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Palaeontology and biostratigraphy of the Lower Cretaceous Qihulin Formation in eastern Heilongjiang, northeastern China

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Abstract

The purpose of the study was to provide conclusive evidence for a chronostratigraphical assignment of the Qihulin Formation of the Longzhaogou Group exposed in Mishan and Hulin counties of eastern Heilongjiang, northeastern China. To develop an integrated view of the formation, all collected fossil groups, i.e. the macrofossils (ammonites and bivalves) and microfossils (agglutinated foraminifers and radiolarians) have been studied. The low-diversity ammonite fauna consists of *Pseudohaploceras* Hyatt, 1900, and *Eogaudryceras* Spath, 1927, which indicate a Barremian–Aptian age. The bivalve fauna consists of eight genera and 16 species. The occurrence of *Thracia rotundata* (J. de C: Sowerby) suggests an Aptian age. The agglutinated foraminifers comprise ten genera and 16 species, including common Lower Cretaceous species such as *Ammodiscus rotalarius* Loeblich & Tappan, 1949, *Cribrostomoides*? *nonioninoides* (Reuss, 1836), *Haplophragmoides concavus* (Chapman, 1892), *Trochommina depressa* Lozo, 1944. The radiolarians comprise ten genera and 17 species, where *Novixitus* sp., *Xitus* cf. *spicularius* (Aliev, 1965), *Archaeodictyomitra* cf. *vulgaris* Pessagno, 1977, *Stichomitra* cf. *tosaensis* Nakaseko & Nishimura, 1981 all indicate an Early Cretaceous age. Thus the Qihulin Formation is assigned to the Barremian–Aptian.

Key words: Barremian, Aptian, Qihulin Formation, Longzhaogou Group, Heilongjiang, China, ammonites, bivalves, agglutinated foraminifers, radiolarians.

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1. Introduction

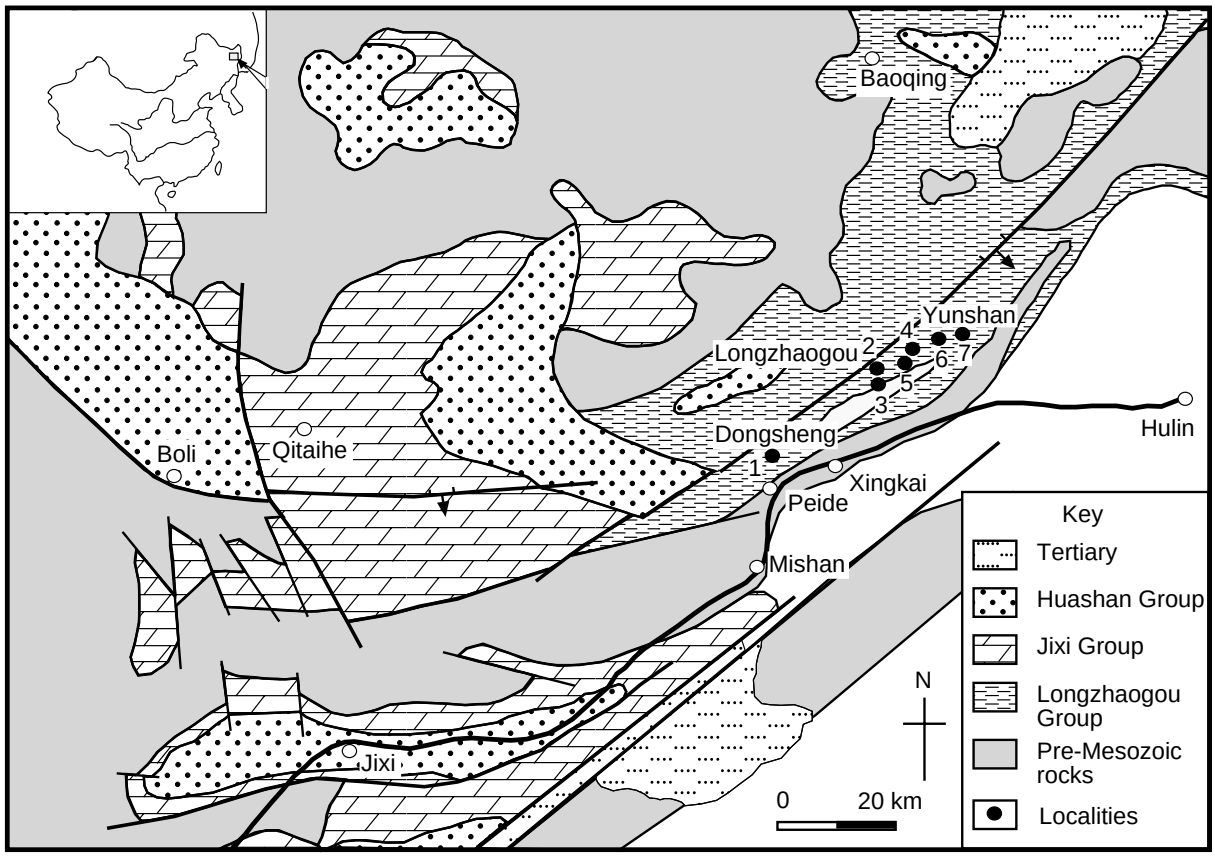

Figure 1.1. Simplified geological map of the Jixi and Hulin areas, eastern Heilongjiang, China (based on data from the Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986). 1. Dongsheng village. 2. Longzhaogou valley. 3. South of Qianjin village. 4. Chaoyang village. 5. Team No. 4 of Farm 850. 6. Test trench No. 1 of Yunshan Farm. 7. Test trench No. 2 of Yunshan Farm.

In the eastern part of Heilongjiang Province, a succession of Lower Cretaceous coal-bearing, alternating marine and nonmarine rocks is exposed. It comprises the Jixi Group in the west and the Longzhaogou Group in the east (figure 1.1). Geologists and palaeontologists have extensively studied the succession over the past decades, not only because of its richness in coal, but also because fossils found in the marine intercalations may provide a reliable age to the succession. In addition, attention is focused on correlation with the nonmarine Jehol Group (table 2.1) to establish the position of the Jurassic-Cretaceous boundary, which in

China is developed in nonmarine facies. The Jehol Group is widely known for the nonmarine Jehol fauna (Gu, 1962; Chen, 1988). In recent years the Jehol Group becomes more famous as an abundant source of remains of early birds (Hou et al., 1995; Hou et al., 1999; Hou & Chen, 1999) and theropod dinosaur with integumentary structures (Chen et al., 1998).

Until the 1980s, the marine fossil assemblages of the Jixi and Longzhaogou groups were dated as Jurassic, and the entire Jixi-Longzhaogou succession was then assigned to the Jurassic, or "chiefly Jurassic" (Huang, 1963; Ju et al., 1982; Gu & Chen, 1983; Li et al., 1986; Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986). In the 1990s, through the reassignment of *Buchia* spp. (Upper Jurassic) to *Aucellina* spp. (upper Lower Cretaceous), in the Chengzihe and Upper Yunshan formations, the Jixi-Longzhaogou succession was reassigned to the upper Lower Cretaceous (Sha et al., 1993, 1994). This revision sparked an interest in restudy of the palaeontology and biostratigraphy of the Longzhaogou Group. Thus, Kelly et al. (1994) reassessed the ammonites described by Liang (1982) and Wang (1983) from the Qihulin Formation and suggested an age range from Barremian to Maastrichtian. Futakami et al. (1995) studied ammonites from the same formation and assigned them to the Barremian. Gu et al. (1997) revised the bivalves of the Jixi and Longzhaogou groups and placed them stratigraphically in the Barremian–Aptian. Recently, He et al. (1999) reported Hauterivian–Barremian dinoflagellate cysts from the Qihulin Formation (Well H87–3 in Hulin) (figure 2.1).

Although an Early Cretaceous age of the Qihulin Formation now appears well established, uncertainty remains, as the ammonite determinations are based on poorly preserved material. Furthermore, until today no microfossils have been found at outcrop. In an attempt to find better preserved ammonites to allow a more precise and reliable determination, and in order to search for new evidence from microfossil groups, extensive field work and sampling was carried out in 1995, 1997 and 1998 in the Mishan and Hulin counties (within IGCP Project 350 "Cretaceous Environmental Change in E & S Asia"). For an integrated palaeontological and biochronostratigraphic study of the Qihulin Formation, ammonites and bivalves and samples for microfossil analysis were collected.

2. Geological setting

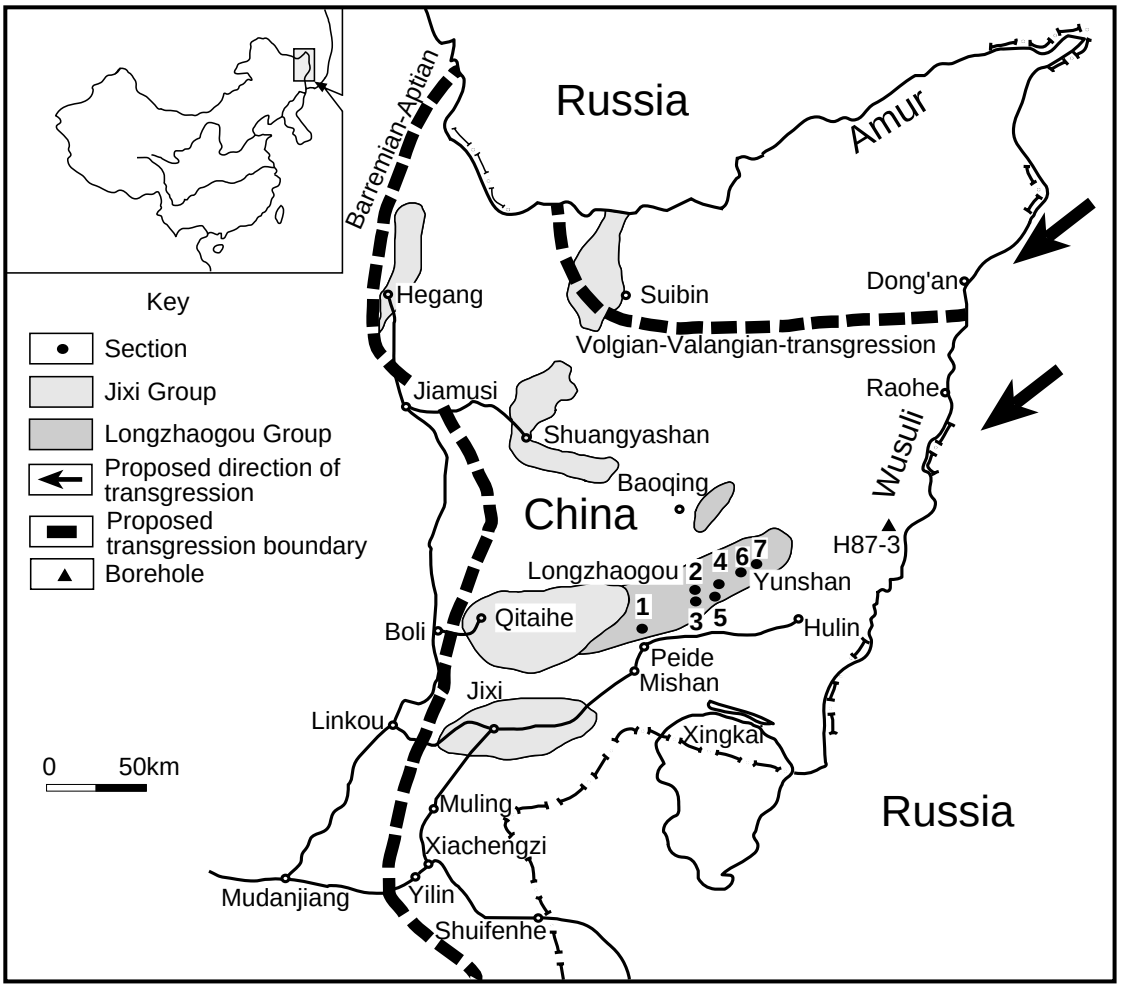

Figure 2.1. Localities studied in eastern Heilongjiang, China (after Sha et al., 1994). 1. Dongsheng village. 2. Longzhaogou valley. 3. South of Qianjin village. 4. Chaoyang village. 5. Team No. 4 of Farm 850. 6. Test trench No. 1 of Yunshan Farm. 7. Test trench No. 2 of Yunshan Farm.

In eastern Heilongjiang Province there are two upper Lower Cretaceous coal-bearing lithological groups, the Jixi Group in the west and the Longzhaogou Group in the east (figure 2.1). These two groups developed in a Mesozoic tectonic basin, which was frequently influenced by marine transgressions. Volcano-clastics and ignimbrites are fairly common in both groups. The coal measures of the Jixi Group are more numerous and thicker than those of the Longzhaogou Group. On the other hand, the marine strata of the Qihulin, Lower Yunshan and Upper Yunshan formations of the Longzhaogou Group are much thicker and numerous than those of the Chengzihe Formation of the Jixi Group. These marine strata

indicate the existence of a Barremian–Aptian embayment that opened towards the northeast or east and gradually shallowed towards the southwest or west (Sha et al., 1994).

The Jixi Group occurs in the Jixi, Muling, Boli, Shuangyashan, and Hegang basins (figure 2.1) and is characterized by terrestrial coal-bearing deposits intercalated locally with thin marine deposits yielding marine bivalves. The Jixi Group rests on the Proterozoic Mashan Group or the old granites, and is overlain by the Cretaceous Dongshan Formation of the Huashan Group. The Jixi Group has a thickness of 3000 m in the Jixi Basin, and is subdivided into three formations in ascending order, i.e. the Didao, Chengzihe and Muling formations (table 2.1).

Table 2.1. Correlation chart of the Jehol, Jixi and Longzhaogou groups (after Chen, 1992; Sha et al., 1994).

<table>
<tr><th colspan="2">Western Liaoning</th><th colspan="2">Jixi</th><th colspan="2">Hulin, Mishan</th></tr>
<tr><td rowspan="3">Jehol Group</td><td>Fuxin Fm</td><td rowspan="3">Jixi Group</td><td>Muling Fm</td><td rowspan="4">Longzhaogou Group</td><td>Zhushan Fm</td></tr>
<tr><td>Shahai Fm
Jiufotang Fm</td><td>Chengzihe Fm</td><td>Upper Yunshan Fm</td></tr>
<tr><td>Yixian Fm</td><td>Didao Fm</td><td>Lower Yunshan Fm</td></tr>
<tr><td></td><td></td><td colspan="2">?
Effusives</td><td>Qihulin Fm
Peide Fm</td></tr>
</table>

The Didao Formation is a continental volcano-sedimentary formation. It consists of effusives and sedimentary clastics with lava and coal intercalations, and conglomerates at the base, and has a thickness of 400 to 800 m. It yields the plants of the early assemblage of *Ruffordia–Onychiopsis* flora: *Acanthopteris gothani* Sze, 1931, *Onychiopsis elongata* (Geyler) Yokoyama, 1906 and *Podozamites reinii* etc. (Zheng & Zhang, 1982).

