

## Early Cambrian stenothecoid molluscs from China

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**Abstract** – A new species of *Stenothecoides*, *S. yochelsoni* sp. nov., is described from the Early Cambrian Huangshandong Member of the Tongying Formation in Eastern Yangtze Gorge, western Hubei, China. This species is one of the new members of the Yangtze micromolluscan fauna. The occurrence indicates that the first appearance of *Stenothecoides* can be dated to the earliest Cambrian, and it is probably the earliest record of the genus. Two other Early Cambrian species, *Bagenovia* cf. *sajanica* Horny and *Stenothecoides* sp., are described from the Xidashan Formation of Kuruktag, Xinjiang, China.

### INTRODUCTION

In 1979, the writer while making a study of the earliest Cambrian molluscs from the Eastern Yangtze Gorge of western Hubei, China, recovered from acid-residues from the Huangshandong Member of the Tongying Formation of the Tianzhushan Section, an undescribed species of *Stenothecoides*. The Tianzhushan Section is located at the west side of the Dianziliang Primary School at Tianzhushan, Liantuo, about 25 km northwest of the city of Yichang. The Huangshandong Member, a richly fossiliferous unit, is composed mainly of purplish brown arenaceous-rudaceous dolomites, intercalated with striped siliceous phosphorites, about 1.88 m in thickness. It conformably overlies the Precambrian Baimatuo Member of the Tongying Formation and is overlain disconformably by the Early Cambrian Shuijingtuo Formation (Zhao *et al.* 1980).

The material in the arenaceous-rudaceous dolomites was preserved in association with other elements of the Yangtze micromolluscan fauna, such as *Tchangsihilton notabilis* Yu, *Sinoconus clypeus* Yu, *Yangtzeconus priscus* Yu, *Obtusconus rostriptutea* (Qian), *Purella tianzhushanensis* Yu, *Igorella hamata* Yu, *Archaeospira ornata* Yu, *Maclurites hubeiensis* Yu and *Heraultipegma yunnanense* He and Yang (Yu 1979, 1984a, b, 1985, 1987, 1990; Qian, Chen and Chen 1979; He and Yang 1982). Of all the micromolluscs, the most interesting and characteristic forms are *Y. priscus*, *A. ornata*, *O. rostriptutea*, *I. hamata* and *H. yunnanense*. These fossils are widely distributed in the Meishucunian Stage in eastern Yunnan, western Sichuan and in corresponding beds in many parts of the Yangtze Platform.

*Bagenovia* cf. *sajanica* Horny and *Stenothecoides* sp. were collected in 1978 by Zhang Sengui, Nanjing

Institute of Geology and Palaeontology, Academia Sinica, from the base of the Early Cambrian Xidashan Formation on the northern slope of Mohurshan of the Kuruktag Mountains, Xinjiang, China. On the basis of palaeontological and lithological characteristics, the Early Cambrian of this area has been divided into two formations: in ascending order, the Xishanbuluk Formation and the Xidashan Formation (Zhang 1983).

The Xidashan Formation is about 88 m in thickness (Zhang 1983). It is composed chiefly of blackish-grey, arenaceous limestones and argillaceous limestones with a basal bed of purplish-grey, arenaceous, lenticular limestone. The basal bed yields a rich fauna of trilobites and archaeocyathids and some monoplacophorans, gastropods, brachiopods and hyolithids. Stenothecoids are rare within the fauna of the Xidashan Formation, only three specimens being obtained; however these include two species placed in two genera, namely: *Bagenovia* cf. *sajanica* Horny and *Stenothecoides* sp. In association with them are the trilobites *Metaredlichioides rectangularis* Zhu and Lin, *Chengkouia xinjiangensis* Zhu and Lin (Zhu and Lin 1983); the archaeocyathids *Aldanocyathus* cf. *belvederi* (Rozanov), *Coscinocyathus xinjiangensis* Zhang (Zhang 1983) and the molluscs *Eocyrtolites radiatus* Yu and *Cyrtodiscus? kuruktagensis* Yu (Yu, 1986). Among the associated fossils, the genera *Metaredlichioides* and *Chengkouia* are zonal fossils of the *Metaredlichioides*–*Chengkouia* zone. This zone is widely distributed in the Middle Tsanglangpu Stage of southeastern Shaanxi, northwestern Sichuan and eastern Guizhou (Zhou and Yuan, 1980). Therefore, the basal part of the Xidashan Formation is considered to be middle Early Cambrian, equivalent to the Middle Tsanglangpu Stage in eastern Southwest–Central

