

The age of the dinosaur-bearing Cretaceous sediments at Dashuiguo, Inner Mongolia, P.R. China based on charophytes, ostracods and palynomorphs

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Abstract

The Dashuiguo Formation has yielded numerous fossils of *Probactrosaurus*, a dinosaur with both iguanodontid and hadrosaurid characteristics. Based on the evolutionary position of *Probactrosaurus*, the dinosaur-bearing sediments have been considered to be Aptian–Albian, but new micropalaeontological data (charophytes, ostracods and palynomorphs) indicate that they may be as old as Barremian. The three charophyte species recovered are indicative of a Barremian–Aptian age. A rich fauna of non-marine Ostracoda (13 species in nine genera) includes two species described as new, *Cypridea pseudomodica* sp. nov. and *C. dashuiguoensis* sp. nov., while the remaining eleven species have been described previously from Lower Cretaceous sediments of the Gobi Basin and adjacent areas in China. Based on the ostracod assemblage, the Dashuiguo Formation can be correlated with the Dzun Bayn suite of the Gobi Basin and can therefore be regarded as Barremian–Albian in age. The palynomorph assemblage is very similar to that described from the nearby Tebch site with an estimated Barremian–Early Aptian age and is radiometrically calibrated on the basis of an overlying basalt layer.

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1. Introduction

In March 1995 the Inner Mongolia Museum in Hohhot and the Royal Belgian Institute of Natural Sciences in Brussels started a collaborative study of the replacement of the Early Cretaceous iguanodontids by hadrosaurids and the phylogenetic relationships between the two groups. In order to achieve these objectives the Sino-Belgian Dinosaur Expedition (1995–2002) conducted some field work in the region north of the Jilantai Salt Lake (Fig. 1). The first discoveries in this region were made by the Sino-Soviet Palaeontological Expedition in

1959 (Chow and Rozhdestvensky, 1960), leading to the description of several new dinosaur taxa. The most interesting find was the new genus *Probactrosaurus* Roshdestvensky, 1966, a dinosaur with both iguanodontid and hadrosaurid characteristics. Based on the intermediate evolutionary position of *Probactrosaurus* an Aptian–Albian age was estimated for the sediments in which it was found. The Dashuiguo locality is situated between the Gobi and Ordos basins, both well known for their dinosaur fossils. In spite of the numerous expeditions to these regions many age estimations of the dinosaur sites are based on dinosaur evidence alone, which leads to circular reasoning. In fact, only three dinosaur sites in the region have been dated independently based on palynology, radiometrics or palaeomagnetism (Eberth et al., 1993; Hicks et al., 1999;

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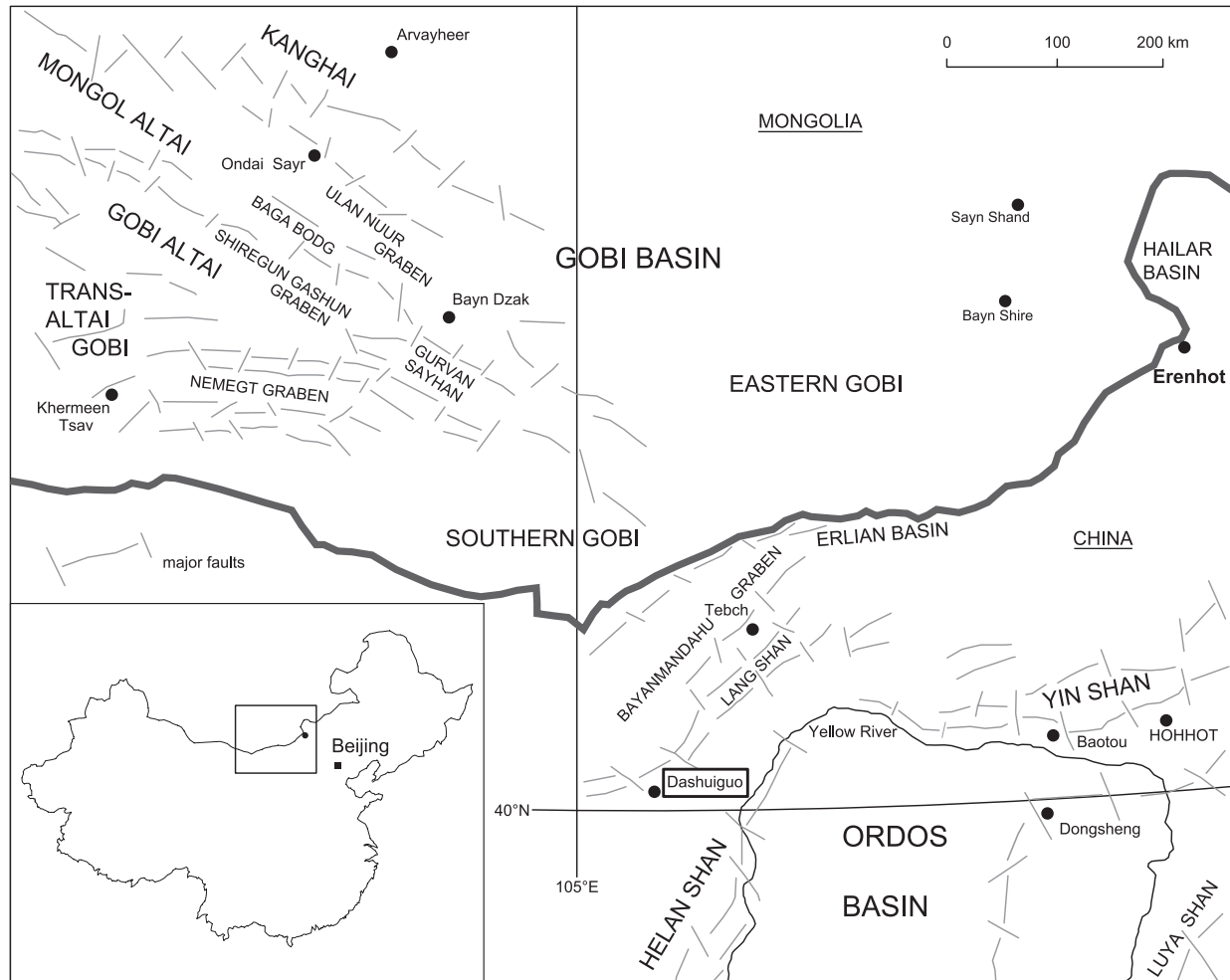


Fig. 1. Generalized map of the Gobi Basin with the location of Dashuiguo (modified after Jerzykiewicz, 1995); inset shows the general location of the area within China.

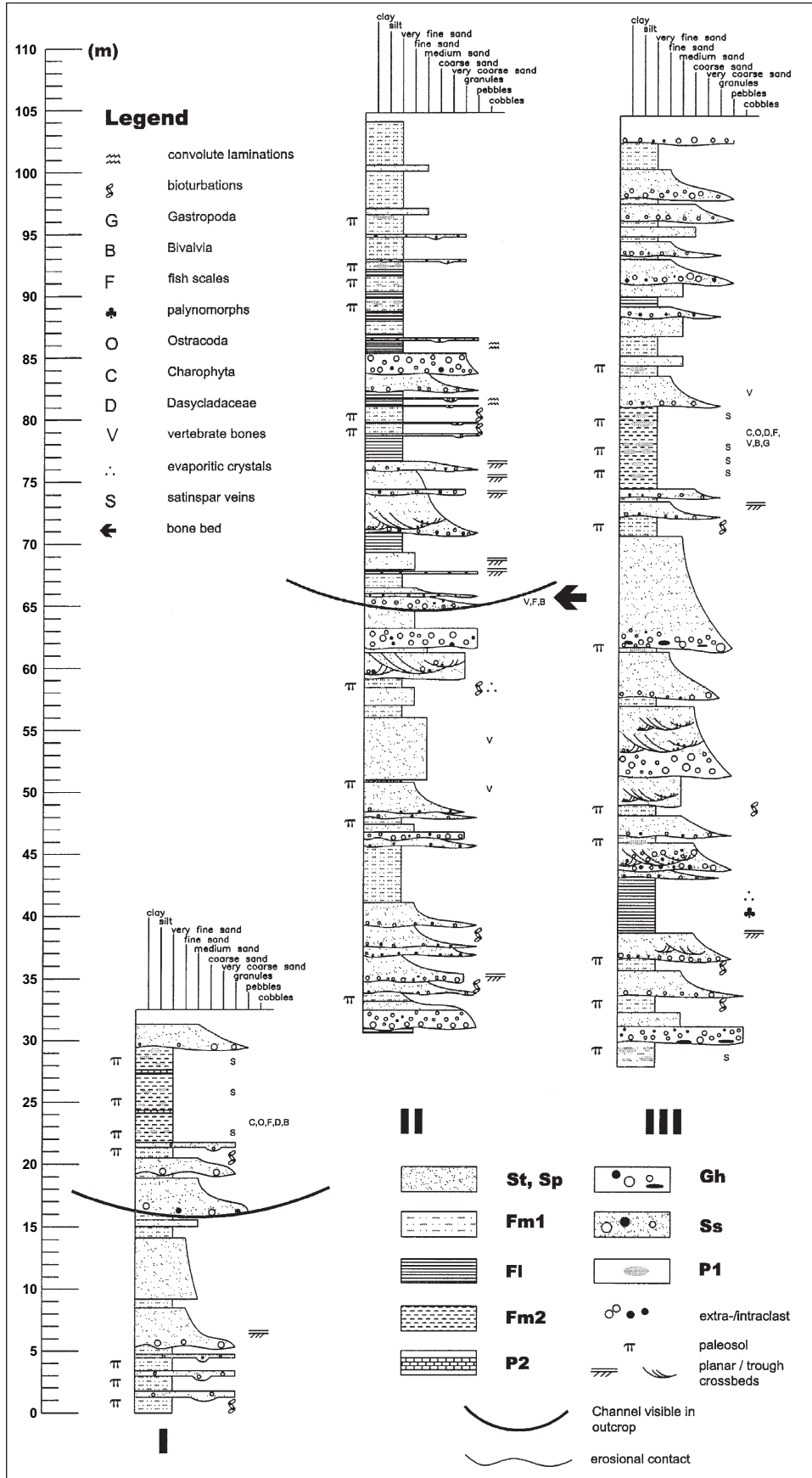
Tang et al., 2001). Here we present an accurate age determination of the non-marine strata at the Dashuiguo site based on micropalaeontological data (charophytes, ostracods and palynomorphs), in order to test the validity of the age estimations based on dinosaur evidence.