The Chengzihe Formation is a mainly nonmarine coal-bearing formation with littoral marine intercalations in the basal part. It is 500 to 2300 m thick, and yields the marine Aptian

bivalve *Aucellina caucasica* (Buch) (Sha et al., 1994), which was reassigned to *Aucellina jixiensis* Gu, 1997 (Gu et al., 1997), the nonmarine bivalves *Unio* aff. *obrutschewi* Martinson,1956 and *Unio* cf. *grabaui* Martinson, 1961 (Gu et al., 1987), the plants of the middle assemblage of *Ruffordia–Onychiopsis* flora (Zheng & Zhang, 1982) and the insect *Boligyrus marginus* Lin, 1983.

The Muling Formation is a continental coal-bearing formation, approximately 500 to 1100 m thick. It consists of greyish green siltstones, fine-grained sandstones and black mudstones with intercalations of ignimbrites, tuffaceous sandstones, shales and coal seams. It overlies the Chengzihe Formation conformably. The Muling Formation yields the plants of the middle assemblage of the *Ruffordia–Onychiopsis* flora (Zheng & Zhang, 1982) and the nonmarine bivalves *Sphaerium subplanum* (Reis, 1910) and *S. selenginense* (Martinson, 1956) (Gu et al., 1987).

The Longzhaogou Group crops out in the Hulin, Mishan and Baoqing counties in eastern Heilongjiang (figure 2.1). The Longzhaogou Group is poorly exposed and strongly faulted. In most areas it is only exposed in test trenches. This makes it very difficult to study the stratigraphy and to subdivide and correlate it with other groups. The succession rests unconformably on either Variscan granites or Permian rocks, yielding the plants *Neoggerathiopsis, Calamites, Comia* and *Zamiopteris* (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986). It is overlain by the Dongshan Formation of the Cretaceous Huashan Group, which yields the plants *Gleichenites*, *Onychiopsis elongata* (Geyler) Yokoyama, 1906, *Cladophlebis* (*Gelichites*?) *dabashanensis* Cao, 1984, *Nilssonia*? sp., *Ginkgoites adjantoides* (Unger) Seward, 1919, *Sphenolepis*? *concinna* Cao, 1984, *S.*? *densifolia* Cao, 1984, *Elatocladus* (*Cephalotaxopsis*) sp., *Sagenopteris* cf. *mantelli* (Dunker, 1846) Schenk, *Carpolithus* sp. (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986) and the fish *Manchurichthys* cf. *uwatatokoi* Saito, 1936 (Liu & Ma, 1983). Upper Triassic rocks are found in faulted contacts with the Longzhaogou Group in the Longzhaogou area (Gu & Chen, 1983).

The Longzhaogou Group has a total thickness of 4300 m and is subdivided into five formations, in ascending order, the Peide, Qihulin, Lower Yunshan, Upper Yunshan and Zhushan formations (table 2.1).

The nonmarine Peide Formation is 500 to 1000 m thick and consists of conglomerates and sandstones in the lower part, of sandstones, siltstones and mudstones with coal seams in the middle, and of yellowish green volcano-clastics, black mudstones and siltstones in the upper part. The most important plant recovered in the Peide Formation is *Coniopteris simplex*

(Indley & Hutten, 1835) Harris, 1961, which is a member of the Middle Jurassic flora of Yorkshire (Cao, 1983a, pl. 1, figs. 7–9a).

The mainly marine Qihulin Formation is 429 to 682 m in thickness, and consists of yellowish green sandstones, dark green siltstones with coal-bearing beds in the lower part. Its upper levels are black thick-bedded mudstones, which yield ammonites, bivalves, foraminifers and radiolarians.

The Lower Yunshan Formation, 1000 m thick, consists of interfingered marine and nonmarine sandstones and coal beds in the lower and middle parts; its upper part consists of effusives and effusive clastics with intercalations of medium- to fine-grained sandstones. It contains plants, bivalves and ostracods.

The Upper Yunshan Formation, 1100 m thick in total, consists of mudstones, siltstones and fine-grained sandstones with intercalations of ignimbrites, coal seams and carbonaceous mudstones. It is a succession of interbedded marine and nonmarine clastics, overlying the Lower Yunshan Formation conformably. It yields plants, bivalves, brachiopods, ostracods and gastropods. The *Aucellina* fauna indicates a Barremian–Aptian age and includes *Aucellina aptiensis* (d'Obigny, 1850), *A. caucasica* (Buch, 1851), *A. apiculata* (X. H. Yu, 1983), *A.* cf. *apiculata* (X. H. Yu, 1983), *A. jeletzkii* (Sha, 1989), and *A. wandensis* Gu, 1997 (Gu et al., 1997).

The mainly nonmarine Zhushan Formation is 910 to 930 m thick. It consists of sandstones, mudstones, coal seams and carboniferous mudstones in the lower part and sandstones, ignimbrites, tuffaceous breccias, coal seams and mudstones in the upper part. It yields plants and bivalves and Lower Cretaceous ("Neocomian"–Aptian) palynological assemblages (Zhang, 1983).

3. Previous work

3.1. Lithostratigraphy

In northeastern China nonmarine Jurassic and Cretaceous rocks are widely developed. Positioning the Jurassic–Cretaceous boundary focuses on the determination of the geological age of the nonmarine "Jehol fauna" and contemporaneous flora.

In 1958 during coalfield geological mapping Xu Y. Q. and Zhao D. Z. (Bureau of Geology & Mineral Resources of Heilongjiang Province) found the first ammonite specimen in the Longzhaogou valley, north of the village of Qianjin in Hulin County, which proved the existence of marine beds in the Longzhaogou area. The discovery raised hopes of using the marine fauna to date the nonmarine Jehol fauna. Furthermore, some molluscan species of the Jehol fauna are also found in the upper Jixi Group, it is very important to subdivide the Longzhaogou Group (figure 3.1) and attempt a correlation between the Jixi and Longzhaogou groups.

The Longzhaogou Group was proposed in 1962–1964 by a working group of the Heilongjiang Coalfield Management Bureau and the Geological Institute of the Heilongjiang Geological Bureau (unpublished), divided into three parts, and assigned a Late Jurassic age.

Huang (1963) subdivided the Longzhaogou Group into three parts. Only the lower part yielded ammonites, which were identified as Callovian *Arctocephalites* sp. and *Subkossmatia* sp. The bivalve and gastropod faunas suggested an age not younger than Late Jurassic.

In 1974 Chen Daokou et al. (unpublished) divided the Longzhaogou Group into three "coal-bearing formations". The lower formation was assigned to the Middle Jurassic, and the upper two formations to the Upper Jurassic. This opinion was accepted by the Compiling Group of the Regional Stratigraphic Scale of Heilongjiang Province (1979).

During the late 1970s and early 1980s three field campaigns were carried out separately in eastern Heilongjiang, i.e.: 1) the Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang (RTMCFH), of the Harbin Scientific and Technical Institute of the Geological Bureau, Northeastern China and Inner Mongolia Coal Company, and the Nanjing Institute of Geology and Palaeontology, Academia Sinica (1978–1980); 2) the Two Groups Research Team (TGRT) studied the correlation of the Longzhaogou and Jixi groups, of the Shenyang Institute of Geology and Mineral Resources, Chinese Academy of Geological

Sciences (1978–1980); and 3) the Regional Geological Research Team (RGRT) studied the correlation of the Longzhaogou and Jixi groups, of the No. 1 Regional Geological Surveying Party, Bureau of Geology and Mineral Resources of Heilongjiang Province, and Changchun College of Geology (1978–1982).

In 1979, at the Second Chinese National Stratigraphic Congress, the RTMCFH (unpublished) presented an abstract on the Longzhaogou Group, subdividing it into the Peide, Qihulin, Yunshan and Zhushan formations, in ascending order. The upper two formations were assigned to Upper Jurassic, the lower two to the Middle Jurassic.

Simultaneously, the TGRT (unpublished) contributed an abstract, in which the Longzhaogou Group was subdivided into the Dongshengcun, Peide (including the intercalation yielding ammonites), and Yunshan (subdivided into three members) formations, in ascending order. The Longzhaogou Group was assigned to the Middle–Upper Jurassic. Their report was subsequently published by Ju et al. (1981).

Gu (1980) correlated the Longzhaogou Group with the Didao and Chengzhihe formations of the Jixi Group, and assigned the overlying Muling Formation of the Jixi Group to the Lower Cretaceous. Later, Gu (1982) formalized the names Peide, Qihulin, Yunshan and Zhushan formations of the Longzhaogou Group, introduced by the RTMCFH in 1979.

Ju et. al. (1982) renamed the lower two members of the Yunshan Formation as Chaoyangtun Formation, whereas the uppermost member of the Yunshan Formation maintained the original name Yunshan Formation.

Gu & Chen (1983) subdivided the original Yunshan Formation into Lower and Upper Yunshan formations, thus a subdivision of the Longzhaogou Group into five formations was proposed, and published by RTMCFH (1986). This is the lithostratigraphical subdivision currently used by most workers.

Li et al. (1986) proposed a subdivision of the Longzhaogou Group into seven formations, i.e., in ascending order, the Peide, Qihulinhe, Hongxingcheng, Chaoyang, Yunshan, Shuguang and Zhushan formations.

The main sequence of the Longzhaogou Group is that its lower part consists of continental coal-bearing volcanic deposits, its middle part is made up of alternating marine and nonmarine coal-bearing sediments with effusive clastic intercalations and, its upper part is mainly nonmarine coal-bearing rocks, with rare littoral or sublittoral intercalations. The total thickness of the group is approcimately 4300 m (RTMCFH, 1986).

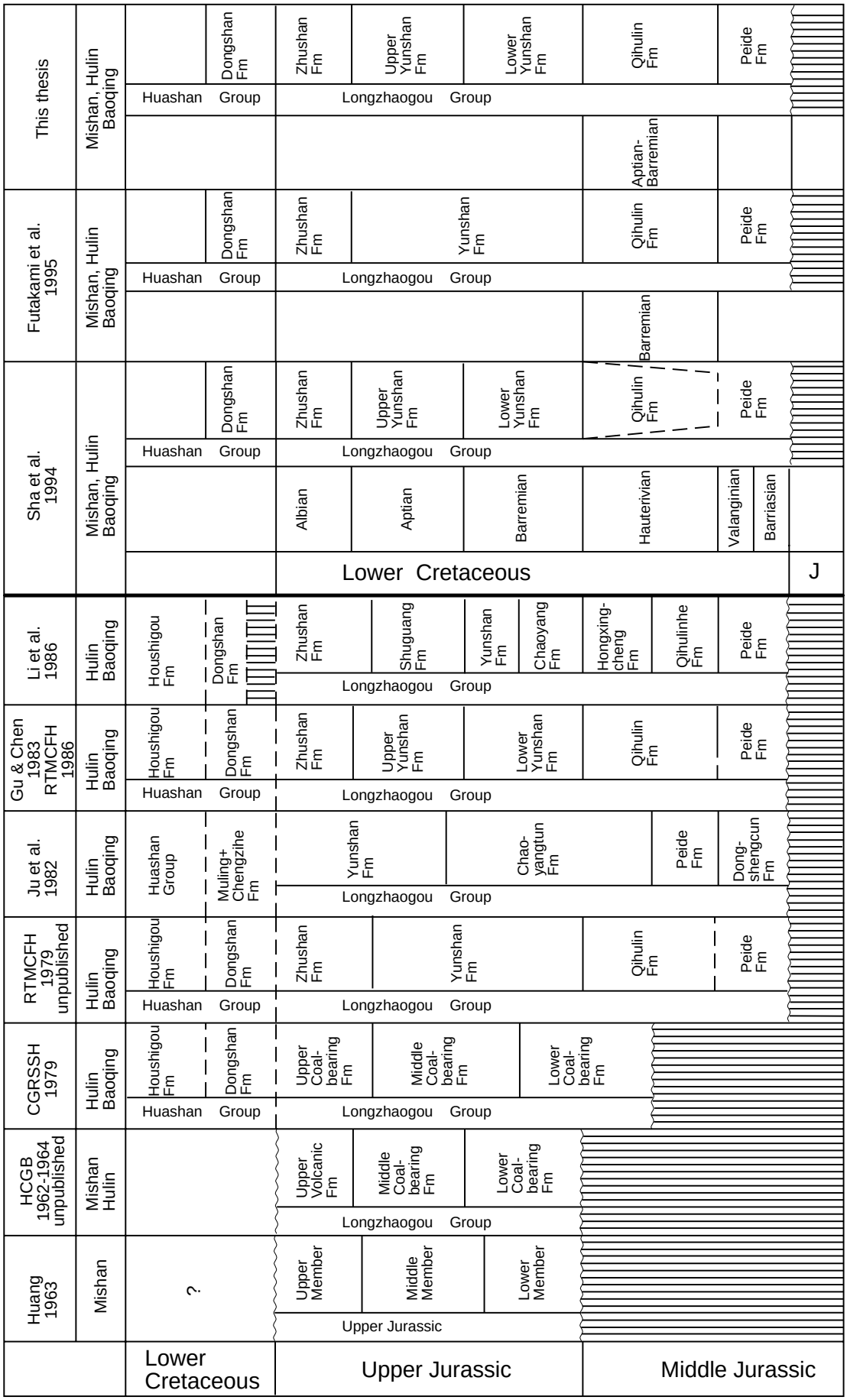

Figure 3.1. Lithostratigraphical synonymy chart for the Longzhaogou Group. Abbreviations: HCGB Heilongjiang Coal-field Management Bureau and the Geological Institute of the Heilongjiang Geological Bureau; CGRSSH Compiling Group of Regional Stratigraphic Scale of Heilongjiang; RTMCFH Research Team on Mesozoic Coal-bearing formations of eastern Heilongjiang; J Jurassic.

The Peide Formation is the lowest unit of the Longzhaogou Group. Its lower part consists of conglomerates and conglomeratic sandstones, which rest unconformably on either Variscan granites or Permian rocks yielding plant remains. Its upper part consists of coal-bearing sandstones, mudstones, intercalated with effusives and effusive clastics. The type section was in the test trench No. 9 north of Peide, Mishan County, eastern Heilongjiang (RTMCFH, 1986).

The Qihulin Formation rests conformably on the Peide Formation. The type section is along the Qihulin river at Chaoyang village in Hulin County (RTMCFH, 1986). It consists of fossiliferous marine beds with nonmarine intercalations developed as thick-bedded black mudstones, fine-grained sandstones and ignimbrites.

The Lower and Upper Yunshan formations consist of interbedded marine and nonmarine coal-bearing black mudstones, yellow siltstones and fine- and medium-grained sandstones, with intercalations of ignimbrites, coal seams and carbonaceous mudstones. A set of effusives and effusive clastics in the upper part of the Lower Yunshan Formation constitute the marker bed to separate the two formations. The total thickness of the two formations reaches approximately 2000 m. The Lower Yunshan Formation probably rests conformably on the Qihulin Formation. The type section is in the Yunshan Farm (RTMCFH, 1986).