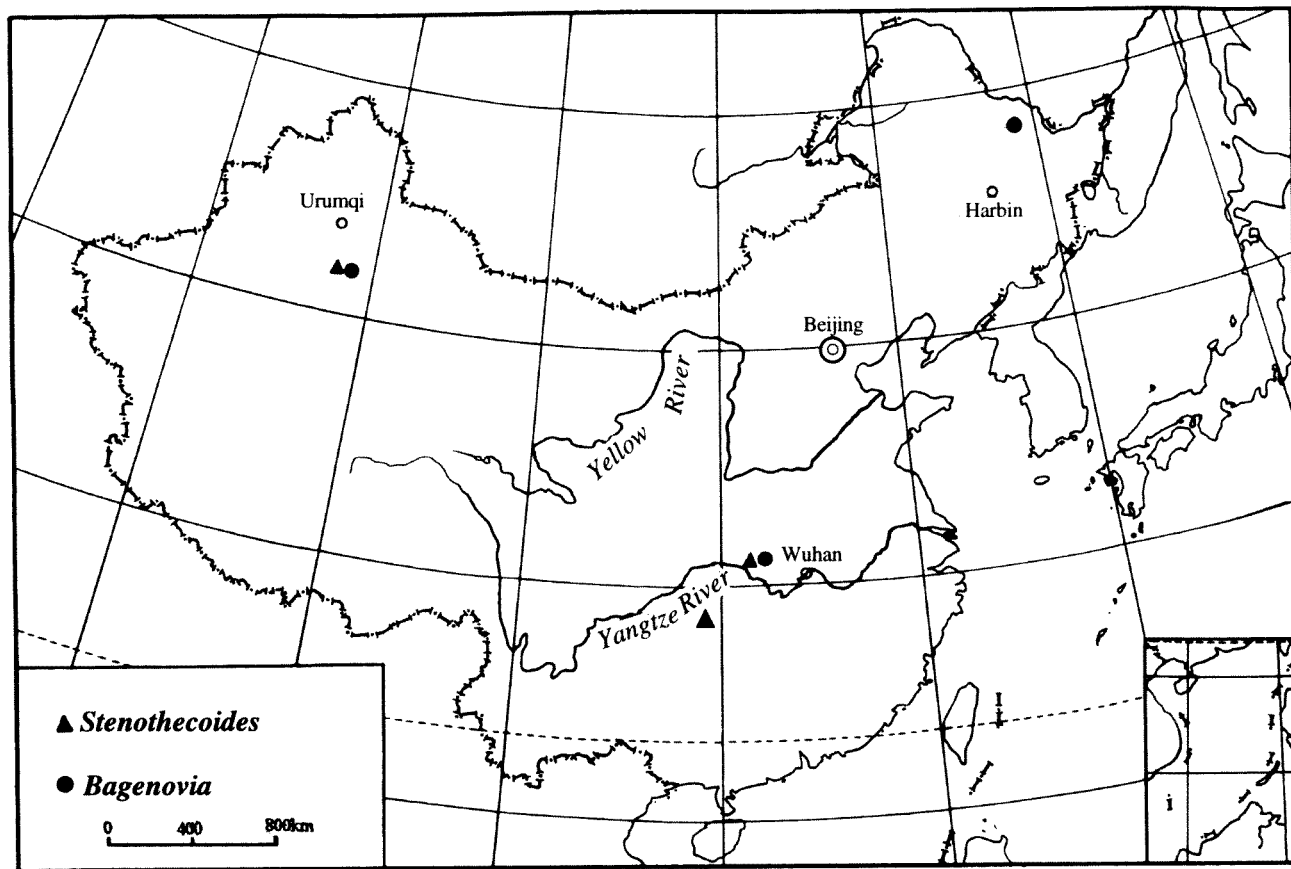


Figure 1 Sketch map showing the fossil localities.

China (Zhang 1983; Zhu and Lin 1983; Yu 1986).

Specimens described in this paper are all deposited at the Nanjing Institute of Geology and Palaeontology, Academia Sinica.