2. Geological setting and depositional framework

The sediments of the Dashuiguo site crop out along a dry river valley near the village of Hanwulan. The different facies recognized within the dinosaur-bearing sediments represent a fluvial environment with meandering channels and a large vegetated floodplain (Van Itterbeek et al., 2001). The channels have a gravel deposit at the base (Gh, Ss on Fig. 2). The thickness of the gravel depends on the scale of the channel. The rest of the channel is filled with cross-bedded sands (St, Sp) representing point bar deposits. Most of the dinosaur remains have been recovered from these channel infills, particularly concentrated at the base of the channel. The

floodplain sediments comprise suspension deposits, crevasse splays (F1, Fm1) and pond deposits (Fm2). All of these sediments are regularly altered by palaeosol (more precisely calcrete) development (P1,2), causing a red coloration and the precipitation of calcareous nodules. The palynomorphs have been recovered from the finely laminated, black silty suspension deposits (F1) in the middle of the measured section (Fig. 2). The green marly facies (Fm2) that have yielded the numerous ostracods and charophytes represent temporary ponds on the floodplain. The lacustrine origin of these deposits is confirmed by the numerous non-marine fish scales, gastropods, bivalves and turtle fragments found within these layers.

Fig. 2. Lithostratigraphic column of the outcropping strata in the Dashuiguo area. The Roman numerals under the columns refer to the different outcrop zones. The relative heights of the different columns reflect the correlation between the columns taken in different parts of the area. The codes mentioned in the legend (e.g., Gh, Ss) are the lithofacies codes given in the text.



3. Methods

The green marly sediments containing the calcareous microfossils were dried and subsequently soaked in hot water. Normally this was sufficient to disaggregate the sample; if not, a small quantity of H₂O₂ was added together with an overdose of solid Na₂CO₃ to temper the reaction. Afterwards the muddy suspension was washed through three meshes: 2 mm, 300 µm and 150 µm, the microfossils being in the fractions between 2 mm and 150 µm. The ostracods and charophytes were picked and sorted under a binocular microscope. Only two samples contained charophytes and ostracods; more than 300 specimens of each group were picked from each sample in order to obtain representative assemblages. No significant difference in fauna or flora was observed between the two samples.

The treatment of the palynological samples was slightly more complicated. From each sample, 200 g of sediment were broken into small pieces and subjected to the following preparation procedures: boiling in 10% KOH; boiling in concentrated HNO₃ and submersion in cold HF. Only one sample proved to contain useful palynomorphs, yielding a large amount (ca. 10 cc) of organic material after concentration in heavy cadmium liquid, much of which comprised plant fragments, while palynomorphs were relatively rare; nevertheless a large number of glycerine slides were studied until more than 300 palynomorphs were counted.

4. Charophytes

The charophyte flora of the Dashuiguo Formation has already been described by Shu and Zhang (1985) and Van Itterbeeck et al. (2001). Shu and Zhang (1985) reported the following species: *Aclistochara caii* Wang S., 1965, *A. huihuibaoensis* Wang S., 1965, *A. lata* Peck, 1937, *Euaclistochara mundula* (Peck, 1941) Wang Z. in Wang et al., 1976, *Flabellochara hangzhouensis* Wang Z., 1981, *Flabellochara* sp., *Mesochara stipitata* (Wang S., 1965) Wang Z., 1981 and *M. voluta* (Peck, 1937) Grambast, 1965. The charophyte flora described by Van Itterbeeck et al. (2001) consists of *Aclistochara bransoni* Peck, 1937 (Fig. 3A–C), *Minhechara xiaoxiaoensis* Yang and Zhou, 1983 (Fig. 3G, H) and *Porochara mundula* (Peck, 1941) (Fig. 3D–F). The *Aclistochara*-species mentioned by Shu and Zhang

(1985) are all junior synonyms of *A. bransoni* (Fu and Lu, 1997; Van Itterbeeck et al., 2001) and *Euaclistochara mundula* is a junior synonym of *Porochara mundula* (Peck) (Feist and Grambast-Fessard, 1982).

Aclistochara bransoni was first reported from the Upper Jurassic of North America (Peck, 1937). In China the species is known from the Upper Jurassic–Lower Cretaceous. *Porochara mundula* is widely distributed in strata of middle and late Early Cretaceous age (Lu and Luo, 1990). However in China and Mongolia it has also been described from Upper Cretaceous deposits, for example, the Nemegt Formation (Karczewska and Ziembinska-Twordzydlo, 1981). Based on these two species, which are common in both reported floras, the age of the Dashuiguo Formation is middle to late Early Cretaceous (Barremian–Albian) in age, consistent with the occurrence of the other charophyte species recorded from the Dashuiguo Formation. The *Flabellochara*-species mentioned by Shu and Zhang (1985) belong to the coenospecies *Clavator harrisii* Peck, 1941 emend. Martin-Closas, 1989 ex Schudack, 1993 (Schudack, 1993; Martin-Closas, 1996, 2000). According to Schudack (1993), *C. harrisii* is a cosmopolitan species that has been reported from the Barremian and Aptian of China. Hence, based on the clavatoraceans, the age estimation may be further refined to the Barremian–Aptian interval. However, although clavatoraceans have been recorded from the Dashuiguo Formation, none has been observed in the sediments at the Dashuiguo site.

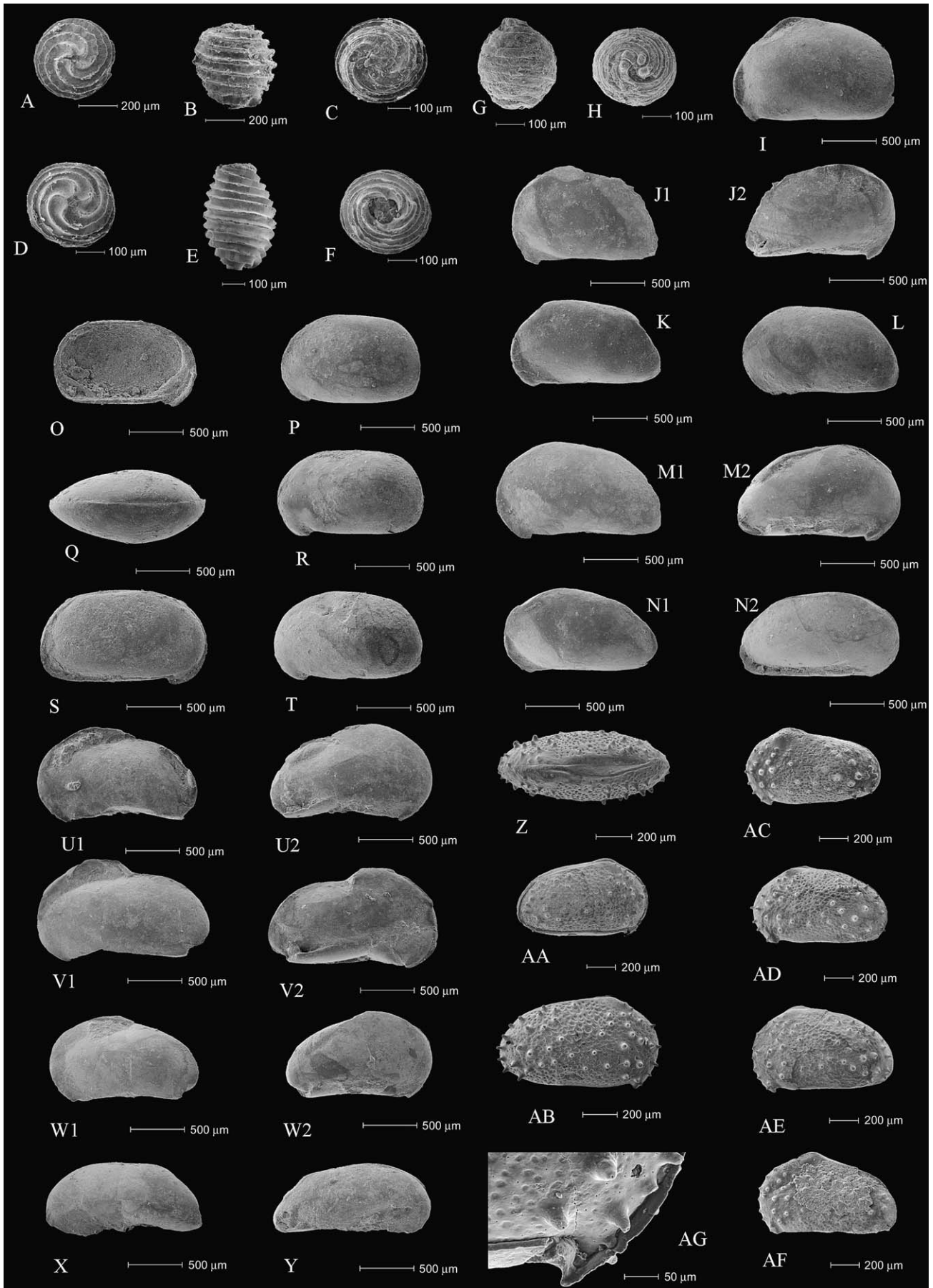
5. Ostracods

In the following section a rather extensive treatment of the ostracod fauna is provided in order to substantiate the species identifications and clarify any taxonomic problems. The type specimens of the newly described taxa and all the figured specimens are deposited in the collections of the Royal Belgian Institute of Natural Sciences (RBINS).