The Zhushan Formation rests comformably on the Upper Yunshan Formation. It consists mainly of nonmarine coalbearing sandstones, mudstones and ignimbrites, with rare intercalations of littoral to sublittoral strata.

3.2. Palaeontology and biostratigraphy

3.2.1. Ammonites

Ammonites have only been found in the Qihulin Formation of the Longzhaogou Group. They have played an important role in dating the formation (table 3.1). The first ammonite, found in 1958 in the Longzhaogou valley, was identified as a Callovian *Subkossmatia* sp. (Chang in Huang, 1963)

The scarcity and the poor preservation of the ammonites made their identification difficult. Liang (1982) identified ten specimens from the “Peide Formation” (corresponding to the Qihulin Formation of the RTMCFH subdivision) in Yunshan and the Longzhaogou valley in Hulin County and Peide in Mishan County. He referred them to seven species belonging to seven genera, with five new species, *Calliphylloceras yunshanense* Liang, 1982, *Oppelia*

Table 3.1. Ammonites reported from the Qihulin Formation, giving the original name and first author; distinction is made between mention (M), noting if there are figures (f) and full taxonomic treatment (T). Generic reassignments and reidentifications from study of original specimens are given in the remarks. Repository of specimens designated by codes as follows: NIGP=Nanjing Institute of Geology and Palaeontology; SIGMR=Shenyang Institute of Geology and Mineral Resource; RGHP=No. 1 Regional Geological Party, Bureau of Geology and Mineral Resources of Heilongjiang Province, PR China.

Taxon	Treat-ment	Assigned Age	Author	Remarks
Subkossmatia sp.	M	Callovian	Chang in Huang 1963	
Calliphylloceras yunshanense sp. nov.	T	J1-K1	Liang 1982	Revised by Kelly et al. (1994) asTetragonitid indet., specimen SIGMR Ce057.
Oppelia (*Oxycerites*) *yunshanense* sp. nov.	T	late Bajocian-Callovian		Revised by Kelly et al. (1994) asTetragonitid indet., specimen SIGMR Ce058.
Lobokosmoceras? *peideense* sp. nov.	T	late Callovian		Revised by Kelly et al. (1994) as Desmoceratacean Group B, by Futakami et al. (1995) as *Pseudohaploceras* cf. *liptoviense* (Zeuschner), specimen SIGMR Ce059.
Arctocephalites peideense sp. nov.	T	middle Bathonian		Revised by Kelly et al. (1994) as Desmoceratacean Group B, by Futakami et al. (1995) as *Pseudohaploceras* cf. *liptoviense* (Zeuschner), specimen SIGMR Ce060, Ce061.
Morphoceras longzhaogouense sp. nov.	T	early Bathonian		Revised by Kelly et al. (1994) as Desmoceratacean Group A, by Futakami et al. (1995) as *Pseudohaploceras* cf. *liptoviense* (Zeuschner), specimen SIGMR Ce064.
Paracadoceras sp.	T	Bathonian-early Callovian		Revised by Kelly et al. (1994) as Desmoceratacean Group A, by Futakami et al. (1995) as *Pseudohaploceras* cf. *liptoviense* (Zeuschner), specimen SIGMR Ce062.
Stenocadoceras sp.	T	Bathonian-early Callovian		Revised by Kelly et al. (1994) as Desmoceratacean Group B, specimen SIGMR Ce063.
Arctocephalites (*Cranocephalites*) *hulinensis* sp. nov.	T	Bajocian-Bathonian	Wang 1983	Revised by Kelly et al. (1994) as Desmoceratacean Group A, specimens NIGP 74412, HM004.
Stenocadoceras sp.	T	Callovian		Revised by Kelly et al. (1994) as Desmoceratacean Group B, specimen NIGP 74415.
Leptosphinctinae gen. et sp. indet.	T			Revised by Kelly et al. (1994) as Desmoceratacean Group B, specimen NIGP 74414.
Lytoceras sp.	Mf	middle Bathonian-early Callovian	Li et al. 1986	Here referred to *Eogaudryceras* (*E.*) *yunshanensis* (Liang, 1982), specimen RGHP P20H10.
Phaulozigzag? sp.	Mf	middle Bathonian-early Callovian		Here referred to *Pseudohaploceras* cf. *nipponicum* Shimizu, 1931, specimen RGHP H5840
Arctocephalites sp.	Mf	middle Bathonian-early Callovian		Here referred to *Pseudohaploceras* cf. *nipponicum* Shimizu, 1931, specimen RGHP P111H46.
Pseudohaploceras cf. *liptoviense* (Zeuschner, 1856)	T	Barremian	Futakami et al. 1995	Specimens NIGPAS124548-124549, 124555, here referred to *Pseudohaploceras* cf. *nipponicum* Shimizu, 1931; specimens NIGP AS124550-124554 here referred to *Pseudohaploceras* sp. 1
Phyllopachyceras sp.	T	Barremian		

(*Oxycerites*?) *yunshanense* Liang, 1982, *Lobokosmoceras*? *peideense* Liang, 1982, *Arctocephalites peideense* Liang, 1982, *Morphoceras longzhaogouense* Liang, 1982, *Stenocadoceras* sp. and *Paracadoceras* sp. Liang (1982) considered the ammonite fauna to be of middle Bathonian age (Middle Jurassic), and similar to contemporaneous Boreal faunas, such as that of Greenland, the Canadian Arctic, northwestern USA and the Russian Arctic.

Wang (1983) described eight specimens from the Qihulin Formation in the Longzhaogou valley and from Chaoyang village in Hulin County. The predominant species was the Boreal species *Arctocephalites* (*Cranocephalites*) *hulinensis* Wang, associated with *Stenocadoceras*? sp. and Tethyan Leptosphinctinae gen. et sp. indet., which may be close to *Leptosphinctes* or "*Cobbanites*". Wang assigned this fauna to the early and middle Bathonian on the basis of the affinity of *Arctocephalites* (*Cranocephalites*) *hulinensis* Wang to *Arctocephalites* (*C.*) *ignekensis* Imlay from the middle Bathonian of Alaska. Wang further pointed out that it was possible that this fauna was younger than middle Bathonian because of the appearance of *Stenocadoceras* known from Callovian strata.

Kelly et al. (1994) reassessed the ammonites of the Qihulin Formation assigning them mainly to the Desmoceratacea, with subordinate tetragonitids, and suggested an age range from Barremian to Maastrichtian. A more precise identification was hampered by the poor preservation of the material.

Futakami et al. (1995) described ten specimens from the Longzhaogou valley as *Pseudohaploceras* cf. *liptoviense* (Zeuschner) and *Phyllopachyceras* sp., and assigned them to the Barremian.

3.2.2. Bivalves

The Longzhaogou Group yields an abundant bivalve fauna, which in the early 1980s was described and assigned a Middle-Late Jurassic age.

Li & Yu (1982) described 155 species grouped in three assemblages. (1) A *Mesosaccella morrisi-Entolium demissum* assemblage (including 54 species) of the Peide Formation (corresponding to the Qihulin Formation) of a middle-late Bathonian age (table 3.2).

(2) An *Isognomon* (*Isognomon*) *isognomonoides–Camptonectes* (*Camptonectes*) *shuguangensis* assemblage (including 83 species) of the Caoyangtun Formation (corresponding to the Lower Yunshan Formation) of an early Callovian–middle Oxfordian age.

(3) A *Sinopsammobia–Arcomya* assemblage (including 29 species) of the Yunshan Formation (corresponding to the Upper Yunshan Formation) of a late Oxfordian–early Kimmeridgian age.

Gu et al. (1984) described 42 species and subspecies belonging to 21 genera and subgenera from the Qihulin Formation (table 3.2), and 98 species belonging to 35 genera and subgenera form the Lower and Upper Yunshan formations. In the Qihulin Formation *Entolium*, *Camptonectes* and palaeontaxodonts are common, whereas *Anisocardioides* and the desmodonts *Goniomya* and *Thracia* occur less frequently. Of the known species *Thracia shokawensis* Hayami, 1959 and *Palaeonucula makitoensis* Hayami, 1959 are recorded from the Mitarai Formation (Callovian) of Japan. *Palaeonucula*? *inconstans* (Roeder, 1882) and *Nuculan*a? *hordeum* (Merian) are recorded from Callovian rocks in Switzerland. *Mesosacella morrisi* (Deshayes) is recorded from the Callovian–Oxfordian? of the United Kingdom. *Entolium demissum* (Philipps) and *Thracia depressa* (J. de C. Sowerby) are worldwide late Early–Late Jurassic species. *Nuculana* (*Praesaccella*) *yatsushiroensis* Tamura is reported from the Torinosu Group (Late Jurassic) of Japan. Based on the above mentioned known bivalve species the Qihulin Formation was assigned to the Callovian.

With respect to the 98 species of the Lower and Upper Yunshan formations, 71 of them are new or unnamed, with only 27 species known or related to known species. In spite of the occurrence of Early Cretaceous *Ostrea* and *Filosina*, the geological age of the Lower and Upper Yunshan formations was assigned to the Oxfordian–early Tithonian (Late Jurassic) because of the presence of *Aguilerella varians* Zakharov (middle Volgian), *Buchia orbicularis* (Hyatt) (middle Kimmeridgian–early Volgian), *Gryphaea* (*Bilobissa*) aff. *dilobotes* Duff (middle Callovian–late Oxfordian), *G*. (*B*.) aff. *dilatata* (J. Sowerby) (middle Callovian–middle Kimmeridgian), *Deltoideum delta* (Smith) (late Oxfordian–middle Kimmeridgian), *Liostrea* aff. *gryphaeata* (Schlotheim) (late Oxfordian–early Kimmeridgian), *L*. aff. *plastica* (Trautschold) (early Kimmeridgian–early Neocomian), *Neocrassina subdepressa* (Blake & Hudleston) (middle Oxfordian).

The RTMCFH (1986) found marine bivalves in the Zhushan Formation of the Longzhaogou Group, including *Quenstedta* cf. *wandaensis* Gu & Chen, *Sinopsammobia ovali* Li, Yu, Yao & Gu, *S. longzhaogouensis* Li, Yu, Yao & Gu, which were in common with those of the underlying Lower and Upper Yunshan formations. The Zhushan Formation was assigned to the latest Jurassic.

Table 3.2. Bivalves reported from the Qihulin Formation. Arrangement and symbols as for Table 3.1.

Taxon	Treat-ment	Assigned Age	Author	Remarks
Nuculoma cf. *maga* Borissjak, 1904	T	middle-late Bathonian	Li & Yu 1982	Revised by Gu et al. (1997) as *Palaeonucula* sp. 2, specimen SIGMR BH0833.
N. nina (Borissjak, 1904)	T			Revised by Gu et al. (1997) as *Palaeonucula yunshanensis* Yu & Li, 1982, specimen SIGMR BH0773.
Palaeonucula cuneiformis (Sowerby, 1840)	T			Revised by Gu et al. (1997) as *Palaeonucula yonghongensis* (Yu & Li, 1982), specimen SIGMR BH1172; as *Palaeonucula* aff. *ishidoensis* (Yabe & Nagao, 1926), specimens SIGMR BH0843, BH0763.
P. kaoraensis Cox, 1940	T			Revised by Gu et al. (1997) as *Palaeonucula yunshanensis* Yu & Li, specimen SIGMR BH0764.
P. mediformis Li & Yu sp. nov.	T			Gu et al. (1995) maintained species name for specimens SIGMR BH0842, BH0867, BH0811; revised specimens SIGMR BH1176, BH0868, BH0872, BH0828 as *Palaeonucula* cf. *makitoensis* Hayami.
P. mishanensis Yu & Li sp. nov.	T			
P. peideensis Yu & Li sp. nov.	T			
Palaeoneilo cf. *amygdala* Borissjak, 1904	T			Revised by Gu et al. (1997) as *Portlandia* aff. *sanchuensis* (Yabe & Nagao, 1926), specimens SIGMR BH0883, BH0896.
Palaeoneilo cf. *bittneri* Borissjak, 1904	T			Revised by Gu et al. (1997) as *Palaeonucula*? sp., specimen SIGMR BH0691, as *Mesosaccella longzhaogouensis* Li & Yu, 1982, specimen SIGMR BH0835; as *Rollieria*? *trapezica* (Yu & Li, 1982), specimens SIGMR BH0812, BH0876.
P. indicus Cox, 1940	T			Revised by Gu et al. (1997) as *Palaeoneilo qihuliensis perlonga* J. Chen & Gu, 1984, specimens SIGMR BH0790, BH0804.
P. peideensis Li & Yu sp. nov.	T			Gu et al. (1997) maintained the species name for specimens SIGMR BH0813, BH0822, BH0872, BH0875, and revised spcimen SIGMR BH0851 as *Palaeoneilo yunshanensis* Li & Yu, 1982.
P. trapezi Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Rollieria*? *trapezica* (Yu & Li, 1982), specimen DH0817.
P. yunshanensis Li & Yu sp. nov.	T			
Nuculana (*Jupiteria*) *acuminata* (Goldfuss, 1836)	T			Revised by Gu et al. (1997) as *Jupiteria* sp.nov.?, specimen SIGMR BH0860.
Nuculana (*Jupiteria*) cf. *acuminata* (Goldfuss, 1836)	T			Revised by Gu et al. (1997) as *Jupiteria* sp., specimen SIGMR BH0862.