#### STENOTHECOIDES AND BAGENOVIA

*Stenothecoides* has mainly been reported from the Early Cambrian of east Greenland (Poulsen 1932), Laborador and Yukon Region of Canada (Resser 1938, Yochelson 1968, 1969), Siberia (Horný 1957; Missarzhevsky in Rozanov and Missarzhevsky 1966; Aksarina 1968, Aksarina and Pelman 1978), central Kazakhstan (Koneva 1979) and western Mongolia (Zhegallo 1982), and the Middle Cambrian of United States (Walcott 1884, 1886; Robison 1964), British Columbia of Canada (Rasetti 1954), central Kazakhstan (Koneva 1979) and central North Greenland (Peel 1988). During the last two decades, this genus has been extensively found in China. It has been collected from the Huangshandong Member of the Early Cambrian Tongying Formation of Eastern Yangtze Gorge, western Hubei, the Early Cambrian Xidashan Formation of Kuruktag, Xinjiang and the Early Cambrian Tianheban Formation of Xianfeng of Hubei and other places (Figure 1). Of the material from these formations, that from the Eastern Yangtze Gorge is a bivalved, asymmetrically

inequivalve form. According to previous records, most species of the genus *Stenothecoides* occur only as a single non-articulated valve. Only a few species were preserved in a bivalve condition, e.g., *Stenothecoides knighti* Yochelson (1969: 59–60, fig. 2) from the Early Cambrian of Yukon, Canada, *S. siberica* (Aksarina) (Aksarina and Pelmen 1978: 115, pl. XVII, figs. 4–6) from the Early Cambrian Lenian Stage of Siberia, *S. bellus* Koneva (1979: 26, pl. V, fig. 1) from the Early Cambrian Lenian Stage of central Kazakhstan and *Stenothecoides* sp. (Yochelson 1969: 51, fig. 1) from the upper Early Cambrian of Siberia.

So far as I am aware, most of the Early Cambrian species of *Stenothecoides* are associated with trilobites or archaeocyathids. However, the new species of *Stenothecoides* described herein is found with a micromolluscan faunas that predates the trilobites. It therefore possibly represents the earliest record of *Stenothecoides*. Therefore, the first appearance of *Stenothecoides* can be traced back to the very earliest Cambrian. Furthermore, it is a new member of the Yangtze micromolluscan fauna, which occurs in the earliest Cambrian Meishucunian Stage of the Yangtze Platform in China. As such it is the first biomineralisation event in the evolutionary history of invertebrates in the Phanerozoic. It also represents the first stage of the diversification in the history of Phylum

Mollusca. The fauna consists of the genera *Yangtzechiton* and *Luyanhaochiton* (Polyplacophora); *Yangtzeimerisma* and *Merismoconcha* (Merismoconchia); *Eosoconus* and *Archaeotremaria* (Monoplacophora); *Yangtzespira* and *Archaeospira* (Gastropoda); *Yangtzedonta* (Bivalvia) and *Heraultipegma* (Rostroconchia) (Yu 1979, 1984 a, b, 1985, 1987, 1990; Jiang in Luo *et al.*, 1982; He and Yang 1982). The new species of *Stenothecoides* described herein, like other Meishucunian micromolluscs, is characterized by its tiny shell. In general, the usual size of *Stenothecoides* is 4–10 mm in length, though specimens can reach a length of 14 mm or so. However, the Meishucunian species is 1.1 mm long.

The discovery of *Stenothecoides* from the Meishucunian Stage provides important material evidence for study of the origin of Stenothecoida and the evolutionary relationship with other molluscs. Of special interest is that most Early Cambrian species of *Stenothecoides* possessed a distinct ridge or fold on the dorsal valve or right valve of variable expression (Rasetti 1954; Yochelson 1969; Koneva 1979; Peel 1988), while in the Middle Cambrian, only a few species have a ridge on the valve. The new species of *Stenothecoides* has a thick ridge on the dorsal valve, occupying more than one-third the width of the valve. These characteristics indicate that this species is a primitive species of the genus *Stenothecoides*.

It is worth noting that the upper part of the Huangshandong Member bears a rich micromolluscan fauna. The polyplacophorans, monoplacophorans, gastropods and rostroconchs either lived a benthonic, creeping life within the subtidal and intertidal zone or were infaunal deposit feeders. Most shells are preserved incompletely, some overlap with each other, while some are fragmentary. These characters show that they were deposited in the turbulent flow of a shallow sea or even in the littoral zone.

One of the forms of stenothecoids in the Xidashan Formation at Kuruktag, Xinjiang is *Bagenovia* cf. *sajanica*. Horný in 1957 named the genus taking *Bagenovia sajanica* Horný as the type species. *Bagenovia sajanica* was first reported from the Early Cambrian of west Sayan, Siberia. This genus has been found in the Early Cambrian of Siberia (Radugin 1937; Horný 1957, Sytchev 1960; Aksarina and Pelmen 1978) and the Early Cambrian Lenian Stage of central Kazakhstan (Koneva 1976, 1979). In China, it has been found in the Early Cambrian Xidashan Formation of Kuruktag, Xinjiang, the Early Cambrian Wuxinzheng Formation of Yichun, Heilongjiang and the Early Cambrian Shipai Formation of Suizhou, Hubei. Two specimens were procured from the Xidashan Formation, including one covered with

radiating costae and one well-preserved internal mould with internal structures.