5.1. Systematic palaeontology

Order: Podocopida G. W. Müller, 1894
 Suborder: Cypridocopina Jones, 1901
 Superfamily: Cypridoidea Baird, 1845
 Family: Cyprididae Baird, 1845
 Genus *Mongolocypriis* Szczechura, 1978

Fig. 3. Charophytes and ostracods from the Dashuiguo Formation, Dashuiguo locality, Inner Mongolia, P.R. China. A–C, *Aclistochara bransoni*: A, basal view; B, lateral view; C, apical view. D–F, *Porochara mundula*: D, basal view; E, lateral view; F, apical view. G–H, *Minhechara xiaoxiaoensis*: G, lateral view; H, apical view. I, *Cypridea impolita* (n° 4319): carapace, left view. J–N, *Cypridea pseudomodica* sp. nov.: M, holotype (n° 4323); J–L, N, paratypes (n° 4320, 4321, 4322, 4324), 1, left view; 2, right view; K, L left views. O–T, *Mongolocypriis rostrata* (n° 4325–4330): O, internal view of left valve; P, R, T, left views; Q, dorsal view; S, right view. U–W, *Cypridea dashuiguoensis* sp. nov.: U, V, paratypes (n° 4331, 4332), W, holotype (n° 4333), 1, left view; 2, right view. X, Y, *Mongolianella* cf. *zerussata* (n° 4334–4335): X, left view; Y, right view. Z–AG, *Cypridea clinodorsata* (n° 4336–4343): Z, dorsal view; AA, AB, right view; AC–AF, left views; AG, detail of antero-ventral part of right valve showing pores and tubercules.



Mongolocypis rostrata (Galeeva, 1955)

Fig. 3O–T

- 1955 *Cypridea rostrata* Galeeva, p. 42, pl. 9, fig. 3a–c.
 non 1969 *Cypridea rostrata* Galeeva, 1955; Szczechura and Blaszyk, pp. 113–114, pl. 28, fig. 3a–c.
 1978 *Mongolocypis rostrata* Szczechura, pp. 93–94.

Material. More than 100 well-preserved specimens.

Measurements. Length 1.29–1.37 mm, height 0.76–0.8 mm, width 0.6–0.68 mm.

Remarks. Variation in shape (Fig. 3O–T) is possibly due to sexual dimorphism, with the more elongate forms representing males.

Szczechura (1978) placed *C. rostrata* Galeeva, 1955 within her new genus *Mongolocypis* and noted that it could be a junior synonym of *M. distributa* (Stankevitch and Sochava, 1974), the type species of the genus *Mongolocypis*. In our material the internal structure of the valves, characterized by the presence of a limen in the postero-ventral part of the left valve and a ‘peculiar list’ crossing the inner lamella in the antero-ventral part (Szczechura, 1981), confirms this generic attribution, but since our form is distinctly smaller than *M. distributa*, we consider it to be a separate species. A very similar species is *Mongolocypis jiangxiensis* Xu, 1993, in which the dorsal margin slopes down a little towards the posterior margin, as seen in some of the Dashuigo specimens (e.g., Fig. 3T). Most of our specimens, however, have a dorsal margin essentially parallel to the ventral margin. Furthermore, *M. jiangxiensis* seems to have the antero-dorsal corner a little further back, resulting in a hinge section similar to that seen in our material and shorter than in those illustrated by Galeeva (1955). In dorsal view *M. jiangxiensis* is the same shape as *M. rostrata*. The two may be synonymous, or at least closely related, but statistical analysis of the shape variation in large assemblages of both species, including the type specimens, is needed to decide on this matter.

Mongolocypis subtera Hou as illustrated by Li and Cao (2002) is similar in its essentially parallel dorsal and ventral margins, an antero-dorsal corner a little behind the point of the rostrum and a quite rounded posterior margin like the studied specimens, but is distinguished from *M. rostrata* by its larger size.

The specimens studied are also very similar to *Cypridea plebia* Gou and W.S. Wang in Gou et al., 1986, but in dorsal view they are tapered towards the anterior end and have their greatest thickness in the posterior half, whereas *C. plebia* has a nearly rectangular shape in dorsal view.

Occurrence. Described from the Bayn Shire suite in the Dzun Bayan region in Mongolia by Galeeva (1955), its range has been extended to the Sainshand suite (Liubimova, 1956) and the Barun Bayan suite of Mongolia (Khand, 1987).

M. jiangxiensis is known from the Zhoujiadian Formation (99.5 ± 1.5 Ma), Xinjiang Basin, Jiangxi, China (Xu, 1993).

Stratigraphic distribution. Albian–Turonian.

Genus *Lycoperocypris* Mandelstam, 1956*Lycoperocypris infantilis* Liubimova, 1956

Fig. 4P

- 1956 *Lycoperocypris infantilis* Liubimova, p. 106, pl. 21, fig. 1a–b.
 2002 *Eucypris infantilis* (Liubimova, 1956), Hou et al., p. 138, pl. 5, fig. 17–18.

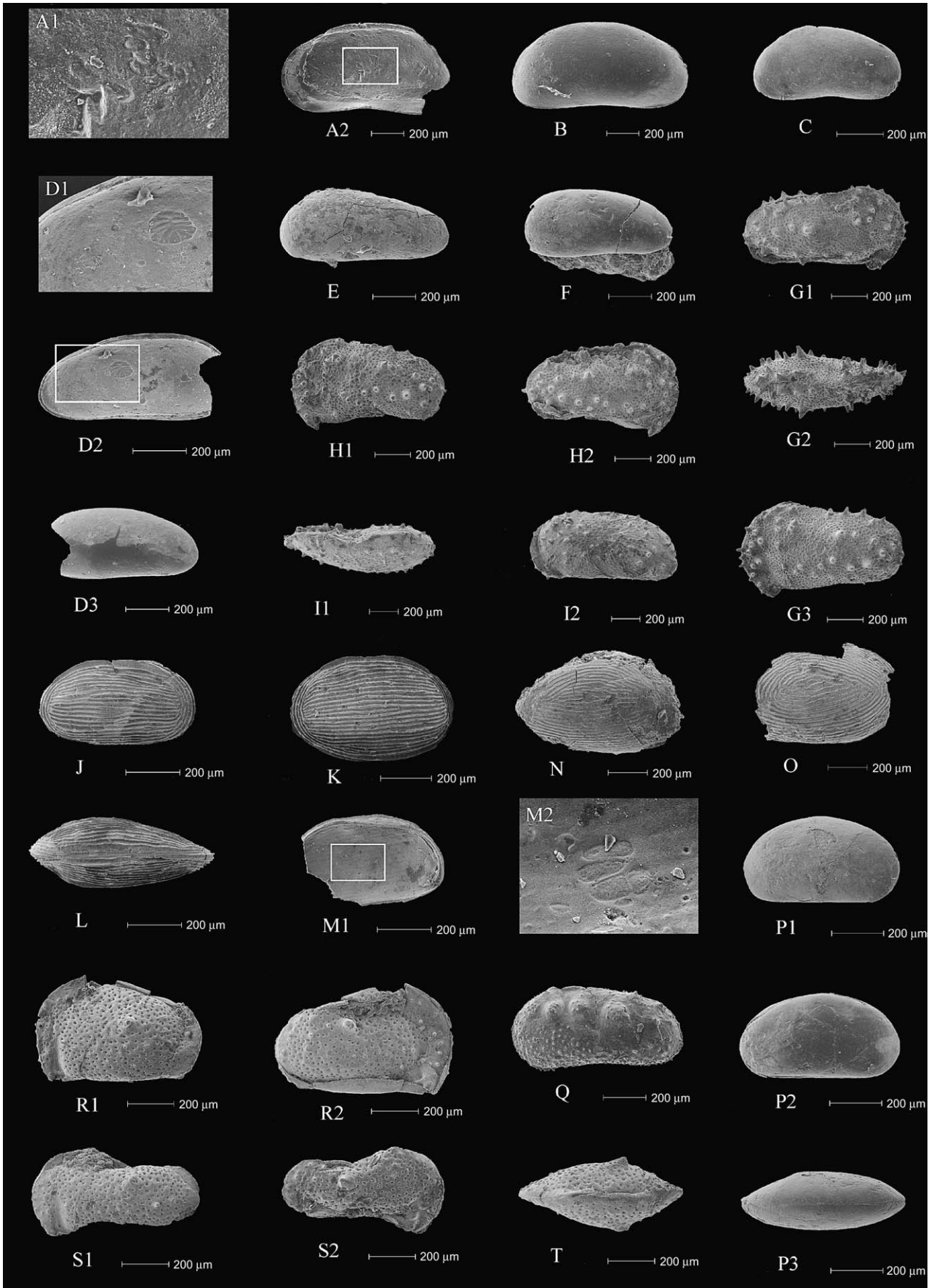
Material. Two carapaces.

Measurements. Length 0.62 mm, height 0.32 mm, width 0.226 mm.