Table 3.2. (continued)

Taxon	Treat-ment	Assigned Age	Author	Remarks
Nuculana (Praesaccella) elongatovata Li & Yu sp. nov.	T	middle-late Bathonian	Li & Yu 1982	
Nuculana (Praesaccella) longzhaogouensis Yu & Li sp. nov.	T			
Nuculana (Praesaccella) yatsushiroensis Tamura, 1959	T			Revised by Gu et al. (1997) as *Nuculana* (*Praesaccella*) cf. *yatsushiroensis* Tamura, 1959, specimen SIGMR BH1167.
Nuculana (Praesaccella) cf. *yatsushiroensis* Tamura, 1959	T			
M. longzhaogouensis Li & Yu sp. nov.	T			Gu et al. (1997) maintained the species name for specimens SIGMR BH0784, BH0789, BH0796, BH0802; revised specimens SIGMR BH0855, BH0870 as *Mesosaccella longa* Yu & Li, 1982.
Mesosaccella longa Yu & Li sp. nov.	T			
M. morrisi (Deshayes,1853)	T			Revised by Gu et al. (1997) as *M. longzhaogouensis* for specimen SIGMR BH0806; as *M*. sp. nov.? for specimens SIGMR BH0797, BH0808, BH0818, BH0847, BH118.
Musculus? *czekanowskii* (Lahusen, 1886)	T			Revised by Gu et al. (1997) as *Modiolus*? sp., specimen SIGMR BH181.
Meleagrinella cf. *ovalis* (Phillips, 1829)	T			
Entolium cf. *demissum* (Phillips, 1829)	T			Revised by Gu et al. (1997) as *E. extensum* Yu & Li, 1982, specimens SIGMR BH1062. BH1065, BH1066, BH1068, BH1072, BH1099, BH1100, BH1107.
E. disciforme (Schiibler, 1833)	T			Revised by Gu et al. (1997) as *E. extensum* Yu & Li, 1982, specimens SIGMR BH0026, BH1056, BH1070, BH1087.
E. extensum Yu & Li sp. nov.	T			
E. longzhaogouense Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *E. extensum* Yu & Li, 1982, specimens SIGMR BH0093, BH1055, BH1059, BH1071.
E cf. *nieniexionglaense* Wen,1976	T			Revised by Gu et al. (1997) as *E. extensum* Yu & Li, 1982, specimens SIGMR BH0024, BH1091.
E. peideense Li & Yu sp. nov.	T			Revised by Gu et al. (1997) as *E. extensum* Yu & Li, 1982, specimens SIGMR BH0031, BH1051, BH1060-1, BH1060-2.
E. yunshanense Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *E. extensum* Yu & Li, 1982, specimens SIGMR BH1093, BH1054.

Table 3.2. (continued)

Taxon	Treat-ment	Assigned Age	Author	Remarks
Camptonectes (*Boreionectes*?) *minutus* Yu & Li sp. nov.	T	middle-late Bathonian	Li & Yu 1982	Revised by Gu et al. (1997) as *Camptonectes* (*Camptonectes*) *wandensis* Li & Yu, 1982, specimens SIGMR BH0028, BH0042.
Camptonectes (*Boreionectes*) *wandaensis* Li & Yu, 1982	T			Revised by Gu et al. (1997) as *Camptonectes* (*Camptonectes*) *wandensis* Li & Yu, 1982, specimens SIGMR BH0020, BH0021-1, BH0021-2, BH0041, BH0048, BH0062.
Camptonectes (*Boreionectes*) *yunshanensis* Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Camptonectes* (*Camptonectes*) *wandaensis* Li & Yu, 1982, specimens SIGMR BH0016, BH00222, BH0029, BH0040, BH0058.
Camtonectes (*Camptochlamys*) sp.	T			Revised by Gu et al. (1997) as *Chlamys* (*Camptochlamys*?) sp., specimens SIGMR BH0052, BH0054, BH0050.
Camptonectes (*Camptonectes*) *clathratus* Li & Yu sp. nov.	T			
Astarte (*Astarte*) *costata* Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Anisocardioides hulinensis Gu, 1984* for specimens SIGMR BH0428, BH0696, BH1145; as *Filosina subovalis* Yao, J. Chen & Gu,1984 for specimen SIGMR BH0434.
A. (*Astarte*) aff. *costata* Yu & Li sp. nov.	T			Revised by Gu et al. (1997), as *Filosina subovalis* Yao, J. Chen & Gu,1984 for specimen SIGMR BH0451.
A. (*Astarte*) *extensa* (Phillips, 1829)	T			Revised by Yu (in Gu et al., 1997) as *Anisocardioides*? *globitriangularis* X. Yu sp. nov. for specimens SIGMR BH0417, BH0433, BH0441, BH0789 (?).
A. (*Astarte*) aff. *extensa* (Phillips, 1829)	T			Revised by Yu (in Gu et al., 1997) as *Anisocardioides*? *globitriangularis* X. Yu sp. nov. for specimens SIGMR BH0411, BH0415, BH0438.
A. (*Astarte*) aff. *girardoti* Loriol, 1900	T			Revised by Gu et al. (1997) as *Anisocardioides hulinensis* Gu, 1984, specimens SIGMR BH0429, BH0430, BH0692, BH0699, BH0450.
A. (*Astarte*) *hypsovata* Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Eriphylopsis*? *hypsovata* (Yu & Li, 1982), specimens SIGMR BH0412, BH0424.
A. (*Astarte*) cf. *blauenensis* Loriol, 1891	T			Specific name erroneously spelled as *lauenensis*; revised by Gu et al. (1997) as *Astarte* sp. 2, specimen SIGMR BH0445.
A. (*Astarte*) cf. *morini* Loriol, 1875	T			Revised by Gu et al. (1997) as *Anisocardioides hulinensis* Gu, 1984, specimens SIGMR BH1150, BH0452, BH1148.
A. (*Astarte*) cf. *nummus* Sauvage, 1871	T			Revised by Gu et al. (1997) as *Anisocardioides subrotundus* Gu, 1984, specimens SIGMR BH0437, BH0447, BH1146.

Table 3.2. (continued)

Taxon	Treat-ment	Assigned Age	Author	Remarks
A. (*Astarte*) *subminia* Yu & Li sp. nov.	T	middle-late Bathonian	Li & Yu 1982	Revised by Gu et al. (1997) as *Eriphylopsis*? *subminia* (Yu & Li, 1982), specimens SIGMR BH0444, BH0455.
A. (*Astarte*) *hulinensis* Yu & Li sp. nov.	T			
Astartoides? *quadratus* Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Astarte*? *quadrata* (Yu & Li, 1982), specimen SIGMR BH1149.
Astartoides? *orbicularis* Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Astarte* cf. *subsenecta* Yabe & Nagao, 1926, specimen SIGMR BH0439; as *Astarte*? sp. 2, specimen SIGMR BH0698.
Astartoides? *longzhaogouensis* Yu & Li sp. nov.	T			Revised by Gu et al. (1997) as *Nicaniella*? *longzhaogouensis* (Yu & Li, 1982), specimen SIGMR BH1181.
Goniomya cf. *literata* (Sowerby, 1819)	T			Revised by Gu et al. (1997) as *Goniomya peideensis* Yu & Li, 1982, specimen SIGMR BH0901.
Goniomya peideensis Yu & Li sp. nov.	T			
Corbula cf. *involuta* Munster, 1840	T			Revised by Gu et al. (1997) as *Corbula* (*Varicorbula*?) sp. nov.?, specimens SIGMR BH0938, BH1028.
Thracia scythica Eichwald, 1869	T			Revised by Gu et al. (1997) as *Thracia yunshanensis* Yu & Li, 1982, specimen SIGMR BH0724; as *Thracia rotundata* (J. de C. Sowerby, 1836), specimens SIGMR BH0726, BH0741.
Nukuloma cf. *oxfordiana* (Roeder, 1882)	T	middle Jurassic	Gu et al. 1984	Revised by Gu et al. (1997) as *Manchurinucula wanensis* Gu gen. et. sp. nov., specimens NIGP 81343, 81344.
Palaeonucula makitoensis Hayami, 1959	T			Revised by Gu et al. (1997) as *Palaeonucula* cf. *makitoensis* Hayami, specimens NIGP 81334-81338.
Palaeonucula? *inconstans* (Roeder, 1882)	T			Revised by Gu et al. (1997) as *Palaeonucula* sp. 1, specimen NIGP 81342.
Mesosaccella morrisi (Deshayes, 1853)	T			Revised by Gu et al. (1997) as *Mesosaccella longzhaogouensis* Li & Yu, 1982, specimens NIGP 81347, 81348.
Palaeoneilo aff. *belaensis* Cox, 1940	T			Revised by Gu et al. (1997) as *Mesosaccella longzhaogouensis* Li & Yu, 1982, specimens NIGP 81354, 81356, 81357; as *Mesosaccella longa* Yu & Li, 1982, specimen NIGP 81355.
Palaeoneilo cf. *longiuscula* (Merian)	T			Revised by Gu et al. (1997) as *Palaeoneilo qihulinensis perlonga* J. Chen & Gu, 1984, specimens NIGP 81358, 81359.
Palaeoneilo peideensis J. Chen sp. nov.	T			Revised by Gu et al. (1997) as *Palaeoneilo yunshaneinsis* Li & Yu, 1982, specimens NIGP 81375-81377.

Table 3.2. (continued)

Taxon	Treat-ment	Assigned Age	Author	Remarks
Palaeoneilo qihulinensis J. Chen & Gu sp. nov.	T	middle Jurassic	Gu et al. 1984	
Palaeoneilo qihulinensis perlonga J. Chen & Gu sp. et subsp. nov.	T			
Palaeoneilo suboppeli J. Chen sp. nov.	T			Revised by Gu et al. (1997) as *Palaeoneilo yunshanensis* Li & Yu,1982, specimen NIGP 81352; as *Rollieria*? *trapezica* (Yu & Li,1982), specimens NIGP 81349-81351.
Palaeoneilo cf. *suboppeli* J. Chen sp. nov.	T			Revised by Gu et al. (1997) as *Rollieria*? *trapezica* (Yu & Li, 1982), specimen NIGP 81353.
Nukulana? *hordeum* (Merian)	T			Revised by Gu et al. (1997) as *Nuculana* (*Praesaccella*) *elongatovata* Li & Yu, 1982, specimen NIGP 81386.
Nukulana (*Praesaccella*) aff. *yatsushiroensis* Tamura, 1959	T			Revised by Gu et al. (1997) as *Nukulana* (*Praesaccella*) cf. *yatsushiroensis* Tamura, 1959, specimens NIGP 81380-81384.
Nukulana (*Praesaccella*) sp.	T			Revised by Gu et al. (1997) as *Jupiteia* (*Ezonuculana*) aff. *mactraeformis* (Nagao, 1932), specimen NIGP 81385.
Rollieria cf. *lorioli* Chavan, 1952	T			Revised by Gu et al. (1997) as *Rollieria*? *trapezica* (Yu & Li, 1982), specimens NIGP 81387-81389.
Musculus cf. *lycetti* (Morris, 1854)	T			Revised by Gu et al. (1997) as *Musculus*? sp., specimen NIGP 81420.
Modiolus sp. 1	T			Revised by Gu et al. (1997) as *Brachidontes* sp., specimen NIGP 81423.
Modiolus sp. 2	T			Revised by Gu et al. (1997) as *Modiolu*? sp., specimen NIGP 81424.
Retroceramus? sp. 1	T			
Retroceramus? sp. 2	T			
Entolium demissum (Phillips, 1829)	T			Revised by Gu et al. (1997) as *Entolium extensum* Yu & Li, 1982, specimens NIGP 81488-81496.
Entolium cf. *cingulatum* (Goldfuss, 1834)	T			
Entolium? *hulinense* J. Chen & Gu sp. nov.	T			Revised by Gu et al. (1997) as *Entolium extensum* Yu & Li, 1982, specimens NIGP 81503-81514.
Entolium? aff. *hulinense* J. Chen & Gu sp. nov.	T			Revised by Gu et al. (1997) as *Entolium extensum* Yu & Li, 1982, specimens NIGP 81515-81523.
Entolium sp. 1	T			Revised by Gu et al. (1997) as *Entolium*? sp. 2, specimen NIGP 81501.

Table 3.2. (continued)

Taxon	Treat-ment	Assinged Age	Author	Remarks
Camptonectes (*Camptonectes*) *wandaensis* Gu sp. nov.	T	middle Jurassic	Gu et al. 1984	Revised by Gu et al. (1997) as *Camptoectes wandensis* Gu, specimens NIGP 81529-81535 and 81538-81539.
Astarte qihulinensis J. Chen sp. nov.	T			Revised by Gu et al. (1997) as *Astarte*? *quadrata* Yu & Li, specimens NIGP 81756-81761.
Astarte cf. *ungulata* Lycett, 1863	T			Revised by Gu et al. (1997) as *Astarte*? sp. 3, specimen NIGP 81755.
Astarte sp.	T			Revised by Gu et al. (1997) as *Astarte* sp. 4, specimen NIGP 81762.
Coelastarte? sp. cf. *C. compresiuscula* (Morris & Lycett, 1855)	T			Revised by Gu et al. (1997) as *Astarte* sp. nov.?, specimens NIGP 81767-81768.
Eriphylopsis sp. cf. *E. cotswoldensis* (Cox & Arkell, 1948)	T			Revised by Gu et al. (1997) as *Eriphylopsis* sp. , specimen NIGP 81769.
Sinopsammobia sp.	T			
Anisocardioides hulinensis Gu gen. et sp. nov.	T			
Anisocardioides subrotundus Gu gen. et sp. nov.	T			
Anisocardioides triangulus Gu gen. et sp. nov.	T			Revised by Gu et al. (1997) as *Anisocardioides hulinensis* Gu, specimens NIGP 81929-81930.
Isocyprina? sp. cf. *I. shizuhamensis* Hayami, 1959				Revised by Gu et al. (1997) as *Isocyprina*? sp., specimen NIGP 81931-1.
Pronoella? sp. cf. *P. sugayensis* Hayami, 1959	T			Revised by Gu et al. (1997) as Family and Genus indet., specimen NIGP 81931-2.
Gonomya sp. nov.?	T			Revised by Gu et al. (1997) as *Goniomya peideensis* Yu & Li, 1982, specimens NIGP 82049-82052, 82054-82056.
Gonomya sp.	T			Revised by Gu et al. (1997) as *Goniomya peideensis* Yu & Li, 1982, specimen NIGP 82057.
Thracia aff. *depressa* (J. de C. Sowerby, 1823)	T			Revised by Gu et al. (1997) as *Thracia rotundata* (J. de C. Sowerby, 1836), specimens NIGP 82062-82064, 82067; as *Thracia* cf. *phillipsi* Römer, 1841, specimens NIGP 82061, 82065; as *Thracia yunshanensis* Yu & Li, 1982, specimen NIGP 82066.
Thracia cf. *parvula* Loriol, 1899	T			
Thracia shokawensis Hayami, 1959	T			Revised by Gu et al. (1997) as *Thracia rotundata* (J. de C. Sowerby, 1836), specimens NIGP 82081, 82084; as *Thracia* cf. *phillipsi* Römer, 1841, specimen NIGP 82083.

Li et al. (1986) assigned the Zhushan Formation to the late Kimmeridgian–late Volgian on the basis of its resting on the Shuguang Formation (corresponding to the Upper Yunshan Formation), which yielded the early Kimmeridgian *Buchia tenuistriata* and *B. mosquensis*.

Chen & Sun (1989) described two *Buchia* zones in the Upper Yunshan Formation exposed on the west bank of Qihulin River in the Yunshan area of Hulin County. The lower zone was the *Buchia concentrica* Zone of early Kimmeridgian age, the upper one was the *B. mosquensis–B. russiensis* Zone of middle Volgian age. In the same article the authors revised the *B. tenuistriata* Zone (Gu et al., 1984) of the Chengzihe Formation, renamed it *B. concentrica* zone, and correlated it with the early *Buchia* Zone of the Upper Yunshan Formation. Although the Jurassic–Cretaceous boundary was defined within the Zhushan Formation of the Longzhaogou Group and the Muling Formation of the Jixi Group, the major part of the Longzhaogou Group and the Jixi Group was assigned to the Upper Jurassic.