The internal structures of the valve consists of four pairs of asymmetrically arranged ridge-like impressions and three concentric impressions visible on the dorsal valve of the internal mould (Figure 3). The structure may correspond to anatomical features, but the soft tissues of stenothecoids are quite unknown. Since they have no expression of the outer surface and the direction of the ridge-like impressions are the reverse of the radiating costae, it seems likely that they reflect the impressions of some organs of the animal. The function of the internal structures is, however, difficult to interpret. It might be assumed that they either had a direct effect on their free movement or, alternatively, relate to the control of the opening and closing of the valves or some other physiological action, perhaps representing muscle attachments (Yochelson 1969).

The taxa *Bagenovia* cf. *sajanica* and *Stenothecoides* sp. co-occur with shallow and warm water fossils, such as archaeocyathids and the trilobite *Metaredlichoides* and *Chengkouia*. Most specimens of archaeocyathids, trilobites, brachiopods and molluscs are preserved incompletely, some of them disorderly preserved in the limestone, others as fragments (Zhang 1983). These characteristics indicate that the fauna reflects a shallow water carbonate facies, perhaps deposited in a epicontinental sea. Their associated sediments, arenaceous limestone, are characteristic of shallow water deposition.

## SYSTEMATIC PALAEOLOGY

### Class Stenothecoida Yochelson, 1968

#### Superfamily Cambriaceae Horný, 1957

#### Family Cambriidae Horný, 1957

#### Genus *Stenothecoides* Resser, 1938

#### *Stenothecoides yochelsoni* sp. nov.

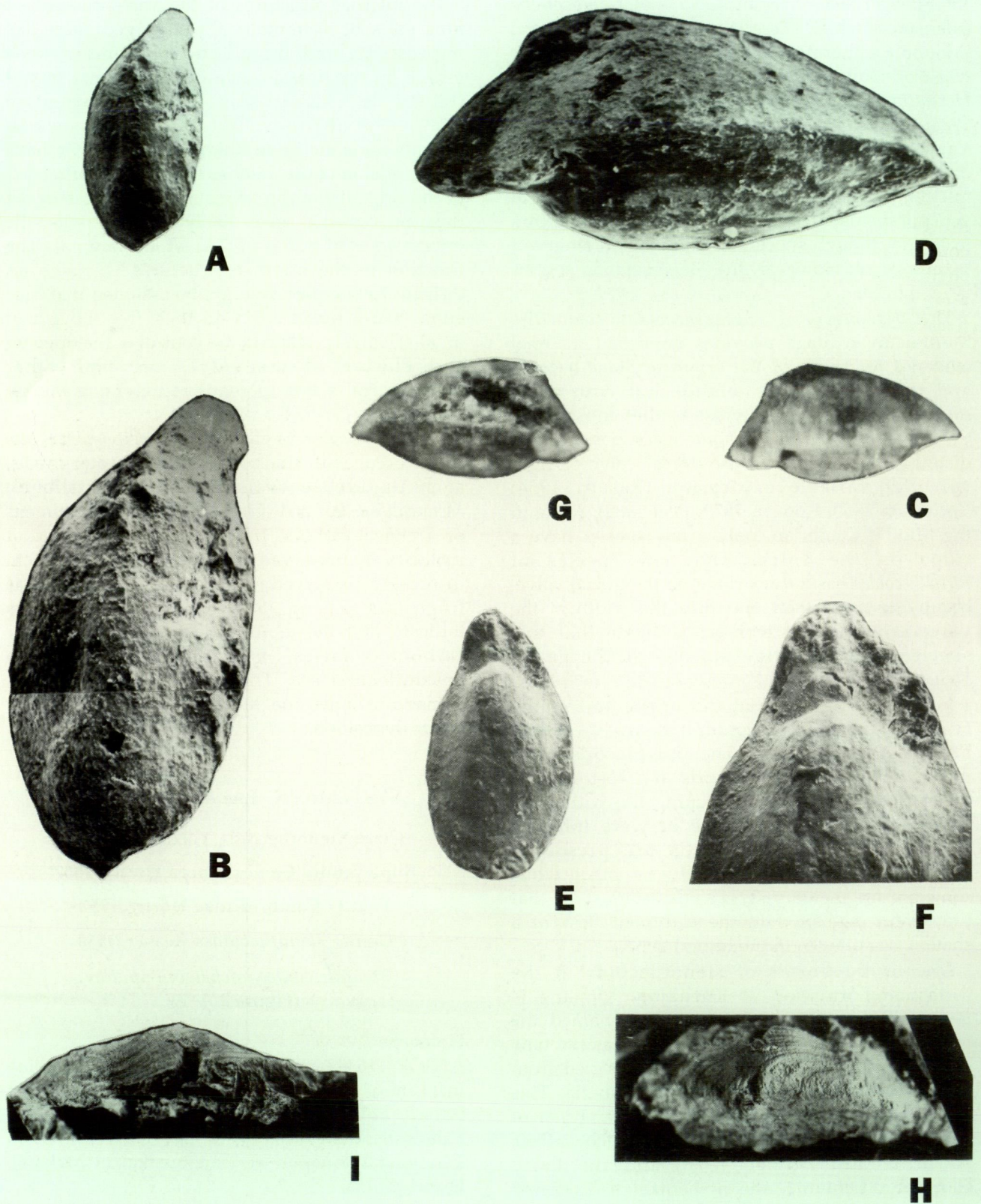
(Figure 2 A–F)

