentiated from disc by umbonal fold; posterior auricle acute; only with simple, coarse, rounded primary costae, which are intersected by similarly spaced commarginal ridges to form reticulated ornamentation; the interspaces smooth, lacking costellae and/or lines; left valve often with costal spines rising from the ridge intersections, distally pointed, circular in cross section with a dorsal groove along the outerside; ligament area aviculopectinid-type, with a large resilifer, most of the resilifer lies before the beak.

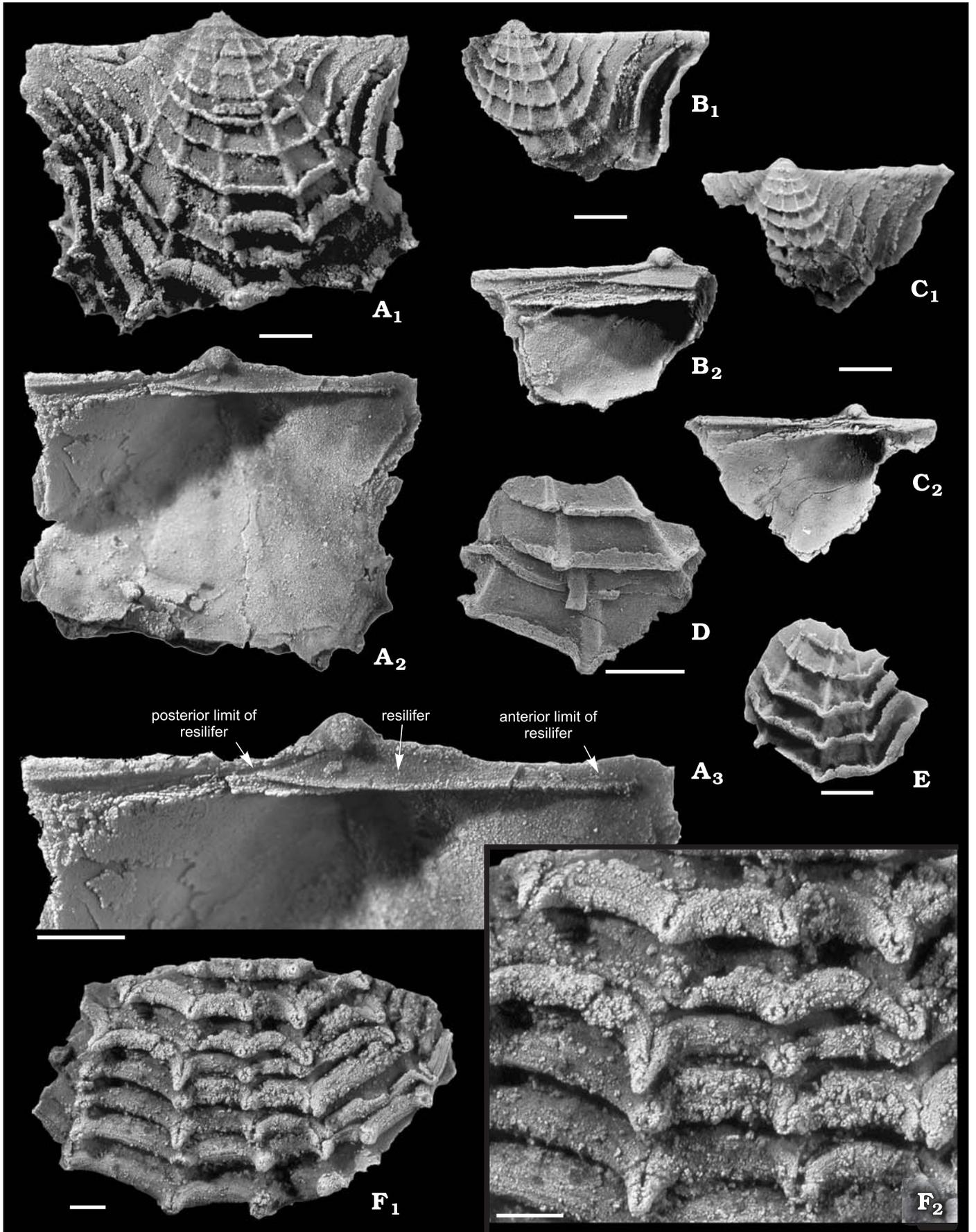
Discussion.—As mentioned above, the resilifers in our specimens are mostly positioned before the beak (Fig. 2A₂, A₃, B₂, C₂). Among them, the anterior part of the resilifer of B₂ is broken, the resilifer of C₂ is not well preserved, only A₃ is in best state of preservation. The resilifer of A₃ is relatively large, having a breadth of nearly 4 mm, with its larger part (3/4) before the beak. This is just the opposite of *Girtypecten sublaqueatus* (Girty, 1908), the type species of *Girtypecten (Girtypecten)* Newell, 1938. In the latter, the greater part of the resilifer lies behind the beaks (Newell 1938: 77, pl. 13: 11; Newell and Boyd 1995, fig. 30: 2b, 4a, 6a). In addition, the costal spines on the left valve of *G. (G.) sublaqueatus* have a ventral groove along the innerside (Newell 1938: fig. 29). On the contrary, in our specimens the groove on costal spines is dorsally situated (Fig. 2F).