Sha (1990) and Sha et al. (1993, 1994) redefined the *Buchia tenuistriata* Zone (Gu et al., 1984) and the two *Buchia* zones of Chen & Sun (1989) into two *Aucellina* assemblages of the Upper Yunshan Formation. The lower one was an *A. caucasica–A. aptiensis–A. jeletzkii* assemblage occurring in the middle part of the Upper Yunshan Formation, which also occurred at the base of the Chengzihe Formation of the Jixi Group; the upper one was an *A.* cf. *caucasica–A.* cf. *aptiensis* assemblage occurring in the upper part of the Upper Yunshan Formation. The Upper Yunshan Formation and the Chengzihe Formation were regarded as mainly Aptian, or possibly late middle or late Barremian–earliest Albian. The entire Longzhaogou Group was assigned to the Early Cretaceous.

Gu et al. (1997) also reassigned the *Buchias* from the Upper Yunshan Formation of the Longzhaogou Group and those from the Chengzihe Formation of the Jixi Group to *Aucellina*. They described a late Early Cretaceous fauna from the Longzhaogou Group, which for a long time had been considered Middle to Late Jurassic. Based on the occurrence of *Palaeonucula* aff. *ishidoensis* (Yabe & Nagao), *Lopatinia* (*Lopatinia*) aff. *arctica* (Bodylevsky), *Grammatodon* aff. *gracilis* Sanin, *Cosmetodon* cf. *nipponicus* (Nagao), *Aguilerella* spp., *Aucellina aptiensis* (D'Orbigny), *A. caucasica* (v. Buch), *Amphidonte subhaliotoidea* (Nagao), *A. conica* (J. Sowerby), *Aetostreon* aff. *couloni* (Defrance), *Ostrea* spp., *Tancredia* sp., *Arctica* cf. *saussuri* (Brongniart), *Filosina* spp., *Corbula* spp., *Pleuromya* spp. and *Thracia rotundata* (J. de C. Sowerby), the Upper Yunshan Formation and the Chengzihe Formation were now dated as Aptian. The occurrence of *Palaeonucula* aff. *ishidoensis* (Yabe & Nagao), *Jupiteria* (*Ezonuculana*) aff. *mactraeformis* (Nagao), *Portlandi* aff. *sanchuensis* (Yabe & Nagao) and *Thracia rotundata* (J. de C. Sowerby) also indicated an Aptian or at the

most a Barremian–Aptian age for the Qihulin Formation. Thus, the entire Longzhaogou Group and at least the middle and upper parts of the Jixi Group, i. e. the Chengzihe and Muling formations, were considered to be Barremian–Aptian.

3.2.3. Ostracods

Li & Zhang (1981) described two ostracod assemblages from the Lower and Upper Yunshan formations of the Longzhaogou Group: (1) a *Protocythere–Palaeocytheridae*?*–Mandelstamia* assemblage from the uppermost part of the second Member of the Yunshan Formation (corresponding to the uppermost Chaoyangtun Formation or the Lower Yunshan Formation), of a Kimmeridgian–Tithonian age; (2) a *Scabriculocypris–Mandelstamia* assemblage from the upper part of the third Member of the Yunshan Formation (corresponding to the Yunshan Formation or the Upper Yunshan Formation), of late Tithonian age.

Zhang (1982) described three ostracod assemblages: (1) a *Protocythere ruidirecticticulata–Galliaecytherideae elegans–Mandelstamia truncata* assemblage in the upper part of the Chaoyangtun Formation (corresponding to the upper part of the Lower Yunshan Formation), of Kimmeridgian–early Portlandian age, characterised by the marine ostracods *Protocythere ruidireticulata* Zhang, 1982, *P. yunshanensis* Zhang & Li, 1981, *Galliaecytheridea elegans* (Sharapova, 1937), *G. postspinosa* Zhang, 1982, *G. obtusovata* Zhang, 1982, *Mandelstamia truncata* Zhang, 1982, *M. longzhuagouensis* Li & Zhang, 1981, *M. unispinosa* Zhang, 1982, *M. acuta* Li & Zhang, 1981, *Paracypris* sp.; (2) a *Scabriculocypris obtusispina–Mandelstamia triangulata* assemblage in the middle part of the Yunshan Formation (corresponding to the middle part of the Upper Yunshan Formation), of late Portlandian age, characterised by brackish ostracods of marine–continental transitional facies: *Scabriculocypris obtusispina* Zhang & Li, 1981, *S*. aff. *cerastes* Anderson, *S. postideclivis* Zhang & Li, 1981, *S. polyspina* Zhang & Li, 1981, *Mandelstamia triangulata* Li & Zhang, 1981, *M. lonzhuagouensis* Li & Zhang, 1981, *Cypridea* sp.; (3) a *Cypridea–Scabriculocypris–Vlakomia–Galliaecythridea* assemblage in the upper part of the Yunshan Formation (corresponding to the Upper Yunshan Formation), of Berriasian age, characterised by brackish ostracods of marine–continental transitional facies: *Cypridea* sp. *Scabriculocypris* aff. *cerastes* Anderson, *Mantelliana mishanensis* Zhang, 1982, *Vlakomia pristina* Zhang, 1982, and *Galliaecytheridea* sp.

Gou (1983) described two assemblages from the Yunshan Formation. The earlier one consisted of *Galliaecytheridea hulinensis* Gou, 1983 and *Mandelstamia* sp., of Kimmeridgian

age; the later one yielding nonmarine *Cypridea* sp. 1 and *Cypridea* sp. 2, was correlated with the Lower Purbeck (Upper Jurassic) of England.

3.2.4. Brachiopods

Li & Gu (1982) described a Callovian–early Oxfordian brachiopod fauna, including 15 species (ten of them new) belonging to nine genera from the Chaoyangtun Formation (corresponding to the Lower Yunshan Formation). The fauna is characterised by *Monticlarella rectoumbonata* Bobanova, 1973 (Callovian of Caucasus), *Kallirhynchia namtuensis* (Buchman, 1917) and *K. parva* (Buckman, 1917) (Callovian of Nyanyaxionla Group and the Menkadun Formation in the Mount Jolmo Lungma (Mount Everest) region of Burma, and the Yanshiping Group of Tibet–Qinghai), *Daghanirhynchia daghaniensis* Muir-Wood, 1937 (Callovian of Pakistan), *Parvirhynchia bella* Tokuyama, 1957 (Late Jurassic of the Torinosu Group of Japan), *Thurmannella yunshanensis* Li & Gu, 1982, *T. acris* Li & Gu, 1982, *Septaliphoria hulinensis* Li & Gu, 1982, *S. yunshanensis* Li & Gu, 1982.

Sun (1983) described an assemblage from the Upper Yunshan Formation of Yonghong, Hulin County, consisting of *Thurmanella yunshanensis* Sun, 1983, *T. longzhaogouensis* Sun, 1983, *Balbekella hulinensis* Su, 1983, and *B. liui* Sun, 1983. Although *Balbekella* was recorded from the Cretaceous (Berriasian–Barremian) of Caucasus and Crimea, Sun considered that the assemblage belonged to the Late Jurassic because of the records of *Thurmanella* Leidhold in Oxfordian of northern France, in Basel, Switzerland, in Yorkshire and Kent in the UK, and also in the Yanshiping Group (Callovian) in the Tibet–Qinghai region.

3.2.5. Gastropods

Yu & Zhu (1983) described seven marine gastropod species of five genera from the Yunshan Formation, including European Late Jurassic forms, such as *Promathild* (*Clathroaculus*) *doncieuxi* Cosmann and *Procerithium limaeforme* (Roemer), and assigned them to the Oxfordian–Kimmeridgian.

3.2.6. Flora

3.2.6.1. Plant remains

Zheng et al. (1981) dated the Dongshengcun and Peide formations (corresponding to the Peide and Qihulin formations respectively) as Middle Jurassic because of the occurrence of the *Coniopteris–Phoenicopsis* flora. Zheng et al. (1982) proposed a three assemblage subdivision of the *Ruffordia–Onychiopsis* Flora (Zhou & Li 1980) of northeastern China: (1) the *Onychiopsis–Nilssonia angustissima* assemblage of Late Jurassic age, occurring in the Chaoyangtun and Yunshan formations of the Longzhaogou Group and the Didao and Shihebei formations of the Jixi Group; (2) the *Ruffordia – Nilssonia sinensis* assemblage of early – middle Early Cretaceous age, occurring in the Chengzihe and Muling formations of the Jixi Group; (3) the *Rhipidocladus–Neozamites–Angiospermae* assemblage of middle–late Early Cretaceous age, occurring in the Dongshan Formation of the Huashan Group in eastern Heilongjiang.

Cao (1983a, 1983b, 1984) described two plant assemblages from the Longzhaogou Group, including 27 genera and 61 species. One of them is from the Peide and Qihulin formations, characterised by the Yorkshire Middle Jurassic species *Neocalamites nathorsti* Erdtman, *Coniopteris simplex* (Lindley & Hutten) Harris and *Cladophlebis denticulata* (Brongniart) Fontaine. The other assemblage is from the Lower and Upper Yunshan formations, characterised by *Equisetites* cf. *buchardti* Dunker, *Coniopteris saportana* (Heer) Vachrameev, *Gonatosorus* cf. *ketovae* Vachrameev, *Gleichenites nordenskioldi* (Heer) Seward, *Cladophlebis contracta* Cao, *C*. (*Gleichenites*?) *yunshanensis* Cao, *Sphenopteris* (*Gleichenites*?) cf. *erecta* Bell, *Nilssonia angustissima* (Chang) Cao, *Pagiophyllum shahozium* Zhang, and is similar to the Early Cretaceous Siberian flora. However, the occurrence of common Jurassic species made Cao assign the flora to the Late Jurassic.

3.2.6.2. Palynomorphs

Palynomorphs have only been found in the Zhushan area of Baoqing County. Pu et al. (1982) identified a palynomorph assemblage characterised by *Laevigatosporites ovatus, Cicatricosisporites australiensis, C. minutaest riatus, C. exilioides, Pilosisporites verus, P. trichopapillosus, Impardecispora apiverrucata, Klukisporites variegatus, K. pseudoreticulatus, Contignisporites glebulentus, Leptolepidites verrucatus, Foraminisporis asymmetricus, Foveosporites pantostiktos, Kuylisporites lunaris, Polycingulatisporites recduncus, Aequitriradites spinulosus, A. verrucosus, Couperisporites complexus,*

Triporoletes reticulatus, and *T. involucratus*. On the basis of this assemblage, a Valanginian–Barremian age was suggested.

Zhang (1983) studied the Neocomian–Aptian palynomorphs of the Zhushan Formation in the Zhushan coal mine of Baoqing County, which consists of 20 genera and 27 species, of which 96% fern spores. The predominant genus is *Gleicheniidites* Ross (66%). Common species are *Gleicheniidites senenicus* Ross, *G. heilongjiangensis* Zhang. The second most common genus is *Osmundacidites* Couper (11%), such as *Osmundacidites gilvus* Verbetzkaya, *O. wellmanii* Couper. *Cicatricosisporites* Potoniè & Gelletich comprises 10% of the samples, represented by *Cicatricosisporites dorogensis* Potoniè & Gelletich, *Cicatricosisporites nankingensis* Zhang. *Trilobosporites* (Pant) Potoniè (1%) has the common species *Trilobosporites applanatus* Zhang, *T. heilongjiangensis* Zhang, and *T. grandis* Zhang. The gymnosperm pollen make up 4%, and angiosperm pollen 0.7%. Zhang (1983) considered the assemblage of the Zhushan Formation to be close to that of the Starosychan Formation of the Nikan Group in far eastern Russia.

3.2.6.3. Dinoflagellate cysts

The recovery of the dinoflagellate cyst *Gonyanlacyst jurassica* from the Yunshan Formation of the Longzhaogou Group (Sun et al., 1992) apparently allowed a more precise dating of the Longzhaogou Group. However, recent work by He et al. (1999) confirmed that *Gonyanlacyst jurassica* was contaminated by other samples from the Dongrong Formation. They recovered Hauterivian–Barremian dinoflagellates from the Qihulin Formation in borehole H87–3 in eastern Heilongjiang (figure 2.1). The assemblage is characterised by (1) a dominance of the genera *Oligosphaeridium, Circulodinium* and *Cunningia* belonging to the gonyaulacaceaens. *Oligosphaeridium* shows particularly great diversity and abundance, and includes *Oligosphaeridium albertense* (Pocock) Davey & Williams, *O.* cf. *complex* (White) Davey & Williams, *O. poculum* Jain, *O.* cf. *totum* Brideaux; (2) an abundance of *Odontochitina operculata* (O. Lwetzel) Deflandre & Cookson, *Gardodinium trabecuosum* (Gocht) Albert and the dominant *Palaeoperidinium cretaceum* Pocock. The assemblage was correlated with the Hauterivian–Barremian dinoflagellate assemblage reported from the Palar Basin in southern India (He et al., 1999).

4. Material and methods

4.1. Fieldwork

The fieldwork was carried out over three periods. The first field season took place in July 1995 within the framework of IGCP 350 Working Group coordinated by Prof. Chen P.-J. (Nanjing Institute of Geology and Palaeontology, Academia Sinica), and concerned the Longzhaogou area. Two sections were studied: the Longzhaogou valley section, north of Qianjin village in Hulin County, and the test trench No. 9 section, north of Dongsheng village in Mishan County (figure 1.1).

The second eight-week fieldwork was carried out in May and July 1997, in an area of 70 $\times$ 10 km^2 in the Longzhaogou area. The following sections were studied: two sections in the northern hills of Chaoyang village; the Longzhaogou valley, north of Qianjin village; Team No. 3 of Farm Yunshan; Team No. 4 of Farm 850; Xingkai of Hulin County; Test trench No.9 near Peide in Mishan County (figure 1.1). The latter four sections are test trench opened 15 years ago, which are now partly filled and overgrown. No rock was found in situ, and no ammonites were collected from these four sections. The Chaoyang and the Longzhaogou sections are better exposed and were therefore the main objects of this second period of fieldwork.

The third period of fieldwork was carried out in August and September 1998. The main purpose was to sample as many localities with marine beds as possible for microfossils, and to search for new ammonite localities in eastern Heilongjiang. The work was concentrated to the Mishan and Hulin counties.

In total seven sections were investigated, including all known localities of the marine Qihulin Formation.

4.2. Material

The material comprises 96 ammonites, 153 bivalves and 79 microfossil samples. Many specimens are impossible to identify owing to their poor and incomplete preservation. In two microfossil samples agglutinated foraminifers were found and one sample yielded radiolarians.

All specimens described are kept in the collection of Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing.