#### Holotype

NIGP 116387, in the collections of the Nanjing Institute of Geology and Palaeontology, Academia Sinica, collected by the writer in 1978 from Huangshandong Member of the Early Cambrian Tongying Formation at Tianzhushan of Yichang, Hubei, China.

#### Diagnosis

Tiny, bivalved, asymmetrically inequivalved, narrowly elongated, about one-third as wide as long. Two valves closed very tight, commissural line curving slightly downward. Conjoined line not known in detail. Apical area high, curves



**Figure 2** A-F. *Stenothecoides yochelsoni* sp. nov. NIGP 116387, Huangshandong Member of Early Cambrian Tongying Formation, Tianzhushan of Yichang, Hubei, A. plan view, x 40. B. enlargement of dorsal valve, showing thick ridge and other internal structures, x 80. C. left side view, x 40. D. enlargement of left side, showing the commissural line, x 90. E. plan view, x 40. F. enlargement of ventral plan view, x 80. G. right side view, x 40. H-I. *Stenothecoides* sp. NIGP 116391, Xidashan Formation, Kuruktag Mountains, Xinjiang, plan and lateral views, x 4.

anticlockwise during growth, strongly protruding and overhanging adapical margin. A prominently thick ridge starting from apical area, extending and widening to the abapical margin. Ventral valve smaller and lower than the dorsal one. Apex large, strongly rounded.

### Description

Shell very tiny, 1.1 mm long, 0.45 mm high and 0.5 mm wide; bivalved, asymmetrically inequivalved and narrowly elongated, about one-third as wide as long. Two valves closed very tight, commissure of valves simple, commissural line curving slightly downward, in particular anteriorly and posteriorly. Conjoined line not known in detail. Apical area strongly arched. Dorsal valve high, strongly arched, the apex being at about one-third of the length. Apical area high, strongly protruding and overhanging the adapical margin and curving anticlockwise during growth. A prominently thick ridge starting from the apical area, extending backward for about two-thirds the total length and then abruptly expanding and widening to the abapical margin. The ridge is bordered by two narrow furrows, occupying about one-third the width at the middle part of the dorsal valve and then almost the whole part at the end. The lateral slopes slightly depressed and then oblique to the lateral margins.

Ventral valve smaller and lower than the dorsal valve. Apex large, strongly rounded and convex, gradually sloping toward the abapical margin. The lateral slopes of the apex abruptly convex and then flatten to the margin.

The surface character is unknown, except for some granules in the dorsal valve.

### Remarks

Judging from the general morphological characters of the shell, *Stenothecoides yochelsoni* sp. nov. is similar to *S. knighti* Yochelson (1969: 59–60, figure 2) from the Early Cambrian of Yukon, Canada. They share such common features as: the asymmetrically bivalve shell, the possession of a prominent ridge on the dorsal valve; and simple commissure of the valves. However, there are still great differences between *S. yochelsoni* and *S. knighti*, essentially in the shell being narrowly elongated in dorsal valve view in the former, but subelliptical in dorsal valve view in the latter; in *S. yochelsoni* the commissural line is curving slightly downward, whereas in *S. knighti* the commissural line is curving slightly upward; in the dorsal valve of *S. yochelsoni* the apical area is strongly protruding and overhanging the adapical margin, but in *S. knighti*, the apical area is low, slightly overhanging the ventral valve; in the former, the dorsal valve is strongly arched and has a prominently thick ridge beginning from the apical

area, extending backward for about two-thirds the total length and then abruptly expanding and widening to the abapical margin, while in the latter, the dorsal valve is low and has a narrow ridge; in *S. yochelsoni* the ventral valve is small and low, with a large and rounded apical area, but in *S. knighti*, the ventral valve is relatively convex and with a curved ridge.