Girtypecten (Sinopecten) newelli sp. nov.

Fig. 2.

Derivation of the name: The new species is dedicated to the late Professor Norman D. Newell of the American Museum of Natural History in recognition of his exemplary studies of Paleozoic pectinoid bivalves. He contributed to the knowledge of the Bivalvia and paleontology for nearly 70 years.

Types: Holotype, PKUM02-0085 (Fig. 2A), is a nearly complete left valve, showing both exterior ornamentation and asymmetrical resilifer. There are five paratypes, PKUM02-0086–PKUM02-0090 (Fig. 2B–F), with additional details of spines and reticulated ornamentation. No right valve has been found, supposedly due to the normally thinner nature of



its shell and being easily damaged during the acid treatment. Similar preservation bias was observed in the type species by Newell and Boyd (1995) who suggested, in consequence, that the genus probably had paradiscordant valves.

Type locality and horizon: Top part of the Tournaisian Muhua Formation at Muhua, Changshun, Guizhou, China.

Diagnosis.—*Girtypecten* with auricles subequal in length; disc covered only by five simple, coarse, wide spaced primary costae, which are intersected by slightly closer spaced commarginal ridges to form reticulated ornamentation; strong costae and ridges maintained throughout growth; the interspaces smooth, broad, lacking costellae and/or lines; pyramidal costal spines distally pointed, with a dorsal groove along the outside; resilifer anteriorly elongate. From *G. spinosus* Chen, 1962 new species differs in being smaller and in having subequal auricles and up to five radial costae. It is differentiated from *G. carboniferous* Zhang, 1987 by fewer costae and well defined spines, and from *G. chitralensis* Reed, 1925 by evidently fewer costae.

Description.—Shell small, probably less than 10 mm in length, nearly acline or slightly prosocline, weakly inflated. Auricles elongate, nearly equal in length, each with acute end above sinus, well differentiated from disc by umbonal fold, and without radial ornament. Beak of the left valve subcentral and orthogyrate, projects slightly beyond the hinge; the hinge margin straight, subequal to shell length. Disc subcircular, surface covered by five simple, coarse, rounded, wide spaced primary costae, set at subequal distances apart and of equal relief; costae crossed at regular intervals by 12 or more, strong, slightly closer commarginal ridges, which continue across auricles and fade away near dorsal margin; strong commarginal ridges are maintained throughout growth in all six specimens. Crossing of costae and concentric ridges produces a reticulated ornamentation; no new ranks of costae and/or lines added with growth, so interspaces between costae are smooth. Costal spines are distally pointed, rising from ridge intersections, circular in cross section, with a dorsal groove along the outside. Ligament area with a large resilifer, having a breadth of nearly 4 mm, with greater part (3/4) of resilifer anterior to beak. Right valve and shell structure unknown.

Measurements.—The holotype restored height is 7 mm; restored length 9 mm.

Discussion.—The new species is similar to *Girtypecten spinosus* (see Chen 1962: 194, pl. 1: 2a, b) in general form and ornamentation. Both of them have only a few widely spaced primary costae and commarginal ridges and should be in-

cluded in the new subgenus. Our specimens differ in being very small, possessing subequal auricles, and surface marked with only five radial costae. *G. spinosus* has seven costae and evidently a larger posterior auricle. *G. carboniferous* Zhang, 1987 (Zhang 1987: 277, pl. 1: 7, 8, 10, 15, 16) from the Late Carboniferous Maping Formation of Guangxi, China resembles the present species in lacking secondary radial costellae and belongs to the new subgenus, but the former has 10 costae without spines at the intersection of the radial and concentric ornamentation, and smaller anterior auricle. *G. chitralensis* Reed, 1925 (Reed 1925: 56, pl. 10: 4) from the Early Permian of India and Pakistan is also classified in the new subgenus, but it is easily distinguished by possessing more numerous radial costae (16–17).