Remarks. The form and general outline of the specimens studied show the greatest resemblance to *L. infantilis*. Based on statistical analysis of external features Geng (1979) stated that *Lycoperocypris* Mandelstam, 1956 is a junior synonym of *Eucypris* Vavra, 1891; Hou et al. (2002) followed this point of view. However some Chinese authors disagree and retain the genus *Lycoperocypris* (e.g., Hao et al., 1983; Gou et al., 1986; Hao, 1988). In the absence of any observations of internal structural details that would confirm the synonymy, *Lycoperocypris* should be considered a valid genus.

Occurrence. First described from the middle part of the Dzun Bayn suite, Mongolia (Liubimova, 1956), *L. infantilis* is a common species in the lower Lower Cretaceous of northeastern and northwestern China

Fig. 4. Ostracods from the Dashuiguo Formation, Dashuiguo locality, Inner Mongolia, P.R. China. A–B, *Mongolianella khamariniensis* (n° 4344–4345): A1, detail of muscle scar; A2, internal view of right valve; B, left view. C, *Candona praevava* (n° 4336): right view. D–F, *Alicenula? contracta* (n° 4347–4349): D1, detail of muscle scar; D2 internal view of right valve; D3, E, F right views. G–H, *Cypridea* sp. 1 (n° 4350–4351): G3, H1, right views; G2, dorsal view; G1, H3, left views. I, *Cypridea* sp. 2 (n° 4352): 1, dorsal view; 2, right view. J–M, *Ziziphocypris simakovi* (n° 4353–4356): J, K, lateral views; L, dorsal view; M1, internal view of right valve; M2, detail of muscle scar. N, O, *Timiriasevia principalis* (n° 4357–4358): N, left view; O, right view. P, *Lycoperocypris infantilis* (n° 4359): 1, left view; 2, right view; 3, dorsal view. Q, *Rhinocypris* sp. (n° 4360): left view. R–T, *Cypridea unitumula* (n° 4361–4363): R1, S1, left view; R2, S2, right view; T, dorsal view.



(Hao, 1988). It has been reported from assemblage 1/3/5 of the Saihan Tal Formation, Eren Basin, Nei Mongol Autonomous Region (Gou et al., 1986), and from the lower part of the Hekou Formation, Xining and Minhe basins (Hao, 1988), the Fuxin, Yixian and Jiufutang formations, Fuxin Basin, Liaoning Province (Li and Liu, 1994; Su et al., 1985), the Dahuichang Formation, Fengtai and Chaoyang districts, Beijing (Pang and Whatley, 1990), the Lisangou and Guyang formations, Guyang County, Inner Mongolia (Pang and Whatley, 1990), the Xiazhuang Formation, Beijing (Pang and Whatley, 1990), and the Quantou Formation, Songliao Basin (Li and Liu, 1994).

Stratigraphic distribution. Berriasian–Cenomanian.

Family: Cyprideidae Martin, 1940
Genus *Cypridea* Bosquet, 1852

Cypridea impolita Galeeva, 1955
Fig. 3I

1955 *Cypridea impolita* Galeeva, pp. 29–30, pl. 8, fig. 1a–d.

Material. One well-preserved specimen.

Measurements. Length 1.49 mm, max. height 0.92 mm, height at posterior end 0.7 mm, width 0.64 mm.

Remarks. The specimen studied resembles *C. tsaganensis* Nuestrueva, 1977 in general outline and dimensions. The latter bears no distinct “beak”, according to the description of Nuestrueva (1977); however, on some of her illustrations such a feature can be observed. The specimen differs from *C. impolita* as illustrated by Galeeva (1955) by not having tubercles. However in her original description Galeeva mentions that these tubercles are not present on all specimens and if present, they are only vaguely expressed.

Occurrence. Galeeva (1955) described the species from the middle part of the upper Dzun Bayn suite. Liubimova (1956) reported it from the upper Dzun Bayn suite.

Stratigraphic distribution. Hauterivian–Albian.

Cypridea pseudomodica sp. nov.
Fig. 3J–N

Derivation of name. After its similarity to *Cypridea modica* Liubimova, 1956, which at first sight it resembles.

Holotype. Carapace (Fig. 3M), RBINS n° 4323, length 1.6 mm, height 0.92 mm, width 0.64 mm.

Type locality and horizon. Dashuiguo Formation, section at Dashuiguo (GPS N40° 17' 50.5", E105° 49' 29.6"), Inner Mongolia, P.R. China.

Material. Twenty well-preserved specimens.

Diagnosis. A smooth *Cypridea* with a small but distinct “beak” on both valves. Carapace irregularly ovate with greatest height in anterior third; the posterior end, lower than the anterior end, is steeply sloped towards the ventral margin and pointed in its lower portion.

Description. Large, irregularly ovate carapaces with a small but distinct “beak” in the antero-ventral part of both valves. Left valve larger than right valve, overlapping the latter along the dorsal and ventral margins. Greatest height in the anterior third. Dorsal margin forming an obtuse postero-dorsal corner. Posterior end angularly rounded. Ventral margin straight to slightly concave. Valve surface is smooth. The studied specimens show considerable variation in the height of the anterior end and the degree of slope of the dorsal margin towards the posterior end. In higher and shorter forms the posterior end is very steep (Fig. 3J), while in more elongated, lower forms the posterior end is more smoothly sloped towards the ventral margin (Fig. 3N). This variability may be due to sexual dimorphism.

Measurements. Length 1.36–1.6 mm, max. height 0.7–0.82 mm, width 0.56–0.64 mm.

Remarks. The shape of *C. pseudomodica*, with its broadly rounded anterior end and steeply sloped, elongate and pointed posterior end, strongly resembles *C. modica* as described by Liubimova (1956), but differs in having a distinct alveolus and rostrum (= a “beak”); no such feature can be distinguished in Liubimova’s illustrated specimen. In some of our specimens the “beak” is rather reduced (Fig. 3L,N), but it is always present.

Occurrence. Currently only known from the sediments of the Dashuiguo Formation (Barremian) of the Dashuiguo section, Inner Mongolia, P.R. China.

Cypridea dashuiguoensis sp. nov.
Fig. 3U–W

Derivation of name. After the locality Dashuiguo, Inner Mongolia, P.R. China.

Holotype. Carapace (Fig. 3W), RBINS n° 4333, length 1.37 mm, height 0.72 mm, width 0.44 mm.

Type locality and horizon. Dashuiguo Formation, section at Dashuiguo (GPS N40° 17' 50.5", E105° 49' 29.6"), Inner Mongolia, P.R. China.

Material. Eighteen carapaces of varying preservation.

Diagnosis. A large, smooth, subovate *Cypridea* with greatest height in front of mid-length; dorsal margin irregularly arched with an obtuse elevation in the anterior half; ventral margin slightly concave and with a distinct pointed step just before the posterior end.

Description. Large subovate carapace with greatest height in anterior half, greatest thickness medially. Dorsal margin irregularly arched with an obtuse elevation in the anterior half, beginning with a distinct bend in the dorsal margin. Ventral margin slightly concave with a distinct pointed step just before the posterior end, formed by the overlap of the postero-ventral part of the right valve by an extended part of the left valve. Anterior end broadly rounded, bearing a small “beak” on the antero-ventral part of both valves (slightly more expressed on the right valve). Posterior end is also rounded but more tapered and lower than anterior end. Left valve larger than the right, overlapping the latter distinctly along the postero-ventral margin. Valve surface smooth.

Remarks. *Cypridea modica* Liubimova, 1956 differs from *C. dashuiguensis* by having a more pointed posterior end and lacking both the pointed step in the ventral margin and the obtuse elevation of the dorsal margin in the anterior half. *Cypridea laeva* Galeeva, 1955 has a more pointed elevation in the antero-dorsal part and a higher and less-tapered posterior end. *Cypridea mediocris* Liubimova, 1956 lacks a beak on the right valve whereas in *C. dashuiguensis* the beak is more pronounced on the right valve.

Occurrence. Currently only known from the sediments of the Dashuigu Formation (Barremian) of the Dashuigu section, Inner Mongolia, P.R. China.

Cypridea clinodorsata W.S. Wang and Gou in Gou et al., 1986
Fig. 3Z–AG

1986 *Cypridea (Cypridea) clinodorsata* W.S. Wang and Gou in Gou et al., p. 88, pl. 12, figs. 1–5.

Material. More than 200 specimens.

Measurements. Length 0.97–1 mm, height 0.54–0.61 mm, width 0.39 mm.

Remarks. Numerous spiny *Cypridea* are known from Early Cretaceous deposits around the world. Our specimens most closely resemble *Cypridea clinodorsata*, although the posterior end of that species as illustrated by Gou et al. (1986) seems to be a bit more angular; the same authors also illustrated a less tapered, more

posteriorly rounded form under the name *C. cf. clinodorsata*. We consider it possible that *C. clinodorsata* is a junior synonym of *C. vitimica*, first described by Galeeva (1955) although attributed by her to Mandelstam; in subsequent publications of Russian authors it is also attributed to Mandelstam and the species name changed from *vitimica* to *vitimensis*. Our specimens differ from *C. vitimica* in having a more convex dorsal and a straighter ventral margin and in having more numerous and more prominent spines. Re-examination of the holotypes is necessary to judge whether these are two different species and, if so, to clearly illustrate the diagnostic differences.

The specimens studied differ from *C. unicastata* Galeeva, 1955 by the lack of a rib on the ventral side and by the less inflated posterior end. *C. spinigera* Liubimova, 1956 is bigger and more inflated laterally, with a more pronounced “beak” in the right valve. *C. priva* Liubimova, 1956 is very similar but does not show a dorsal depression and a “beak” on the right valve. *Cypridea concina* Hou, 1958 has more pronounced ornamentation. The specimen illustrated in Fig. 3A–C, somewhat resembles *C. polita* Galeeva, 1955, but compared to our other specimens that species has a straighter dorsal margin; the specimens of *C. polita* illustrated by Gou et al. (1986) are a good match in shape but have more prominent tubercles.