In possessing a narrowly elongate valve, *S. yochelsoni* is closely related to *Stenothecoides* sp. (Yochelson 1969: 51, figure 1) from the upper Lower Cambrian of Siberia, but it is strongly distinguished from Siberian species in the more convex dorsal valve, the less convex ventral valve, in the presence of a distinctly thick ridge on the dorsal valve and the more protruded apical area.

In some respects this species resembles *Stenothecoides bellus* Koneva (1979: 26, pl. V, fig. 1) from the Early Cambrian Lenian Stage of central Kazakhstan. It differs from the latter in the more narrowly elongated shell; the thicker ridge, the more protruded apical area and in the smaller ventral valve.

### Etymology

The specific name is in honour of Dr Ellis L. Yochelson of the Department of Paleobiology, National Museum of Natural History, Washington D.C., U.S.A.

### Occurrence

Upper part of the Huangshandong Member of the Early Cambrian Tongying Formation at Tianzhushan of Liantuo, Yichang, Western Hubei.

### *Stenothecoides* sp. (Figure 2 H–I)

### Material

A single specimen, NIGP 116391, in the collections of the Nanjing Institute of Geology and Palaeontology, Academia Sinica. Collected by Zhang Sen-gui in 1978 from the base of the Early Cambrian Xidashan Formation on the northern slope of the Mohurshan of the Kuruktag Mountains, Xinjiang, China.

### Description

Shell of large size, 13 mm long and 6 mm wide; asymmetric, fairly elongately ovate in plan view. Apex sharply pointed, distinctly protruding and overhanging the adapical margin and curving anticlockwise during growth. In plan view the valve is convex and tends to be most pointed at the adapical margin; narrowly rounded abapical margin and somewhat bent to right. Sides unequally convex, with the greatest width of the valve at about one-third of the length.

Surface of the shell ornamented by prominent, irregularly spaced coarser or finer growth lines.

#### Remarks

Although *Stenothecoides* sp. from the Early Cambrian Xidashan Formation in Kuruktag is an incomplete specimen, it represents a bivalved stenothecoid with distinct characteristics: the narrowly elongated and asymmetrical dorsal valve; the apex curves anticlockwise during growth and with irregularly spaced growth lines. This species should be unquestionably assigned to the genus *Stenothecoides*.

This form is very similar to *Stenothecoides* sp. from the upper Lower Cambrian of Siberia (Yochelson 1969: 51, figure 1) in such characters as the narrowly elongated dorsal valve, the pointed apex and the convex dorsal valve, but differs from the latter in the proportion between the length and width of the valve, in the more rounded posterior and in the coarser growth lines. In plan view, this species somewhat resembles *Stenothecoides carinatus* Koneva (1979: 27–28, pl. VI, figs. 5, 6) from the Early Cambrian Lenian Stage of central Kazakhstan, differing in the slender and more curved valve, in the narrower abapical margin and in the irregularly spaced growth lines. It is also allied to *Stenothecoides elongata* (Walcott) (1886: 129, pl. 12, figs. 4 a–b (not figure 4); Resser 1938: 24; Rasetti 1954: 63, pl. 11, figs. 3, 4), but differs from the latter in the more bent dorsal valve, in the wider abapical margin and in the irregularly spaced growth lines.

#### Occurrence

Basal part of the Early Cambrian Xidashan Formation of Mohurshan, Kuruktag Mountains, Xinjiang, China.

#### Genus *Bagenovia* Horný, 1957

##### *Bagenovia* cf. *sajanica* Horný, 1957

(Figures 3, 4 A–I)

*Bagenovia sajanica* Radugin, 1937: 301, fig. 5, (nomen nudum).

*Bagenovia sajanica* var. *raricostata* Radugin, 1937: 301, fig. 5a (nomen nudum).

*Bagenovia sajanica* Horný, 1957: 428, pl. III, figs. 1–6; Knight and Yochelson, 1960: I83, fig. 50, 8.