Occurrence.—Conodont Lower *Siphonodella crenulata* Zone, near the top of the Muhua Formation of the Lower Carboniferous (Tournaisian) at Muhua, Changshun County, Guizhou Province, China.

Conclusions

The study of species included in the genus *Girtypecten* shows that they form two different groups at the subgeneric rank. One group of species is characterized by multicostate ornamentation, posteriorly elongate resilifer, and costal spines distally pointed, with a dorsal groove along the innerside. Members of the second group are unicostate, possess anteriorly elongate resilifer, and costal spines with an outside groove. The first group represents subgenus *Girtypecten* (*Girtypecten*) whereas the latter belongs to *Girtypecten* (*Sinopecten*) subgen. nov. Silicified material described here from the late Tournaisian of Muhua (Guizhou Province, China) represents a new species *G. (S.) newelli*. It is the oldest known representative of *Girtypecten* which was known till now almost exclusively from Permian.

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← Fig. 2. Aviculopectinid bivalve *Girtypecten* (*Sinopecten*) *newelli* subgen. et sp. nov. from the Tournaisian Muhua Formation of Guizhou, China. **A.** Holotype PKNM02-0085, a nearly complete left valve in exterior view (A_1), showing unicostate, reticulated ornamentation, and in interior view (A_2) showing alivincular external ligament and details of asymmetrical resilifer (A_3). **B.** PKUM02-0086, an incomplete left valve in exterior (B_1) and interior (B_2) views. **C.** PKUM02-0089, an incomplete left valve in exterior (C_1) and interior (C_2) views. **D.** PKUM02-0088, SEM image of exterior of left valve fragment showing the reticulated ornamentation. **E.** PKUM02-0090, exterior of left valve fragment, showing reticulated ornamentation and the stronger commarginal ridges. **F.** PKUM02-0087, exterior of left valve fragment (F_1) and enlargement (F_2) showing details of costal spines, which have a dorsal groove along the outside. Scale bars 1 mm.