Occurrence. Known from its type locality and horizon, the Third Member of the Saihan Tal Formation, Eren Basin, China. Galeeva (1955) described *C. vitimica* from the lower part of the upper Dzun Bayn suite. *C. vitimica* (under the name *vitimensis*) has been reported from the Tsagantsav and Dzun Bayn suites (Liubimova, 1956), the Lower Cretaceous (Hauterivian) of the lowlands of western Siberia (Liubimova et al., 1960), the Lower Cretaceous (Barremian) of the Transbaikalian region, Russia (Mandelstam and Schneider, 1963), the Saihan Tal Formation, Eren Basin, Inner Mongolia (Gou et al., 1986), the Jiufotang Formation, Rehe Group, Fuxin Basin, Liaoning (Li et al., 1988), the middle part of the Wanxiu Group, Guide Basin, Qinghai (Sun, 1997), the Suhongtu Formation, Sohungtu Basin, Inner Mongolia (Qi and Zhang, 1990) and the Jingangshan Formation and the Qingquan Basin, Yanshan region, Hebei (Pang and Whatley, 1990).

Stratigraphic distribution. Hauterivian–Albian.

Cypridea unitumula Galeeva, 1955
Fig. 4R–T

- 1955 *Cypridea unitumula*, Galeeva, p. 31, pl. 6, fig. 1a–d.
non 1955 *Cypridea sulcata* Mandelstam; Galeeva, p. 41, pl. 9, fig. 2a–b.

- 1956 *Cypridea sulcata* Mandelstam; Liubimova, p. 23, pl. 4, fig. 3a–b.
 1960 *Cypridea sulcata* Mandelstam; Liubimova et al., pp. 42–44, pl. 3, fig. 5a–b.
 non 1963 *Cypridea sulcata* Mandelstam; Mandelstam and Schneider, p. 109, pl. 14, fig. 3a–b.
 2002 *Cypridea sulcata* Mandelstam 1955; Hou et al., p. 493, pl. 202, figs. 1–8.

Material. Five carapaces, one completely broken up.

Measurements. Length 0.715 mm, height 0.44 mm, width 0.276 mm.

Remarks. From the Lower Cretaceous of Mongolia two species of *Cypridea* with a spinose tubercle were described by Galeeva (1955): *C. unitumula* and *C. sulcata*. The latter is smaller and lacks an antero-ventral “beak”. Although Galeeva (1955) provided the first description, the species has commonly been attributed to Mandelstam. Liubimova (1956) and Liubimova et al. (1960) considered *C. unitumula* Galeeva to be a junior synonym of *C. sulcata* Mandelstam, without any reference to a description by Mandelstam. The drawings given by these authors are nearly exact copies of the drawings accompanying Galeeva’s (1955) description of *C. unitumula*. Mandelstam and Schneider (1963) published the first description of *C. sulcata* by Mandelstam, which corresponds perfectly with the description of *C. sulcata* as given by Galeeva (1955). Based on the presence or absence of a “beak”, *C. unitumula* and *C. sulcata* are considered to be two different species. Our specimens are considered to belong to *C. unitumula* although they are slightly smaller; *C. sulcata* is similar in size but lacks a “beak”.

Occurrence. In Mongolia *C. unitumula* is known from the Tsagantsav and Dzun Bayn suite (Galeeva, 1955; Gou et al., 1986; Liubimova, 1956). The species has been reported from the Lower Cretaceous (Hauterivian–Barremian) of the lowlands of western Siberia (Liubimova et al., 1960). In China the species has been reported from assemblage 1 of the Saihan Tal Formation, Eren Basin, Nei Mongol Autonomous Region (Gou et al., 1986) and from the Yixian Formation, Fuxin Basin, Liaoning Province (Li et al., 1988).

Stratigraphic distribution. Berriasian–Albian.

Cypridea sp.1
 Fig. 4G–H

Material. Two complete carapaces.

Measurements. Length 0.86 mm, height 0.462 mm, width 0.3 mm.

Remarks. The specimens studied differ from all the known spiny *Cypridea* species of the Lower Cretaceous of Asia, such as *C. priva* Liubimova, 1956, *C. spinigera* Liubimova, 1956 and others, in general outline, the distinct tubercles, the presence of the beak on both valves and the absence of a depression on the dorsal margin. However, we do not consider it advisable to describe a new species on the basis of only two specimens.

Cypridea sp.2
 Fig. 4I

Material. One partial carapace and one detached valve.

Measurements. Length 1.015–1.030 mm, height 0.445 mm.

Remarks. The specimens studied resemble the general outline of *Cypridea stenolonga* Pang in Pang et al., 1984, but differ in having smaller dimensions and a less pronounced ornamentation of the valves. The available material is too incomplete to justify the description of a new species.

Family: Ilyocyprididae Kaufmann, 1900
 Genus *Rhinocypris* Anderson, 1941

Rhinocypris sp.
 Fig. 4Q

Material. Five detached valves.

Measurements. Length 0.81 mm, max. height 0.368 mm, height of posterior end 0.284 mm.

Remarks. The presence of the two depressions, three nodes and the thin shell place the specimens studied within the genus *Rhinocypris*. The specimens of *R. potanini* (Liubimova) as figured by Gou et al. (1986) are very similar to our form, but they do not seem to match the original illustrations of *R. potanini*, which was originally described by Galeeva (1955) and not by Liubimova (1956) as erroneously stated by Gou et al. (1986). Contrary to *R. panosa* Liubimova, 1956, the three nodes on the dorsal part are of an equal size and are aligned in our specimens. *R. pustulata* as illustrated by Li and Cao (2002) is a very similar species. Further consideration of this species might be indicated if comparative material can be obtained. Our material also resembles *Rhinocypris jurassica* (Martin, 1940), a European Late Jurassic–Early Cretaceous species, the name of which has been applied, perhaps uncritically and erroneously, to specimens from elsewhere, including China (see e.g., Hou et al., 2002). The extent and significance of both inter- and intra-specific

variation in ornament in the Ilyocyprididae is poorly understood, and the genus *Rhinocypris* is certainly in need of revision.

Occurrence. In Inner Mongolia this species is known from the Lower Cretaceous, from assemblage 5 of the Saihan Tal Formation, Eren Basin (Gou et al., 1986). *R. pustulata* is known from the Jingangquan Formation (Cenomanian), Chaoshui Basin, northwest China (Li and Cao, 2002).

Stratigraphic distribution. Hauterivian–Cenomanian.

Family: Trapezoidellidae Sohn, 1979

Genus *Mongolianella* Mandelstam in Galeeva, 1955

Mongolianella khamariniensis Liubimova, 1956

Fig. 4A–B

1955 ostracoda sp., Galeeva, pl. 14, fig. 1a–b.

1956 *Mongolianella khamariniensis* Liubimova, pp. 89–90, pl. 19, fig. 1a–b.

Material. Four valves and one carapace.

Measurements. Length 1.048–1.089 mm, height 0.51–0.517 mm.

Remarks. Although the specimens studied are a little smaller and slightly less tapered posteriorly than *M. khamariniensis* as illustrated by Liubimova (1956), they do fall within the range of variation of this species. They match very well the shape of “ostracoda sp.” as figured by Galeeva (1955). Perhaps Liubimova (1956) was referring to this specimen when she described *M. khamariniensis* Galeeva in litt. The muscle scar pattern has some similarities with that of *M. palmosa* Mandelstam, 1956. *M. zerussata* Galeeva, 1955 differs by having a more pointed posterior end. The studied specimens are also very like *Candona disjuncta* Hao as illustrated by Jiang et al. (2000) from the Early Cretaceous of the Baiyinchagan Depression, Inner Mongolia; without comparative material we cannot say more.

Occurrence. Galeeva (1955) reported “ostracoda sp.” from the Sainshand and Bayn Shire suites. Liubimova (1956) described *M. khamariniensis* from the middle and upper part of the Dzun Bayn suite. Stankevitch and Sochava (1974) reported the species from the Barungoyot and Nemegt suites at the Nemegt and Bugin Tsav localities, Mongolia. In China the species is known from assemblage 2 of the Saihan Tal Formation, Eren Basin, Nei Mongol Autonomous Region (Gou et al., 1986) and from the Quantou Formation, Songliao Basin (Li and Liu, 1994).

Stratigraphic distribution. Barremian–Maastrichtian.

Mongolianella cf. *zerussata* Galeeva, 1955

Fig. 3X–Y

1955 *Mongolianella zerussata*, Galeeva, p. 46, pl. 11, fig. 1a–e.

non 1955 *Mongolianella palmosa* Mandelstam; Galeeva, p. 46, fig. 2a–b.

1956 *Mongolianella palmosa* Mandelstam, p. 113, pl. 23, fig. 5a–c.

1963 *Mongolianella palmosa* Mandelstam; Mandelstam and Schneider, p. 117, pl. 16, fig. 3a–b.

2002 *Mongolianella palmosa* Mandelstam, 1956, Hou et al., p. 635, pl. 206, fig. 13–15.

Material. Eleven carapaces, only a few well-preserved.

Measurements. Length 1.45 mm, height 0.65 mm.