4.3. Laboratory techniques

4.3.1. Microfossils

For microfossil extraction, the procedure outlined by Pessagno et al (1972) was followed, viz.:

1. A sample fragment is first etched for three to five minutes with concentrated hydrofluoric acid (45%), then removed from the acid, and washed in water. The cleaned fragment is observed under the microscope to identify whether radiolarians stand out in relief on the etched surface.
2. The sample is crushed with a ceramic mortar and pestle into 1 cm fragments.
3. Crushed fragments are placed in a plastic beaker with dilute hydrofluoric acid (one part acid to nine parts of water) for 20 hours.
4. The acid is discarded and the sample washed in a two sieves set, the lower one with a mesh diameter of 0.063 mm, the upper one with a mesh diameter of 0.315 mm. The fine residue in the lower sieve is dried; the coarser residue in the upper sieve is put back into the plastic beaker, and processed with hydrofluoric acid once more.

4.3.2. Nannofossils

4.3.2.1. Processing of the samples

Despite repeated efforts none of the microfossil samples yielded any nannofossils. The following procedure outlined by Smith (1981) was utilized: the samples were crushed with a ceramic mortar and pestle into powder. Approximately 0.5 g of the powder was placed in a 250-ml glass beaker, and 100 ml distilled water added. The beaker was then placed in an ultrasonic vibrator for 15 s. After sonification, the beaker was covered and allowed to rest undisturbed for 90 s. During this time, the coarse non-coccolith fraction (> 20 μm) settled to the bottom of the beaker. The decantant, which would have contained the coccoliths and fine-clay fraction (< 20 μm), was carefully poured into a second beaker, covered and allowed to settle for 12 min. The residue on the bottom of the second beaker contained the coccolith-size fraction, consisting of particles of about 1-20 μm in diameter. After the settling and decanting, the residue was resuspended in a few millilitres of distilled water and transferred to small glass vials.

4.3.2.2. Slide preparation

Two types of slide preparations were utilized, a permanent slide prepared for light microscopic investigation; a coverslip prepared for examination under the scanning electron microscope.

(1). Permanent slides were prepared by first placing two drops of distilled water on a 20 × 20 mm square coverglass. The vial containing the concentrate was agitated, and one drop of the suspension was allowed to fall from an eyedropper onto the centre, and one drop on either side of the coverglass. No further stirring or mixing of suspension was necessary. After one minute the grains settled on the surface of the coverglass, and the excess water can be absorbed by absorbent paper towels. Then the coverglass was transferred on a warm hotplate, and allowed to dry. Next one or two drops of Caedax (mounting medium, having the same characteristic like Canada balsam) were placed on a 25 × 50 mm glass slide and allowed to cure on a hotplate at about 120 °C for 10 minutes. After curing, which removes the volatile xylene from the Caedax, the glass slide was removed from the hotplate, and the coverglass was immediately mounted in the cured Caedax.

(2). The coverslip for scanning electronic microscope was a 5 × 5 mm square coverglass cut out of a 20 × 20 mm normal coverglass. A drop of distilled water was placed on it. Next a single drop of concentrated nannofossil suspension was placed in the water. After 15 to 20 seconds the grains settled to the surface of the coverslip, and the excess water was absorbed by a strip of absorbent paper towels. After drying the coverglass was fitted onto a metal plug and transferred to a vacuum evaporator for metal coating. Then the coverglass was examined at a magnification of × 1,000 or less under the scanning electronic microscope (Philips, SEM 505; LEO 440).

4.3.3 Palynomorphs and dinoflagellates

Tow samples were analysed by Dr. S. Feist-Burkhard (Technische Universität Darmstadt) for palynomorphs and dinoflagellates. However, the organic material has completely changed into charcoal. Therefore, the above fossil groups are not preserved in the material.

5. Localities

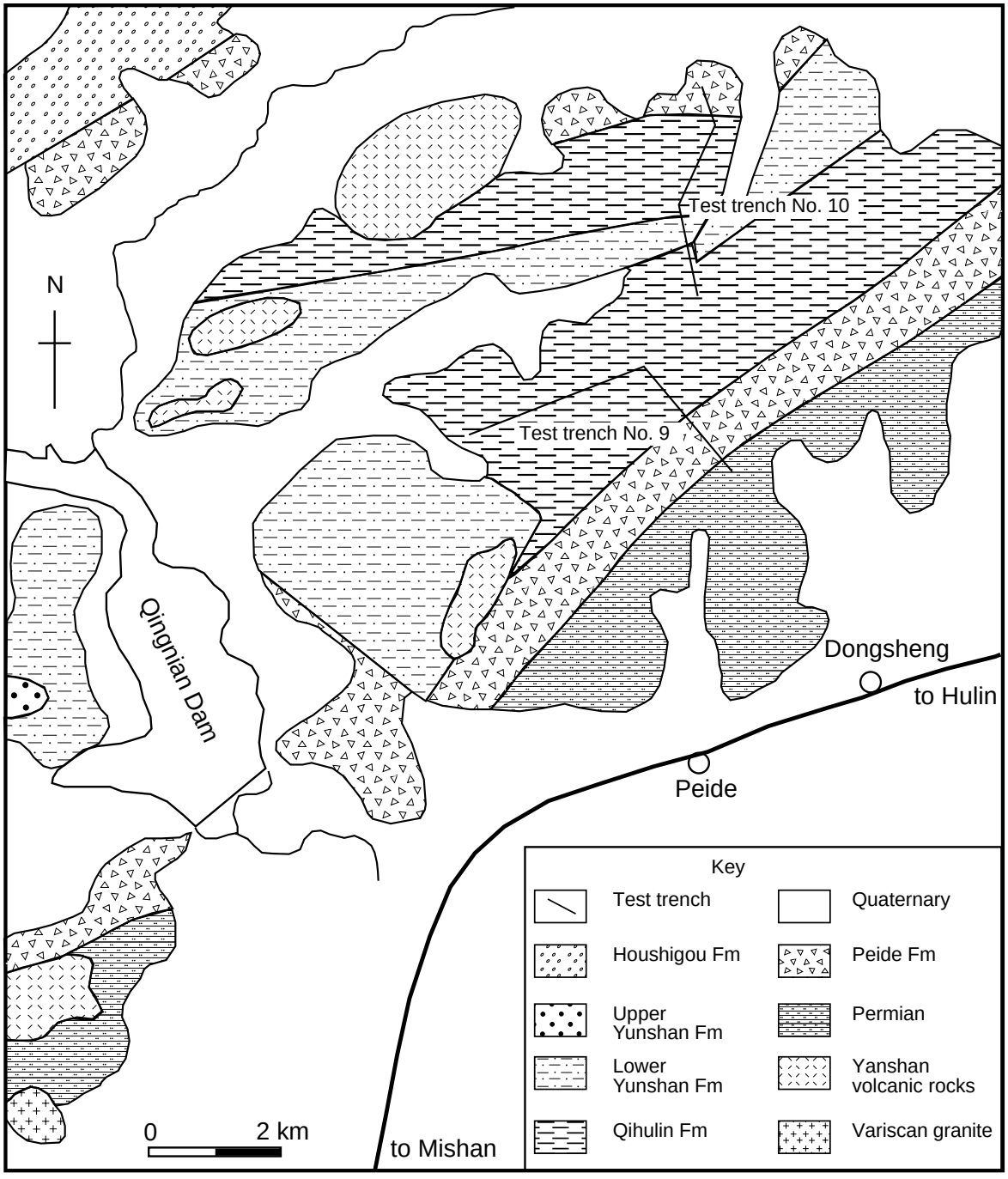

Figure 5.1. Geological map of the Peide area (based on data from the Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986). For location see figure 2.1.

Figure 5.2. A cleaned channel containing an ammonite horizon in black mudstones of the Qihulin Formation. Test trench No. 9, north of Dongsheng village.

5.1. Dongsheng section

Test trench No. 9 was dug in the hills about 5 km north of Dongsheng village (figure 5.1) 20 years ago. The trench channels have been covered, with the debris and vegetation now about 1 m thick. During the fieldwork the channels containing the ammonite horizon was cleaned (figure 5.2). One complete *Pseudohaploceras* sp. 2 (EH3–1) and several broken ammonites were recovered. The bivalves *Palaeonucula mishanensis* Yu & Li, 1982, and *P. yunshanensis* Yu & Li, 1982, and microfossil samples were also collected. The section was measured by the 108th Coal-prospecting Company of Geological Coal Bureau of NE China (figure 5.4, appendix 12.1) (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986).

Figure 5.3. Outcrop of ammonite-bearing thick black mudstones of the Qihulin Formation in the Longzhaogou valley.

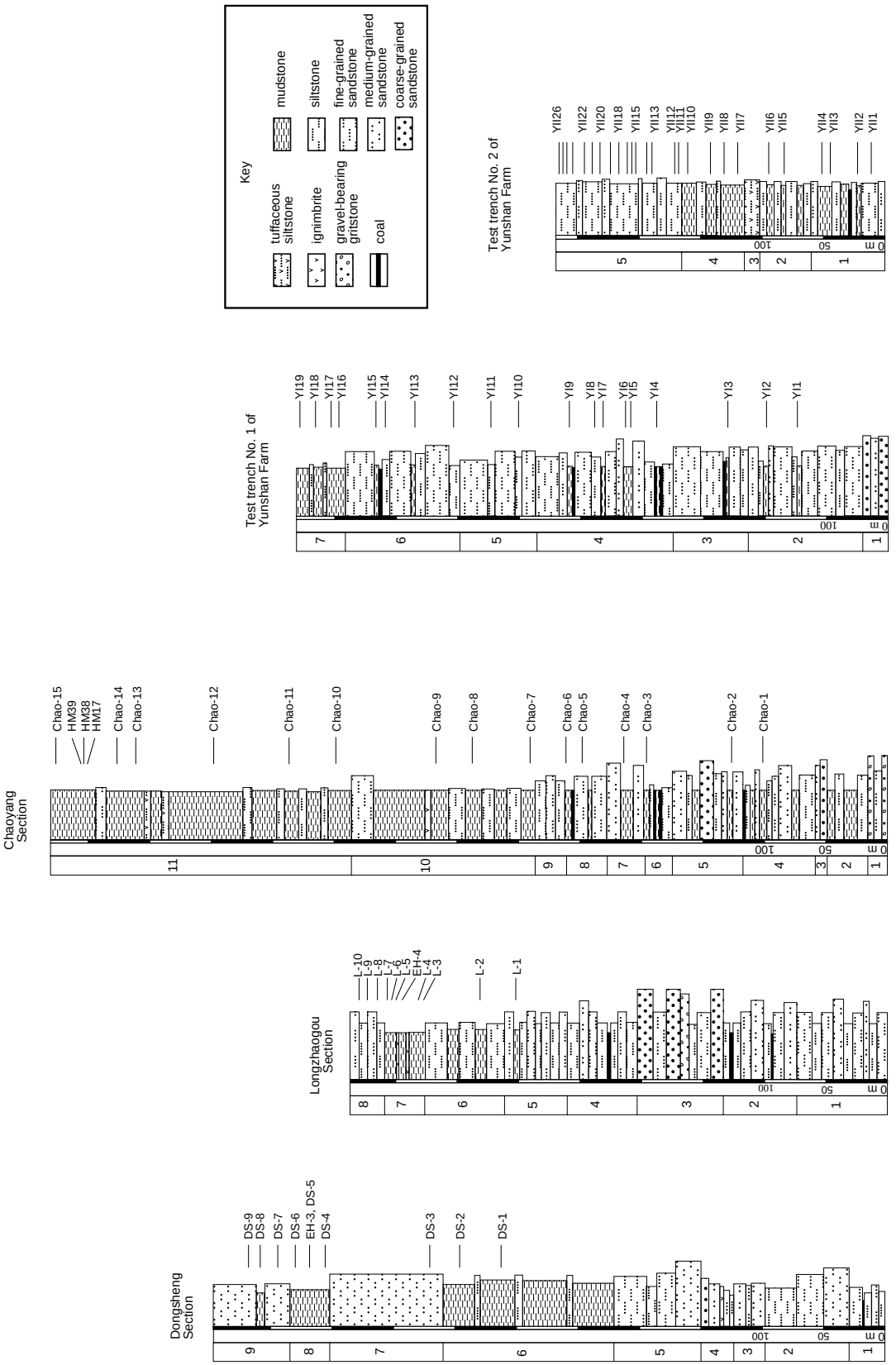

Figure 5.4 Profiles of the Qihulin Formation in the Dongsheng, Longzhaogou, Chaoyang and Yunshan sections (based on data from the Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986). Sample abbreviations: DS Dongsheng village, L Longzhaogou, Chao Chaoyang, EH east Heilongjiang, HM Heilongjiang Mesozoic, YI Test trench No. 1 of Yunshan Farm, YII Test trench No. 2 of Yunshan Farm.