References

- Baliński, A. 1999. Brachiopods and conodonts from the Early Carboniferous of South China. *Acta Palaeontologica Polonica* 44: 437–451.
- Baliński, A. and Sun, Y. 2005. A new Early Carboniferous micro-productid brachiopod from South China. *Palaeontology* 48: 447–454.
- Chen, C.-Z. 1962. Lamellibranchiata from the Upper Permian of Ziyun, Guizhou (Kueichow) [in Chinese with English summary]. *Acta Palaeontologica Sinica* 10: 191–204.
- Gemmellaro, G.G. 1896. La fauna dei Calcari con *Fusulina* della Valle del Fiume Sosio nella Provincia di Palermo, Pelecypoda. *Giornale di Scienze Naturali ed Economiche Palermo* 21: 183–230.
- Girty, G.H. 1908. The Guadalupian fauna. *U.S. Geological Survey Professional Paper* 58: 1–651.
- Hind, W. 1901–1905. *A Monograph of the British Carboniferous Lamellibranchiata*, Vol. 2. 222 pp. The Palaeontographical Society, London.
- Hou, H., Ji, Q., Wu, X., Xiong, J., Wang, S., Gao, L., Sheng, H., Wei, J., and Turner, S. 1985. *Muhua Section of Devonian–Carboniferous Boundary Beds* [in Chinese with English summary]. 226 pp. Geological Publishing House, Beijing.
- Liu, L. 1976. *Girtypecten* [in Chinese]. In: Editorial Group on “The Lamellibranch Fossils of China” of Nanjing Institute of Geology and Palaeontology (ed.), *The Lamellibranch Fossils of China*, 182–183. Science Press, Beijing.
- Meek, F.B. and Hayden, F.V. 1864. Palaeontology of the Upper Missouri. *Smithsonian Contributions to Knowledge* 14 (172): 1–135.
- Newell, N.D. 1938. Late Paleozoic Pelecypods: Pectinacea. *Kansas Geological Survey* 10: 1–123.
- Newell, N.D. 1969. Family Aviculopectinidae. In: R.C. Moore and C. Teichert (eds.), *Treatise on Invertebrate Paleontology. Part N, Mollusca 6, Bivalvia*, N335–N341. Geological Society of America and University of Kansas Press, Lawrence.
- Newell, N.D. and Boyd, D.W. 1995. Pectinoid bivalves of the Permian–Triassic crisis. *Bulletin of American Museum of Natural History* 227: 1–95.
- Paul, H. 1937. Die Transgression der Viséstufe am Nordrande des Rheinischen Schiefergebirges. *Abhandlungen der preussischen geologischen Landesanstalt, Neue Folge* 179: 1–117.
- Phillips, J. 1836. *Illustrations of the Geology of Yorkshire; or a Description of the Strata and Organic Remains: Accompanied by a Geological Map, Sections, and Diagrams, and Figures of the Fossils. Part 2. The Mountain Limestone District*. 253 pp. John Murray, London.
- Rafinesque, C.S. 1815. *Analyse de la nature ou tableau de l'Univers du des corps organisés*. 225 pp. C.S. Rafinesque, from the Press of Jean Barravecchia, Palermo.
- Reed, F.R.C. 1925. Upper Carboniferous fossils from Chitral and the Pamirs. *Palaeontologia Indica, new series* 6: 1–154.
- Richter, E. and Amler, M.R.W. 1994. Bivalven und Rostroconchien aus dem Velberter Kalk von Velbert (Unter-Karbon; Bergisches Land). *Geologica et Palaeontologica* 28: 103–139.
- Roberts, J. 1963. A Lower Carboniferous fauna from Lewinsbrook, New South Wales. *Journal and Proceedings of the Royal Society of New South Wales* 97: 1–29.
- Sun, Y., Baliński, A., Ma, X., and Zhang, Y. 2004. New bizarre micro-spiriferid brachiopod from the Early Carboniferous of China. *Acta Palaeontologica Polonica* 49: 267–274.
- Sun, Y., Ma X., Baliński A., and Zhang, Y. 2004. A new meristid brachiopod genus from the Lower Carboniferous of Guizhou, China. *Journal of Paleontology* 78: 204–244.
- Yang, Z.-R. 1983. Bivalvia [in Chinese]. In: Regional Geological Survey Team of Xinjiang Autonomous Region, Xinjiang Institute of Geological Sciences, Bureau of Geology and Mineral Resources of Xinjiang Autonomous Region, and Geological Survey Department, Bureau of Petroleum of Xinjiang Autonomous Region (eds.), *Paleontological Atlas of Northwest China, Volume of Xinjiang, Vol. 2*, 386–448. Geological Publishing House, Beijing.
- Yin, H. 1982. Uppermost Permian (Changhsingian) Pectinacea from South China. *Rivista Italiana di Paleontologia e Stratigrafia* 88: 337–386.
- Zhang, R.-J., Wang, D.-Y., and Zhou, Z.-R. 1977. Bivalvia [in Chinese]. In: Hubei Institute of Geology, Bureau of Geology and Mineral Resources of Henan Province, Bureau of Geology and Mineral Resources of Hubei Province, Bureau of Geology and Mineral Resources of Hunan Province, Bureau of Geology and Mineral Resources of Guangdong Province, and Bureau of Geology and Mineral Resources of Guangxi Autonomous Region (eds.), *Paleontological Atlas of Central South China, Vol. 2*, 470–533. Geological Publishing House, Beijing.
- Zhang, Y.-X. 1987. The characters of the bivalves near the Carboniferous–Permian boundary in Longlin, Guangxi [in Chinese with English summary]. *Bulletin of the Yichang Institute of Geology and Mineral Resources* 11: 267–284.
- Zhang, Z.-M., Lu, Y.-J., and Wen, S.-X. 1979. Late Paleozoic Bivalvia [in Chinese]. In: Qinghai Institute of Geology and Nanjing Institute of Geology and Palaeontology (eds.), *Paleontological Atlas of Northwest China, Volume of Qinghai Province*, 225–230. Geological Publishing House, Beijing.
- Ziegler, W. and Sandberg, C. 1984. Important candidate sections for stratotype of conodont based Devonian–Carboniferous boundary. In: E. Paproth and M. Streeb (eds.), *The Devonian–Carboniferous boundary. Courier Forschungsinstitut Senckenberg* 269: 231–239.
- Ziegler, W., Ji, Q., and Wang, C.-Y. 1988. Devonian–Carboniferous boundary—final candidates for a stratotype section. *Courier Forschungsinstitut Senckenberg* 100: 15–19.