Remarks. The specimens studied match the description of *M. zerussata* Galeeva, 1955. The drawings given by Galeeva show a convex ventral margin whereas in our specimens it is concave; however, Galeeva’s (1955) description states that the ventral margin is slightly concave. Some specimens (Fig. 3X) appear strongly concave because of the deformation of the ventral margin of the carapace. The concavity seems to increase with the degree of deformation. Undeformed specimens have not been recovered. Because of this apparent difference in concavity of the ventral margin between our specimens and *M. zerussata* as illustrated by Galeeva (1955), they are attributed to *M. cf. zerussata*. They differ from *M. khamariniensis* by having a more pointed posterior end. *M. adulata* Liubimova, 1956 is similar in size but the general outline is different. The description and figures of *M. palmosa*, as given by Mandelstam (1956), are identical to those of *M. zerussata* Galeeva, 1955. Although *M. palmosa* Mandelstam is frequently used, *M. zerussata* has priority. Galeeva (1955) also published a description of *M. palmosa* that differs from *M. zerussata* and attributed it to Mandelstam. However no earlier description of this species by Mandelstam can be found.

Occurrence. *M. zerussata* has been described from the lower part of the upper Dzun Bayn suite. The species has been reported, as *M. palmosa* Mandelstam, from the Barremian of Transbaikalia, Russia (Mandelstam, 1956), the Tsagantsav and Dzun Bayn suites (Liubimova, 1956), the Bayn Shire, Bayn Dzakh and Barungoyot suites (Khand, 1987) and the Second Member of the Saihan Tal Formation, Eren Basin, Inner Mongolia (Gou et al., 1986).

Stratigraphic distribution. Hauterivian–Albian.

Family Candonidae Kaufmann, 1900

Genus *Candona* Baird, 1845

Candona praevara Zhang and Zhang, 1982

Fig. 4C

1982 *Candona praevara*, Zhang and Zhang, p. 365, pl. 2, fig. 4–5.

Material. Five carapaces.

Measurements. Length 0.638 mm, height 0.304 mm, width 0.219 mm.

Remarks. The specimens studied have a more convex dorsal margin than *Candona humanensis* Guan in Guan et al., 1978. *C. declivis* Ruan in Hao et al., 1974 has a more angular posterior end and *C. deflecta* Jiang and Guan in Guan et al., 1978 has a different length/height-ratio. *C. disjuncta* Hao in Hao et al., 1974 is slightly larger. Our specimens show considerable resemblance to *C. shangshuiensis* Zhang, 1988. The latter is very close to *C. praevara* but can be distinguished by an evenly convex dorsal margin and the greatest height in the middle part (Zhang, 1988).

Occurrence. Known from the Fuxin Formation of the Fuxin Basin, Liaoning Province (Zhang and Zhang, 1982).

Stratigraphic distribution. Aptian–Albian.

Family uncertain

Genus *Ziziphocypris* Chen, 1965

Ziziphocypris simakovi (Galeeva, 1955)

Fig. 4J–M

1955 *Timiriasevia simakovi* Mandelstam; Galeeva, p. 63, pl. 15, fig. 8a,b.

1965 *Ziziphocypris simakovi* (Mandelstam); Chen, pp. 15–16, pl. 2, fig. 6–8.

Material. More than 50 well-preserved specimens.

Measurements. Length 0.583–0.691 mm, height 0.308–0.4 mm, width 0.258 mm.

Remarks. *Ziziphocypris simakovi* (Galeeva, 1955) strongly resembles *Z. costata* (Galeeva, 1955) which was described from the same stratigraphic level. The difference between the two species is the greater prominence of some ribs in *Z. costata*. It is unclear whether the variation in the development of the ribs justifies the division of two species. Our specimens are closer to *Z. simakovi*.

Occurrence. Galeeva (1955) described *Timiriasevia simakovi* from the Bayn Shire suite, Mongolia. Liubimova (1956) extended the range downward into the Sainshand suite. Chen (1965) revised the generic assignment and found *Ziziphocypris simakovi* in the Jurassic rocks in Ishien, Liaoning Province. *Z. simakovi* has been reported from assemblage 4/5 from the Saihan Tal Formation, Eren Basin, Nei Mongol Autonomous Region (Gou et al., 1986), the Jufutang (Lower Cretaceous) and Fuxin (Lower–mid Cretaceous) Formation, Fuxin Basin, Liaoning Province (Su et al., 1985), the Xiazhuang Formation, Beijing (Pang and Whatley, 1990), the Zuoyun Formation, Shaanxi (Pang and Whatley, 1990) and the upper part of Zhoujiadian Formation (99.5 Ma), Xinjiang Basin, Jiangxi province (Xu, 1993).

Stratigraphic distribution. Jurassic–Turonian.

Suborder: Darwinulocopina Sohn, 1988

Superfamily: Darwinuloidea Brady and Norman, 1889

Family: Darwinulidae Brady and Norman, 1889

Genus *Alicenula* Rossetti and Martens, 1998

Alicenula? contracta (Galeeva, 1955)

Fig. 4D–F

1955 *Darwinula contracta* Mandelstam; Galeeva, pp. 54, pl. 15, fig. 1a–d.

1956 *Darwinula contracta* Mandelstam; Liubimova, pp. 117, pl. 22, figs. 1–2.

Material. Fifteen mostly broken and compacted specimens.

Measurements. Length 0.708–0.8 mm, height 0.316–0.336 mm.

Remarks. The presence of the typical muscle scar places the specimens studied within the Darwinulidae, but the generic assignment is somewhat problematic. Rossetti and Martens (1998) divided the genus *Darwinula* into five genera: *Darwinula s.s.* Brady and Robertson in Jones, 1885, *Microdarwinula* Danielopol, 1968, *Alicenula* Rossetti and Martens, 1998, *Vestalenula* Rossetti and Martens, 1998 and *Penthesilenula* Rossetti and Martens, 1998. The valve overlap (left over right) in our specimens, as well as in those figured by Liubimova (1956) rules out the genus *Darwinula s.s.* Based on the valve overlap and general form, our specimens are tentatively attributed to the genus *Alicenula*; however, we have been unable to find a well-enough preserved left valve to confirm the generic assignment on the basis of internal features.

Liubimova (1956) attributed two slightly different forms to *D. contracta*: a fairly low and more elongated form (Liubimova, 1956, pl. 22, fig. 1a–c) and a higher

more contracted form (Liubimova, 1956, pl. 22, fig. 2a–c). Both forms seem to be present among our specimens. Geng (1979) considered *D. contracta* to be a junior synonym of *D. leguminella* (Forbes in Lyell, 1855), while Martens et al. (2003) demonstrated that *D. leguminella* should be placed in the genus *Alicenula*. This synonymy would confirm the generic assignment postulated above, but in more recent publications (Hou et al., 2002), the two are maintained as separate species.

Occurrence. Galeeva (1955) described *D. contracta* from the lower part of the upper Dzun Bayn suite. In Mongolia this species is also known from the Tsagan Tsav suite (Liubimova, 1956) and the Barunbayan suite (Khand, 1987). In China it was reported from Xiaoguo Formation (Barremian), Jiedabangou, Huahai Basin, Gansu Province (Fu and Yuan, 1998), the middle part of the Wanxu Group (Berriasian–Valangian), Guide Basin, Qinghai Province (Sun, 1997), the Lincheng Formation, Hebei (Pang and Whatley, 1990), the Lisangou and Guyang formations, Inner Mongolia (Pang and Whatley, 1990) and the Shahai, Yixian and Jufutang formations, Jehol Group, Liaoning and Hebei provinces (Li and Liu, 1994). *D. leguminella* is known from assemblage 1/2/5 from the Saihan Tal Formation, Eren Basin, Nei Mongol Autonomous Region (Gou et al., 1986) and from the upper part of the Zhoujiadian Formation (99.5 Ma), Xinjiang Basin, Jiangxi Province (Xu, 1993).

Stratigraphic distribution. Berriasian–Albian.

Suborder: Cytherocopina Grunzel, 1967
 Superfamily: Cytheroidea Baird, 1850
 Family: Limnocytheridae Klie, 1938
 Genus *Timiriasevia* Mandelstam in Galeeva, 1955

Timiriasevia principalis Liubimova, 1956
 Fig. 4N–O

1956 *Timiriasevia principalis* Liubimova, pp. 129–130, pl. 24, fig. 1a–b.

1965 *Metacypris miaogouensis* Chen, pp. 19–20, pl. 1, figs. 10–13.

Material. Two broken valves.

Measurements. Although both specimens are incomplete, the length varies between 0.75–0.8 mm and the maximum height is 0.5 mm.

Remarks. In spite of the incomplete material, the observed thickness and the distinct ornamentation allow the attribution of the specimens to *T. principalis* Liubimova, 1956. *Metacypris miaogouensis* Chen, 1965 is considered to be a junior synonym of *T. principalis*, a possibility already mentioned in the original description (Chen, 1965). Our specimens show a great resemblance to

T. crustiformis Mandelstam. According to the original description, *T. crustiformis* is smaller, has a heartshaped form in dorsal view, and the ribs are more concentric.

Occurrence. Described from the Sainshand suite, Mongolia (Liubimova, 1956). In China the species (as *Metacypris miaogouensis*) is known from the Cretaceous in the Miaogou District, Gansu Province (Chen, 1965) and from the Sunjiawan Formation, Fuxin Basin, Liaoning Province. *T. principalis* has been reported from the Xiazhuang Formation, Beijing (Pang and Whatley, 1990).

Stratigraphic distribution. Aptian–Albian.

5.2. Discussion of ostracod data

The ostracod fauna of the Dashuiguo Formation is characterized by a dominance of the genus *Cypridea* and the occurrence of the cypridoidean genera *Ziziphocypris*, *Mongolianella* and *Rhinocypris*. Cypridoidean ostracods did not become the dominant element of non-marine ostracod faunas before the Tithonian (Whatley, 1992). The absence of typical Upper Cretaceous genera like *Talicypridea* Khand, 1977, *Altanicypis* Szczechura, 1978, *Khandia* Szczechura, 1978 and *Bogdocypis* Khand, 1994 limit the age of the assemblage to the Early Cretaceous (Khand, 2000). The genus *Mongolocypris* Szczechura, 1978 is known from the Upper Cretaceous although some occurrences in the upper part of the Lower Cretaceous (Xu, 1993) have been mentioned. The occurrence of this genus within a typical Lower Cretaceous assemblage places the age of the sediments studied in the late Early Cretaceous.