5.2. Longzhaogou section

The Longzhaogou valley (figure 5.5), where the first ammonite was found in 1958, is situated some 8 km north of Qianjin village. The Qihulin Formation is well exposed along the valley. Its lower part comprises grey, yellow, rarely greyish yellow sandstones, siltstones,

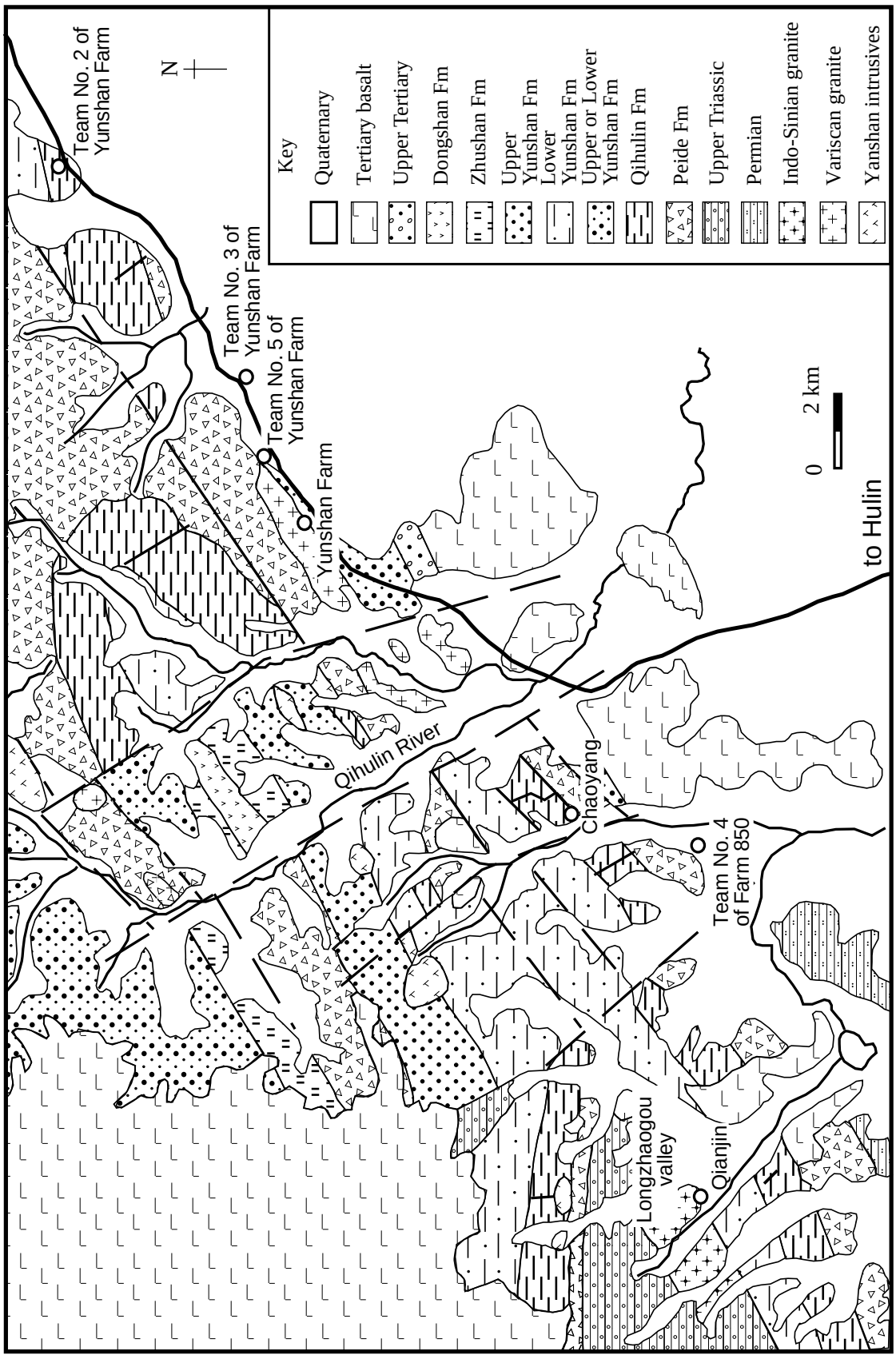

Figure 5.5 Geological map of the Yunshan Farm area (based on data from the Research team on Mesozoic coal-bearing formations in eastern Heilongjiang, 1986). For location, see figure 2.1.

and black mudstones intercalated with thin coal seams and intrusive rocks, yielding plant remains in the mudstones. The upper part contains thick black mudstones and siltstones, intercalated with sandstones (figure 5.4). The thickness of the formation is 428.6 m in the

valley (for the description of the section see appendix 12.2). The ammonites are found only in a 1.5 m thick bed (bed no. EH4) in the thick black mudstones (figure 5.3), associated with bivalves. We concentrated our attention on this. A total of 50 specimens of ammonites were found. Numerous bivalves and ten microfossil samples for microfossil analysis were also collected.

5.3. Section south of Qianjin village

A 10 m long section of the Qihulin Formation crops out ca 4 km south of Qianjin village near a small road, which was used to transport coal from a small coal mine in the south. Yellowish green siltstones, and mudstones exposed here. Only a few broken bivalve specimens were recovered, and three microfossil samples were collected.

5.4. Team No. 4 of Farm 850

The test trench in the team No. 4 of Farm 850 was dug in 1980, and is now overgrown. The test trench was cleaned, but no macrofossils were found. No other outcrops were found in this area.

5.5. Chaoyang section

Chaoyang village lies at the foot of small hills along the western bank of Qihulin river (figures 5.4, 5.5). The sections were studied with the help of test trenches in the hill north of Chaoyang village (figure 5.6, for the description of the section see appendix 12.3) and measured by the Research Team on the Mesozoic coal-bearing Formations in Eastern Heilongjiang (1986). The Longzhaogou Group is faulted here, and four formations are exposed, i.e., Peide, Qihulin, Lower Yunshan and Upper Yunshan formations. The underlying beds are not exposed. The base of the Peide Formation is in contact with the Lower Yunshan Formation along a fault. The overlying Zhushan Formation is not exposed. Ammonites are found only in the upper part of the Qihulin Formation. On top of the hill north of Chaoyang, three levels yielded ammonites (HM17, HM38 and HM39) (figure 5.7) as well as one level (HM2) at the foot of the hill. These fossiliferous levels were also found when the section was measured by the Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang (1986). The ammonites are extremely scarce, and poorly preserved. Besides ammonites, bivalves and microfossil samples were collected.

Figure 5.6. Test trench of yellowish grey and black mudstones of the Qihulin Formation in the hill at Chaoyang village.

Figure 5.7. Outcrop of ammonite-bearing yellowish grey mudstones of the Qihulin Formation at the top of the hill at Chaoyang village.

5.6. Yunshan sections

In the Yunshan Farm area the Qihulin Formation is only exposed in test trench. Test trench No. 1 (figures 5.4, 5.5, for the description of the section see appendix 11.4.1) was dug in the northern hill of team No. 5 of Yunshan Farm. Test trench No. 2 (figure 5.4, 5.5, for the description of the section see appendix 11.4.2) was dug in the hill between the No. 2 and No. 3 teams of Yunshan Farm. The trench channels are filled with soil and vegetation. No macrofossils were recovered, but microfossil samples were taken in test trenches No. 1 and 2.

6. Biostratigraphy

6.1. Ammonites

The ammonite fauna of the Qihulin Formation consists of *Pseudohaploceras* cf. *nipponicum* Shimizu, 1931, *Pseudohaploceras* sp. 1, *Pseudohaploceras* sp. 2, and *Eogaudryceras* (*Eogaudryceras*) *yunshanense* (Liang, 1982). The genus *Pseudohaploceras* was described from the Barremian in the Carpathians, and ranges into the Aptian (Wright et al., 1996). *Pseudohaploceras nipponicum* Shimizu was described from the upper Aptian of Japan (Shimizu, 1931). *Eogaudryceras* (*Eogaudryceras*) ranges from Barremian to Albian (Wright et al., 1996). Although there is no stratigraphically diagnostic ammonite taxa were found, it can be inferred that the ammonite fauna is of Barremian–Aptian age.

6.2. Bivalves

The bivalve fauna consists of eight genera and 16 species: *Palaeonucula peideensis* Yu & Li, 1982, *Palaeonucula* cf. *makitoensis* Hayami, 1959, *Palaeonucula yunshanensis* Yu & Li, 1982, *Palaeonucula*? *mishanensis* Yu & Li, 1982, *Mesosaccella longzhaogouensis* Li & Yu, 1982, *Mesosaccella longa* Yu & Li, 1982, *Palaeoneilo peideensis* Li & Yu, 1982, *Palaeoneilo yunshanensis* Li & Yu, 1982, *Entolium extensum* Yu & Li, 1982, *Camptonectes* (*Camptonectes*) *wandaensis* Li & Yu, 1982, *Camptonectes* (*C.*) cf. *clathratus* Li & Yu, 1982, *Astarte*? *quadrata* Yu & Li, 1982, *Astarte*? sp., *Goniomya peideensis* Yu & Li, 1982, *Thracia rotundata* (J. de C. Sowerby, 1836) and *Thracia* sp. All the genera extend over a long time, and a large number of the species are endemic and provide no indication for the age assignment of the Qihulin Formation. *Thracia rotundata* (J. de C. Sowerby) (Woods, 1909) was described in the Aptian Hythe beds of Lympne in southern England, and may thus suggest an Aptian age of the formation. Gu et al. (1997) described *Palaeonucula* aff. *ishidoensis* (Yabe & Nagao, 1926) from the Qihulin Formation. *Palaeonucula ishidoensis* was described from the upper Neocomian–lower Aptian of Japan (Yabe et al., 1926; Hayami & Oji, 1980). Thus, the bivalve fauna is in agreement with the Barremian–Aptian age suggested by the ammonites for the Qihulin Formation.

6.3. Agglutinated foraminifers

The agglutinated foraminiferal fauna consists of ten genera and 16 species: *Bathysiphon* sp., *Ammodiscus rotalarius* Loeblich & Tappan, 1949, *Glomospirella* sp., *Cribrostomoides nonioninoides* (Reuss,1863), *Asanospira nakagawaensis* (Asano, 1950), *Haplophragmoides concavus* (Chapman, 1892), *Haplophragmoides multiformis* Akimets, 1966, *Haplophragmoides neocomiana* (Chapman, 1894), *Haplophragmoides* sp., *Ammomarginulina* sp., *Recurvoides* sp., *Spiroplectammina* sp., *Trochammina depressa* Lozo, 1944, *Trochammina umiatensis* Tappan, 1957 and *Trochammina* sp.

Ammodiscus rotalarius occurs in the Aptian–Albian of DSDP site 416 in the eastern North Atlantic (Sliter, 1980) and in Queensland (Haig, 1980), in the Albian of USA (Loeblich & Tappan, 1949) and Alaska (Tappan, 1962). *Cribrostomoides nonioninoides* is a cosmopolitan species in the Barremian–Aptian (Haig, 1980), and was recorded in the Valanginian–Barremian in DSDP site 263 in the Indian Ocean (Holbourn & Kaminski, 1995). *Haplophragmoides concavus* is a cosmopolitan species throughout the Cretaceous (Weidich, 1990). *Asanospira nakagawaensis* is an Upper Cretaceous species in Japan (Takayanagi, 1960). *Haplophragmoides multiformis* is a Lower Cretaceous species in Belarus (Akimets, 1966) and the northern calcareous Alps (Weidich, 1990). *Haplophragmoides neocomiana* was recorded by Chapman (1894) from the "middle Neocomian" of Surrey (England), and by Ten Dam (1946) from Hauterivian of Glanerbrug (Netherlands). *Trochammina depressa* is a cosmopolitan lower Cretaceous species (Weidich, 1990). *Trochammina umiatensis* occurs in the Albian of Alaska, and in the Aptian–Albian of DSDP site 416 (Sliter, 1980). Among the species found *Cribrostomoides nonioninoides* is very common, and *Haplophragmoides neocomiana* is very rare, only one specimen having been recovered. Based on the agglutinated foraminiferal fauna, only a broad Early Cretaceous age (Hauterivian–Albian) can be inferred. The Barremian–Aptian age as suggested by the ammonites and bivalves is not in conflict with the foraminifers.

6.4. Radiolarians

The radiolarian fauna consists of ten genera and 17 species: *Orbiculiforma* sp., *Archaeospongoprunum*? sp., *Praeconocaryomma*? sp., *Archaeodictyomitra* cf. *vulgaris* Pessagno, 1977, *Novixitus* sp., *Xitus* cf. *spicularius* (Aliev, 1965), *Xitus* sp., *Stichomitra* cf. *tosaensis* Nakaseko & Nishimura, 1981, *Stichomitra* sp. 1–7. Most of the genera are known from both Jurassic and Cretaceous deposits, with the exception of *Novixitus* which occurs

only in the Cretaceous. *Xitus spicularius* is known from the Berriasian to the Middle Cretaceous (mainly Albian) (Pessagno, 1977b). *Archaeodictyomitra vulgaris* is recorded from the Lower Cretaceous of California (Pessagno, 1977b) and the Barremian of Japan (Thurow, 1988; Tumanda, 1989). *Stichomitra tosaensis* is reported from the Albian–Cenomanian of Japan (Nakaseko & Nishimura, 1979, 1981), Italy and Spain (D'Ogherty, 1994). Thus, the radiolarian fauna is also in agreement with an Early Cretaceous age.

7. Taxonomy

All the specimens are deposited in the Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing.

The specimen designation consists of the locality code and the specimen number:

EH is the abbreviation of **E**astern **H**eilongjiang Province, the following number designates the locality as follows:

3=Test trench No. 9, north of Peide, Mishan County.

4=the Longzhaogou valley, 8 km north of Qianjin village, Hulin County.

TT10 = **T**est **t**rench No. **10**, north of Peide, Mishan County.

DS=Dongsheng section, north of Peide, Mishan County.

L=Longzhaogou section, north of Qianjin village, Hulin County.

Chao=Chaoyang section, Hulin County.

YI=Test trench No. 1 of Yunshan Farm, Hulin County.

YII=Test trench No. 2 of Yunshan Farm, Hulin County.

HM indicates **H**eilongjiang **M**esozoic. HM2, HM17, HM38, HM39 are the locality and horizons for ammonites in the northern hills of Chaoyang village (Research Team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986).

Bivalve specimen designations contain a letter B (for bivalve) between the locality code and the specimen number, for example EH4–B1. Foraminifers and radiolarians have the letters F and R respectively, between the locality code and the specimen number, for example EH4–F1 for foraminifera, EH4–R1 for radiolaria.

The ammonite specimen TT10–1 is from the collections of Prof. Chen P.-j., and the specimen 091 is from the collections of Prof. Chen J.-h.

7.1. Ammonites

Abbreviations for measurements of ammonites are: D: diameter; Wh: whorl height; U: umbilical diameter. As the specimens are flattened by compaction, the whorl breadth (Wb) was not measured.

Superfamily Desmoceratacеae Zittel, 1895

Family Desmoceratidae Zittel, 1895

Subfamily Puszosiinae Spath, 1922

Genus *Pseudohaploceras* Hyatt, 1900

Type species: *Ammonites liptoviensis* Zeuschner, 1856

Pseudohaploceras cf. *nipponicum* Shimizu, 1931

Plate 1, figures 1–8

cf. 1931 *Pseudohaploceras nipponicum* Shimizu nov. sp., pp. 27–28, pl. 1, figs 17–19.

1982 *Cadoceras* (*Paracadoceras*) sp.; Liang, p. 66, pl. 1, fig. 5.

1982 *Morphoceras longzhaogouense* (sp. nov.); Liang, p. 67, pl. 1, fig. 3a, b.

1983 *Arctocephalites* (*Cranocephalites*) *hulinensis* sp. nov.; Wang, pp. 100–101, pl. 1, figs 1–5.

cf. 1991 *Pseudohaploceras nipponicum* Shimizu; Obata & Futakami, p. 127, pl. 31, figs 6–8.

1994 Desmoceratacean group A; Kelly et al., pp. 511–512, pl. 1, figs 1–3.

1995 *Pseudohaploceras* cf. *liptoviense* (Zeuschner); Futakami et al., pp. 82–83, pl. 1, figs 3–10.

Material Eight specimens: EH4–31 and 019 are complete, poorly preserved specimens and EH4–8, 26, 27, 28 are fragmentary specimens, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County; HM17–3 is a complete, poorly preserved specimen from the northern hill of Chaoyang village in Hulin County; TT10–1 is a fragmentary specimen from Test trench No. 10 in north of Peide in Mishan County.

Measurements (mm)

Specimen No.	D	Wh	U	U/D(%)
091	46.1	22.5	10.0	21.7
HM17–3	34.0	15.0	17.0	20.6

Description The specimens are of moderate size. All are crushed and preserved with flattened flanks. The whorl section is possibly compressed. The whorl flanks are flat. The shell coiling is fairly involute, the umbilicus narrow. Inner whorls are preserved in specimen EH4–27 (plate 1, figure 1). The body chamber is about 2/3 of the outer whorl.