*Bagenovia multicostrata* Yu, in Zhang, 1983: 10 (nomen nudum); Gao *et al.*, 1984: pl. IX, figs. 6, 9 (nomen nudum); Yu, 1986: 10 (nomen nudum).

#### Material

Three specimens, NIGP 116388–116390 in the



Figure 3 *Bagenovia* cf. *sajanica* Horný, showing the internal structures, X 8.

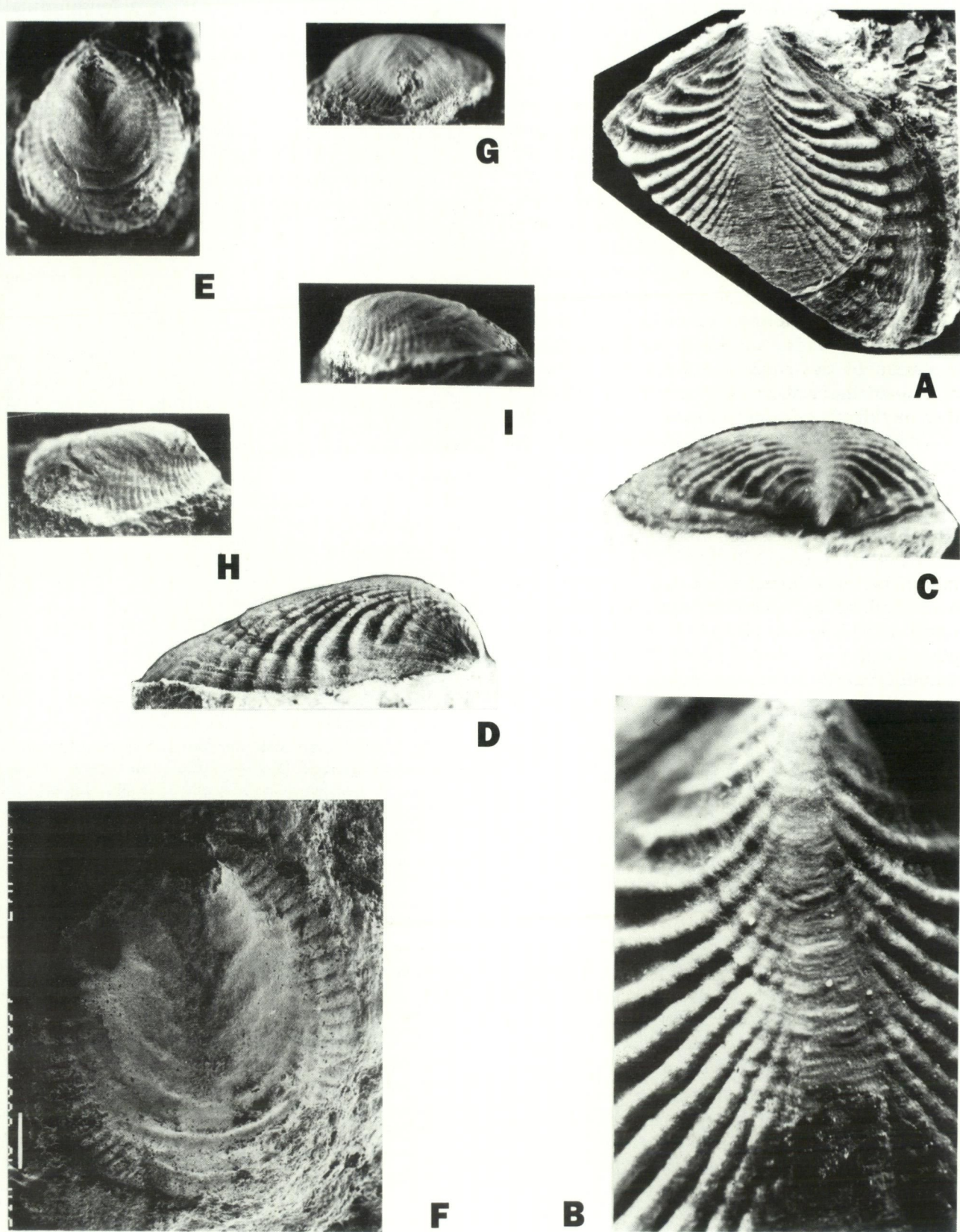
collections of the Nanjing Institute of Geology and Palaeontology, Academia Sinica. NIGP 116388 and 116389 were collected in 1978 by Zhang Sengui from the base of the Early Cambrian Xidashan Formation on the northern slope of the Mohurshan of the Kuruktag Mountains, Xinjiang, China. NIGP 116390 in the Nanjing Institute of Geology and Palaeontology, Academia Sinica, was collected by a geological party from the Geological Bureau of Hubei from the Early Cambrian Shipai Formation of Suizhou, Hubei, China.