The Dashuiguo assemblage strongly resembles the fauna of the early Cretaceous Saihan Tal Formation, Eren Basin, Inner Mongolia (Gou et al., 1986). Both are comparable on a genus level, and they have some species in common. Based on palynological evidence the age of the Saihan Tal Formation was estimated by Li and Liu (1994) to be Hauterivian–Aptian. Based on the correlation with the Shinekhudag Formation, its age was estimated by Hicks et al. (1999) to be Middle–Late Albian. The fauna studied shows the greatest resemblance with that of the Dzun Bayn suite, Mongolia, which according to Khand et al. (2000) ranges in age from Hauterivian to Albian.

6. Palynomorphs

Gymnosperm pollen grains make up 70% of the total palynological assemblage, and are mainly composed of monosulcate *Ginkgoecycadophytus* and rimulate *Classopollis*. They are associated with pollen attributed to the Pinaceae (*Alisporites aequalis*, *A. similes*, *A. sp.*,

Cedripites cretaceous, *C. parvisaccatus*), Podocarpaceae (*Podocarpidites ellipticus*, *P. major*, *P. multessimus*) and Araucariaceae (*Araucariacites australis*, *A. sp.*). *Podozamites glaber*, *Psophosphaera sp.*, *Inaperturopollenites dubius* and *Gnetaceapollenites certus* are rare.

Spore diversity (more than 20 taxa) is quite high. Among them, smooth trilete spores attributed to the Cyatheaceae (*Cyathidites australis*, *C. minor*, *Dictyophyllidites equixinus*, *D. harrisii*) and *Leiotriletes* spp., as well as to the Schizaeaceae (*Concavissimisporites asper*, *C. variverrucatus*, *Impardecispora apiverrucata*, *Klukisporites variegatus*) are dominant. *Osmundacidites* (*O. parvus*, *O. wellmanii*, *O. sp.*), *Gleicheniidites* (*G. laetus*, *G. sp.*), *Laevigatosporites ovatus* and striate spores (*Cicatricosisporites dorogensis*, *C. ludbrookii*, *C. tersus*) are insignificant. Spores of lycopods and mosses (*Densoisporites vellatus*, *Leptolepidites verrucatus*, *Foveosporites canalis*, *Stereisporites stereoides*, *Concavissimisporites juriensis*) are rare.

The general characteristics of the palynological assemblage (Table 1, Fig. 5) can be summarized as follows: no angiosperm pollen have been observed; gymnosperm pollen (70%) are dominated by *Ginkgocycadophytus* (45.5%); spore diversity is high but cicatricose spores are insignificant.

Correlation of the taxonomic composition showed some similarity with the palynofloras of Barremian age from the Chagdamynskaya Formation of the Bureya Basin (the middle Amur River region), the lower Starosuchanskaya Formation of the Partizanskaya Basin (Markevich, 1994, 1995), the Damoquahe Formation in Hinggan Ling Region, northeast China (Pu and Wu, 1985), the Huolinhe Formation of the Huolinhe Basin and the Damoquahe Formation of Hailar area, east Inner Mongolia (Deng and Chen, 2001). All of these assemblages are similar to the assemblage of the Dashuiguo Formation in the following major characteristics: *Ginkgocycadophytus* is predominant, while *Classopollis*, Schizaeaceae (mainly *Concavissimisporites* and *Impardecispora*) and Cyatheaceae are common. Unlike the assemblage from the Dashuiguo Formation, they contain significant amounts of the cicatricose spores *Cicatricosisporites* and *Appendicisporites*.

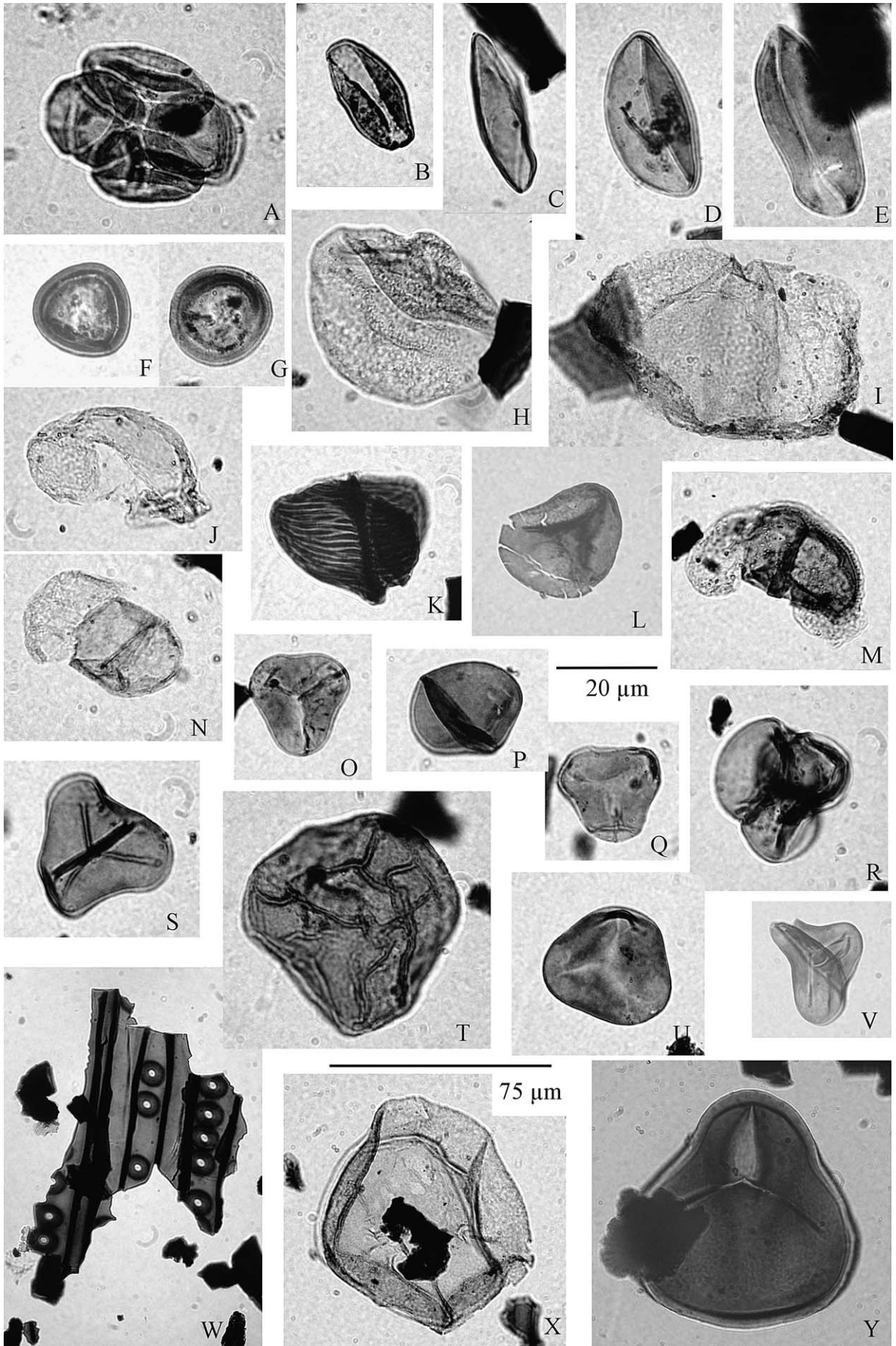
Comparison of the assemblage studied with that recovered from the Xinminbao Group (Tang et al., 2001), another site of *Probactrosaurus*, shows that the ratio of gymnosperms to pteridophytes is comparable but that the latter assemblage has an important angiosperm flora (4% of the total, four different

Table 1

Taxonomic composition of the palynological assemblage from the Dashuiguo Formation