#### Diagnosis

Subcircular, slightly asymmetrical, apex pointed, slightly curved anticlockwise during growth, with twenty-two pairs of radiating costae from the flat keel. There are four pairs of asymmetrically arranged ridge-like impressions and three concentric impressions visible on the dorsal valve of the internal mould.

#### Description

Valve of medium size, slightly asymmetrical. Moderately convex, subcircular in plan view. Apex small, pointed, distinctly protruding and overhanging the adapical margin; slightly curved anticlockwise during growth. In plan view, the individual valve tends to be narrowly rounded adapically, broad rounded abapical margin, with the greatest width of the valve at about one half of the length. A distinctly flat keel situated near the median part of the dorsal valve, which gradually flattens and widens to the abapical margin. From the flat keel about twenty-two pairs of costae radiate. They are small and short in the adapical part, with sharp crests, separated by wider depressions and curved forward, gradually becoming larger and longer in the middle part and gradually crowded, indistinct abapically, with obtusely rounded crests and separated by the narrower depressions. Radiating threads which can be observed in the flat keel very fine and dense (Fig. 4B). Growth lines very fine and undulating;



**Figure 4** A-I, *Bagenovia* cf. *sajanica* Horný. A-D, NIGP 116388, Xidashan Formation, Kuruktag, Xinjiang, A, plan view, x 5. B, enlargement of dorsal keel, showing the cancellated sculpture, x 15. C-D, adapical and lateral views, x 5. E-I, NIGP 116389, E, plan view, x 6. F, enlargement of valve, to emphasize the internal structures, x 12. G-I, adapical, right and left side views, x 5.

crossed by the radiating threads to form a cancellated sculpture. With the increase in shell size, the growth lines become progressively thicker, and the radiating threads more and more obscure on the margin of the valve.

Shown in Figure 4 E-I is a nearly completely preserved internal mould. In plan view the valve appears subcircular and the apex is slightly broken. The traces of radiating costae can be seen on the margin of the valve. In the centre of the valve there is a longitudinal shallow depression, starting from the apex and gradually disappearing to the posterior. On the sides of the longitudinal shallow depression there are about four pairs of asymmetrically arranged ridge-like impressions and three concentric impressions (Figure 3). The direction of the ridge-like impressions is the reverse of the surface radiating costae. The first pair of ridge-like impressions are short and very obscure, situated near the apex. The second pair are situated at about two-fifths of the valve length from the adapical margin and gradually extended forward and inclined to the adapical margin; the left ridge-like impression is longer, and narrower than the right one. The third pair are similar morphologically to the second pairs, situated at the mid-length of the valve but longer and larger. The fourth pair is fainter and more obscure than the others, which is situated at about two-thirds of the valve from the adapical margin. The outer concentric impression is thin, forming a ring on the periphery. The middle one is stronger and shorter than the others; while the inner one is faint, gradually extending to the adapical side.

#### Dimensions (in mm)

	LENGTH	WIDTH
NIGP 116388	7.00	7.50
NIGP 116389	6.80	4.40

#### Remarks

In the general shape of the valve, this form appears to be similar to the type species *Bagenovia sajanica* Horný (Radugin 1937: 301, figs 5, 5a; Horný 1957: 428, pl. III, figs. 1-6) from the Early Cambrian of west-Sayan, Siberia, but differs in the presence of more numerous radiating costae and in the subcircular outline. In apical view, this species is also similar to *Bagenovia kazakhstanica* Koneva (Koneva 1976: 127, Figure 1; 1979: 22, pl. II, figs. 1-10, pl. III, figs. 1-2) from the Early Cambrian Lenian Stage of central Kazakhstan. It can be distinguished by the coarser and more numerous radiating costae, and the undulating growth lines. The most important distinguishing feature of *Bagenovia* cf. *sajanica* is that the internal structure of the valve is characterized by four pairs of asymmetrically arranged ridge-like impressions and three concentric impressions on the dorsal

valve of the cast. The internal structure of *Bagenovia kazakhstanica* possesses a longitudinal carina and more ridge-like short impressions and the presence of some small pits, especially near the apex.

#### Occurrence

Basal part of the Early Cambrian Xidashan Formation of Mohurshan, Kuruktag, Xinjiang and the Early Cambrian Shipai Formation of Suizhou, Hubei, China.

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