	#	%
Spores	119	30.59
<i>Stereisporites stereoides</i> (Potonié et Venitz)	2	0.51
Pflug, 1953		
<i>Concavissimisporites juriensis</i> Balme, 1957	1	0.26
<i>Leptolepidites verrucatus</i> Couper, 1953	2	0.51
<i>Densoisporites vellatus</i> Weyland et Krieger, 1953	1	0.26
<i>Foveosporites canalis</i> Balme, 1957	2	0.51
<i>Cyathidites australis</i> Couper, 1953	15	3.86
<i>C. minor</i> Couper, 1953	19	4.88
<i>Dictyophyllidites equixinus</i> (Couper)	2	0.51
Dettmann, 1963		
<i>D. harrisii</i> Couper, 1958	2	0.51
<i>Rouseisporites reticulatus</i> Pocock, 1962	1	0.26
<i>Leiotriletes</i> spp.	21	5.40
<i>Gleicheniidites laetus</i> (Bolchovitina)	2	0.51
Bolchovitina, 1968		
<i>Gleicheniidites</i> sp.	3	0.77
<i>Laevigatosporites ovatus</i> Wilson et	5	1.29
Webster, 1946		
<i>Osmundacidites parvus</i> De Jersey, 1962	1	0.26
<i>O. wellmanii</i> Couper, 1953	3	0.77
<i>Osmundacidites</i> sp.	3	0.77
<i>Concavissimisporites asper</i> Pocock, 1962	25	6.43
<i>C. variverrucatus</i> (Couper) Brenner, 1963	2	0.51
<i>Impardecispora apiverrucata</i> (Couper)	2	0.51
Venkatachala, Kar et Raza, 1969		
<i>Klukisporites variegatus</i> Couper, 1958	2	0.51
<i>Cicatricosisporites dorogensis</i> Potonié et	1	0.26
Gelletich, 1933		
<i>C. ludbrookii</i> Dettmann, 1963	1	0.26
<i>C. tersus</i> (Kara-Murza) Pocock, 1964	1	0.26
Gymnosperm pollen	270	69.41
<i>Araucariacites australis</i> Cookson, 1947	8	2.06
<i>Araucariacites</i> sp.	2	0.51
<i>Jiaohepollis verus</i> Li, 1981	1	0.26
<i>Alisporites aequalis</i> Mädlar, 1964	20	5.14
<i>A. similis</i> (Balme) Dettmann, 1969	7	1.80
<i>Alisporites</i> sp.	2	0.51
<i>Cedripites parvisaccatus</i> (Sauer) Krutzsch, 1971	2	0.51
<i>C. cretaceus</i> Pocock, 1962	1	0.26
<i>Podocarpidites multessimus</i> (Bolchovitina)	4	1.03
Pocock, 1962		
<i>P. major</i> (Bolchovitina) Chlonova, 1976	2	0.51
<i>P. ellipticus</i> Cookson, 1947	3	0.77
<i>Ginkgocycadophytus</i> spp.	177	45.50
<i>Inaperturopollenites dubius</i> (Potonié et Venitz)	2	0.51
Thomson et Pflug, 1953		
<i>Podozamites glaber</i> Verbitskaja, 1962	11	2.83
<i>Psophosphaera</i> sp.	2	0.51
<i>Gnetaceapollenites certus</i> (Bolchovitina)	1	0.26
Verbitskaja, 1979		
<i>Classopollis classoides</i> Pflug, 1953 emend.	25	6.43
Pocock et Jansonius, 1961		
Total	389	

Fig. 5. Palynomorphs of the Dashuiguo Formation, Dashuiguo locality, Inner Mongolia, P.R. China. A, F, G, *Classopollis classoides*; B–E, *Ginkgocycadophytus* spp.; H, I, *Alisporites aequalis*; J, *Cedripites cretaceous*; K, *Cicatricosisporites ludbrookii*; L, *Leiotriletes* sp.; M, *Cedripites parvisaccatus*; N, *Alisporites similis*; O, Q, *Concavissimisporites juriensis*; P, U, *Cyathidites minor*; R, *Inaperturopollenites dubius*; S, *Dictyophyllidites harrisii*; T, *Rouseisporites reticulatus*; V, *Leiotriletes* sp.; W, cycad wood fragment; X, *Jiaohepollis verus*; Y, *Concavissimisporites asper*. Figs. T, X, Y, scale bar represents 75 µm; fig. W, length 200 µm; other figs., scale bar represents 20 µm.



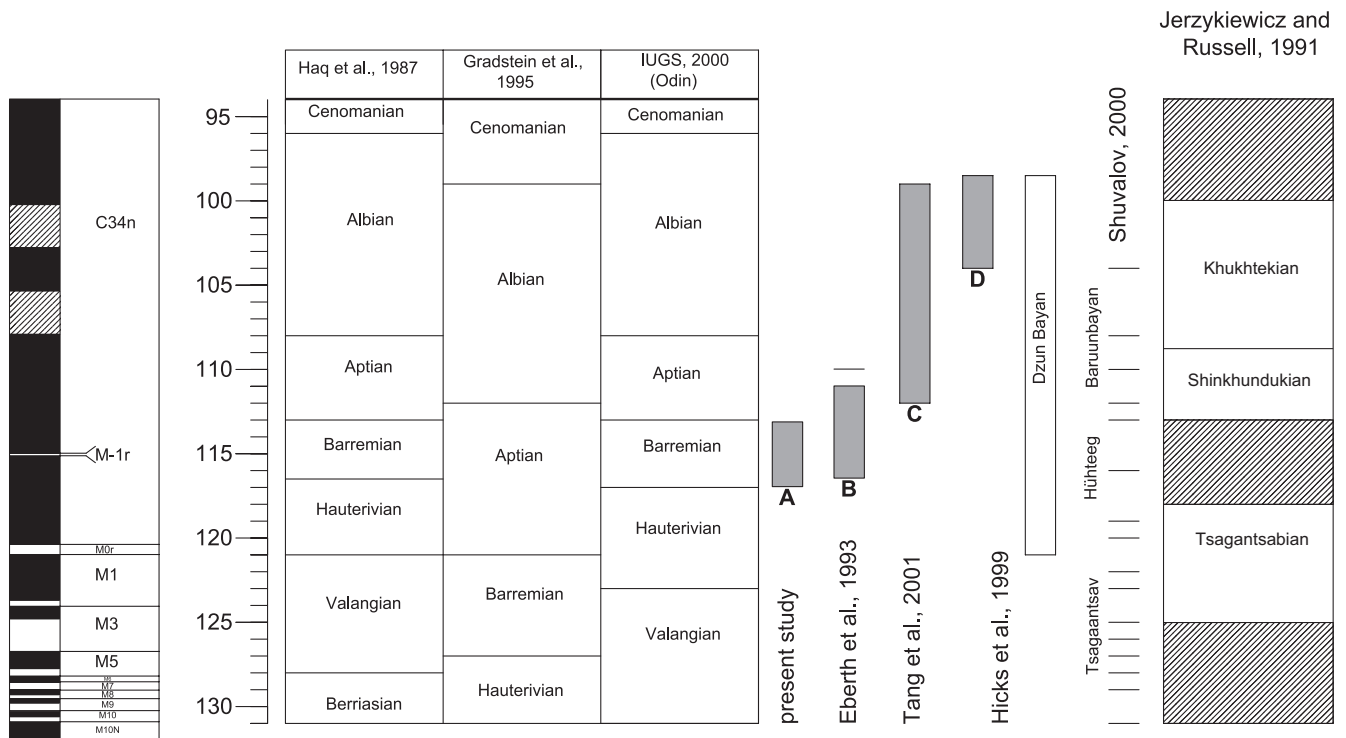


Fig. 6. Summary diagram with the Cretaceous stage boundaries after different authors, the estimated ages of the Dashuiguo Formation, Dashuiguo locality (A), the dinosaur-bearing sediments, Tebch locality (B) with the radiometric age of the Tebch basalt, the Xinminbao Group, Mazongshan locality (C) and the Shinekhudag Formation, Khuren Dukh locality (D). For comparison, the age of some of the Lower Cretaceous formations of the Gobi Basin are given. The grey rectangles represent estimations based on palynology; the horizontal lines represent radiometric ages.

species). The age of the lower part of the group is determined as Barremian–Albian, based on the presence of the angiosperms. The main fossil sites are probably Albian in age (Tang et al., 2001).

The assemblage from the Dashuiguo Formation resembles most closely the palynology of the dinosaur-bearing sediments at the Tebch locality, Inner Mongolia (Eberth et al., 1993). That assemblage is mainly composed of gymnosperm pollen (94%) with a predominance of *Ginkgoecycadophytus* (28%), and although spore diversity is high, cicatricose spores are absent. Based on the occurrence of the angiosperm pollen *Asteropollis*, and the radiometric dating of a basalt layer capping the sediments at Tebch, the age of the Tebch assemblage has been determined as Barremian or possibly early Aptian (Eberth et al., 1993). Considering the good taxonomic correlation for the gymnosperm pollen and the pteridophyte spores between the Tebch and Dashuiguo assemblages, the sediments at Dashuiguo are considered to be Barremian in age (Fig. 6), and in the absence of angiosperm pollen, probably slightly older than the sediments at Tebch.

Associated with the palynomorphs an abundance of plant tissue with a distinctive cellular structure and cuticles with stomata has been observed in the Dashuiguo material. The sinuous walls and syndetocheilic laterocytic stomata of the cuticles suggest bennettitalean origin.

7. Conclusions

Based on charophyte, ostracod and palynomorph evidence, the age of the dinosaur-bearing sediments of the Dashuiguo Formation is determined as Barremian. Palynomorphs provide the most accurate age as they have enabled correlation of the Dashuiguo sediments with the independently dated Tebch site (Eberth et al., 1993).

An accurate age based on charophytes or ostracods can only be obtained if a well-calibrated zonation has been established. In Central Asia, charophyte floras and ostracod faunas from numerous formations have been studied, but the ages of these formations are often poorly established or based on a circular reasoning. Therefore, no well-calibrated charophyte or ostracod zonation exists for the region. The Barremian age determined on palynological evidence is more accurate, and older, than the Aptian–Albian age based on dinosaur evidence. Age estimations of dinosaur sites based on dinosaur evidence, as demonstrated herein, need to be confirmed by independent age estimations.

In addition to the age, the microfossils also allow an appraisal of the palaeo-environment of the dinosaur-bearing sediments. The floodplain of the ancient river was covered by gymnospermous trees with an undergrowth of ferns. Although cicatricose spores occur throughout the Cretaceous and even abundantly in the

Barremian, they are insignificant in the assemblage studied. At Tebch, another Barremian dinosaur site in Inner Mongolia, cicatrose spores are absent (Eberth et al., 1993). These observations may indicate that the environment was unfavourable for these ferns during the Barremian in the Inner Mongolian area; however, further study is needed to confirm this. The ostracod fauna indicates that the ponds on the floodplain were mainly temporary water bodies. Ostracods with desiccation-resistant eggs and without broodcare (e.g., *Cypridea*) dominate the fauna while ostracods with broodcare (e.g., *Darwinula*, *Timiriasevia*) are poorly represented. This suggests that conditions probably favoured drought-resistant species. This is confirmed by sedimentological and charophyte data (Van Itterbeeck et al., 2001).

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