The ribbing is flexuous on the flanks with ribs projecting forward on the venter. The primary ribs begin either singly on the umbilicus wall or are bundled together on the flank near the umbilicus. Primary ribs are first prorsiradiate near the umbilicus, then bifurcate into secondaries between 1/3 and 2/3 of the flank height. The secondary ribs bend backwards at the branching points, then turn forward on the outer flank, and cross the venter continuously. The primaries are thin near the umbilicus and become stronger on the flank, but not stronger than the secondaries. The ribs are rounded and as broad as their interspaces. There are no tubercles on the flank or on the venter.

The outer whorl is marked by seven deep, flexuous regular constrictions, which cross the venter without interruption. Some constrictions are collared, especially in later growth stages. The collared constrictions intersect only one rib backwards, or touch one primary rib backwards on the inner flank. In specimen HM17–3 (plate 1, figure 8) the second last constriction collar has a parabolic structure, a feature that is common in kosmoceratids. The inner whorls and the inner chambers are crushed, and the ornament is not preserved. The number of constrictions is unknown.

Suture lines are not preserved.

Discussion The specimens probably belong to *Pseudohaploceras nipponicum* Shimizu (1931) on account of the density of the constrictions, the regular ribbing and the degree of involution. Specimen EH4–27 (plate 1, figure 1) is very similar to the paratype of *P. nipponicum* Shimizu figured by Obata & Futakami. (1991, pl. 31, fig. 8). However, the whorl section and the suture line of the Chinese specimens are not preserved. The other specimens referred to this species herein carry only four constrictions on the outer whorl; constrictions on the crushed inner whorls are not visible.

Obata et al. (1984) described *P. japanicum* from the Barremian of Japan. This species is similar to the Chinese species in ornamentation but differs in having a crater-like umbilical wall (Futakami et al., 1995).

The specimen of *Paracadoceras* sp. of Liang (1982, pl. 1, fig. 5) shows strong, sigmoidal ribs bifurcating near the umbilicus and also deep constrictions. However, in *Paracadoceras* there are no constrictions, and the ribs are less curved than in the Chinese form (Arkell, et al., 1957, p. 302).

With respect to *Arctocephalites* (*Cranocephalites*) *hulinensis* Wang (1983, pl. 1, figs. 1–5), all the specimens of Wang show marked constrictions, which number three or four on the last half of the outer whorl. Wang considered the constrictions a diagnostic feature as the

species level. But *Cranocephalites* has only one constriction. It seems that Wang's new species should not be allocated to *Cranocephalites*, and Kelly et al. (1994) placed it in the Desmoceratacea.

The specimen of *Morphoceras longzaogouense* Liang (1982, pl. 1, fig. 3a, b) is fragmentary. It has four constrictions preserved on the outer whorl; the inner whorls are not preserved. The constrictions transect only one main rib backwards. But in *Morphoceras*, the oblique constrictions transect several ribs backwards. Liang's specimens is poorly preserved and fragmentary, its whorl shape and the inner whorls are not preserved, and its ventral features are unknown. It is here referred to *Pseudohaploceras*; Liang's proposed species name should not be upheld.

Futakami et al. (1995) described *P.* cf. *liptoviense* (Zeuschner, 1856), but failed to observe the ventral features. *P. liptoviense* has bundled primary ribs near the umbilical seam and the constrictions cross the venter without distinct projections. Because in the Chinese specimens most primary ribs spring singly from the umbilical seam, and the constrictions project forward on the venter, it should not be referred to *P. liptoviense*.

The Chinese specimens seem to have flat whorl flanks, and a narrow umbilicus. They differ from the Caucasian Aptian species *P. falsistriatum* (Anthula, 1899) in that the latter has more convex flanks, a wider umbilicus and less curved ribs.

Avram (1978) described two upper Barremian species from Svinita, Romania, *P. tachthaliae* (Tietze, 1872) and *P. portaeferreae* (Tietze, 1872), which carry 12–14 and 15–16 constrictions, respectively. The Chinese specimens, although similar, have much fewer constrictions.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China. *Pseudohaploceras nipponicum* has been reported from the upper Aptian of Japan.

Psuedohaploceras sp. 1
Plate 1, figures 9–12; plate 2, figures 1–4

Material Thirteen specimens: EH3–1 is a complete specimen, and TT10–1 is a fragmentary specimen, both from Dongsheng village in Mishan County. EH4–3, 7, 9, 10, 12, 13, 15, 23 are complete, and all from the Longzhaogou valley, 8 km north of Qianjin village in Hulin

County. HM17–4, HM38–4 are complete, poorly preserved specimens and HM17–6 is a fragmentary specimen from the hill north of Chaoyang village in Hulin County.

Measurements (mm)

Specimen No.	D	Wh	U	U/D(%)
EH3–1	64.7	29.7	12.0	18.5
EH4–3	45.9	20.3	11.5	25.1
EH4–7	43.9	17.8	9.9	22.6
EH4–9	41.6	20.6	8.5	20.4
EH4–10	31.9	17.0	7.0	21.9
EH4–12	64.0	28.3	13.0	20.3
EH4–13	50.6	26.4	10.7	21.1
EH4–15	39.5	18.5	8.9	22.5
EH4–23	38.5	17.3	9.3	24.2
HM17–4	32.4	14.5	7.4	22.8
HM17–6	125.0	--	--	--
HM38–4	57.4	33.9	10.6	18.5

Description All specimens are flattened; their inner whorls are not preserved. The conch is medium to large, the largest specimen having a diameter of 125 mm, with most specimens between 30 and 60 mm. Coiling is fairly involute, with the ratio of U/D (umbilical diameter to the whorl diameter) between 18.5 and 25.1, which suggests that by early to middle growth stages the shell may be more involute, and in later growth stages the last quarter whorl becomes more evolute. The aperture is simple. A rounded umbilical wall is observed in some specimens.

The outer whorls are ornamented with constrictions and ribs but there are no tubercles. The ribbing is gently flexuous on the flank, and slightly bent forward on the venter. Primary ribs begin singly on the umbilical shoulder and become slightly prorsiradiate and stronger ventrally. Most of the primary ribs bifurcate near mid flank or at 2/3 of the flank height, but some remain single, and some are indistinctly connected with secondary ribs. The secondary ribs seem weak on the venter because of the smooth outer side of the body chamber, and there is no ventral keel or furrow. The primary ribs become gradually stronger with growth, and the last half whorl is ornamented with approximately 25 primary ribs.

There are two or three constrictions on the last quarter whorl; they are deep, flexuous, lightly collared on the fore edge, and parallel to the ribs forward, but the back edge slightly

cuts or tightly connects with only one rib backward. The first constrictions are irregular, and fairly variable in individual cases.

The suture line is preserved in only one specimen. It consists of a bifid first lateral saddle and a very strong asymmetrical trifid first lateral lobe. The detailed suture pattern is impossible to trace.

Discussion The specimens differ from *P*. cf. *nipponicum* in having weaker constrictions and two or three constrictions on the last quarter whorl.

Stratigraphical and geographical occurrence: Barremian–Aptian of Heilongjiang, northeastern China.

Psuedohaploceras sp. 2
Plate 2, figures 5–11

Material Six specimens. EH4–1, 2, 4 are complete, poorly preserved specimens and EH4–5 is a fragmentary specimen, all from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County. HM38–1, 8 are complete, poorly preserved specimens from the hill north of Chaoyang village in Hulin County.

Measurements (mm)

Specimen No.	D	Wh	U	U/D(%)
EH4–1	53.0	25.0	10.0	18.9
EH4–2	60.0	30.0	12.0	18.5
EH4–4	52.5	20.8	11.4	21.7
HM38–1	51.0	23.0	11.0	21.6
HM38–8	47.0	22.0	10.0	21.3

Description The specimens are flattened, and medium sized. Whorl coiling is fairly involute with very small umbilicus, and the ratio of U/D (umbilical width to whorl diameter) is approximately 0.2. In crushed specimens the whorl section is uncertain; the umbilical wall is not preserved. Inner whorls and suture lines are not preserved. The outer whorl is ornamented with ribs and constrictions. There are three strong constrictions near the aperture, with further

constrictions on the outer whorl. The constrictions are weakly collared, flexuous, prorsiradiate, nearly parallel to the ribs or intersecting only one rib backward. Ribbing is gently flexuous. There are about 25 primaries on the body chamber that spring singly or occasionally in pairs from the umbilical wall, but there are no tubercles or bullae on the umbilical shoulder. The primary ribs are strong and prorsiradiate on the 1/3 inner flank, then branch into secondary ribs at 2/3 of the flank height. Most primaries are bifurcated, but at the beginning of the body chamber the primaries branch into bundled secondary ribs (plate 2, figure 5). On the outer flank some secondaries are intercalated between the primaries. The external flank becomes smooth.

Discussion The present specimens differ from *Psuedohaploceras* sp. 1 by having stronger primary ribs and more numerous secondary ribs. Specimen EH4–2 (plate 2, figure 7) has fairly fine and dense secondary ribs. It appears similar to *Eogunnarites alaskaensis* (Matsumoto, 1959; McLearn, 1972), but the latter is more evolute and, according to McLearn the constrictions intersect several ribs backwards.

The genus *Moffites* was erected by Imlay (1959), who described two species from the lower Albian of Alaska. It has never been reported from other areas. The Chinese specimens resemble *Moffites* in lateral view with their coarse primary ribs, fine secondary ribs, and constrictions. However, the lack of information about the whorl section, suture lines, and the venter makes further comparison impossible.

The ribbing and the fairly involute whorl coiling have also been observed in *Umaltites era* (Krymgolz) (Krymgolz, 1988, pl. 5, figs. 2–4) from the upper Bajocian (Middle Jurassic) of Far Eastern Russia. However, the Bajocian species have concave coarse primary ribs, whereas the Chinese specimens have prorsiradiate primary ribs.

With respect to the ribbing and the irregular appearance of constrictions, the Chinese specimens are similar to *Leconteites* (lower Albian) (Jones et al., 1965) but they differ in lacking umbilical bullae.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Tetragonitaceae Hyatt, 1900

Family Gaudryceratidae Spath, 1927

Genus *Eogaudryceras* Spath, 1927

Subgenus *Eogaudryceras* Spath, 1927

Type species *Ammonites numidus* Coquand in Sayn, 1880

Eogaudryceras (*Eogaudryceras*) *yunshanense* (Liang, 1982)

Plate 2, figures 12–14

1982 *Oppelia* (*Oxycerites*) *yunshanense* (sp. nov.); Liang, p. 65, pl. 1, fig. 8.

1986 *Lytoceras* sp.; Li, et al., pl. 4, fig. 2.

1994 Tetragonitid; Kelly, et al., p. 514, pl. 1, fig. 7.

Material Six specimens: EH4–20, 25 are fragmentary specimens from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County. HM2–1, HM39–1 and HM38–3, 12 are fragmentary specimens from the hill north of Chaoyang village in Hulin County.

Description Specimen HM39–1 (plate 2, figure 14) is an external mould of an outer whorl fragment. Its inner whorls are not preserved. The wide whorl flank (27 mm) indicates the large size of the specimen. The specimen surface is ornamented with three strong constrictions, which correspond to three coarse collars on the shell. Dense, fine growth lines and lirae decorate both the collars and the whorl flank. The features of the venter and the umbilicus are not seen. The whorl section is unclear. All the other specimens are 20–30 mm in diameter, and their surface is decorated with fine, dense growth lines and lirae. There are no constrictions and collars. The specimens may represent young growth stages, i.e. the inner whorls, which can be seen in the complete specimen of Li et al. (pl. 4, fig. 2). Fragments of suture line are observed on the small specimens, but the poor preservation makes it difficult to trace the details.

Discussion The present specimens correspond to the species *Oppelia* (*Oxycerites*) *yunshanense* Liang (1982, pl. 1, fig. 8). Liang's specimen was also collected from Chaoyang, Hulin. It is a crushed shell fragment with three strong, slightly flexuous collars. The shell flank and the collars are covered with dense, fine growth lines and lirae. This specimen was revised by Kelly et al. (1994, pl. 1, fig. 7) and referred to the Tetragonitidae.

Because the specimens are fragmentary, the complete shell ornamentation, whorl shape and coiling features are not clear. This makes it difficult to compare with known species of the subgenus *Eogaudryceras (Eogaudryceras)*. Here I prefer to uphold Liang's species name, until well preserved specimens allow more detailed study and confirmation.

The specimen of *Lytoceras* sp. (Li et al., 1986, pl. 4, fig. 2) was collected from the Qihulin Formation of Peide, Mishan County. It is a crushed specimen comprising approximately five whorls, with 72 mm whorl diameter (measured from the plate figure). Coiling is evolute and the ornament consists of fine, dense almost straight lirae and strong constrictions on the outer whorl. Whereas in *Lytoceras* the whorls are covered with crinkled growth lines or riblets, this feature is not observed on Li's et al. specimen. Therefore it can not be accommodated within *Lytoceras*.

On the present form the typical ornament pattern comprises fine, dense lirae and strong collars, which make it clearly distinct from involute, smooth haploceratids such as *Lissoceras* (middle Bajocian, *sowerbyi* zone–lower Bathonian), *Lissoceratoides* (upper Callovian–upper Oxfordian), *Haploceras* (Kimmeridgian–Tithonian), *Neolissoceras* (upper Tithonian–Hauterivian). The evolute coiling separates it from the fairly involute phylloceratids and oppeliids. The same ornamental pattern may also be found on desmoceratacean such as *Barremites* (upper Hauterivian–upper Barremian), *Pachydesmoceras* (upper Albian–upper Turonian), *Desmoceras* (upper Aptian–Cenomanian), *Pseudouhligella* (upper Albian–lower Turonian). All these forms are normally covered with more sigmoid collars and the coiling is more involute.

On the basis of the evolute coiling, the fine, dense growth lines and lirae, the strong collars with constrictions, the present specimens should be assigned to Tetragonitaceae (Barremian–Maastrichtian), a family containing *Eogaudryceras* (Barremian–upper Albian), *Eotetragonites* (upper Aptian–middle Albian), *Gabbioceras* (upper Aptian–lower Cenomanian), *Anagaudryceras* (middle Albian–Maastrichtian).

In *Eotetragonites* the outer surface of the shell is ornamented with frequent constrictions at all growth stages, except for the fine, dense growth lines and lirae. They appear on the external shell as narrow grooves that are commonly preceded by a weak collar. Because the present specimen has less frequent constrictions, it differs clearly from *Eotetragonites*.

In *Gabbioceras* the inner whorls are evolute and highly depressed, with flat, sloping umbilical walls and a sharp ventrolateral angle; the outer whorls become rounded, compressed with no ventrolateral angle; the shell surface is decorated with lirae and collars. The present

form (plate 2, figures 13a, b) seems to have flat, sloping umbilical walls, but the broken state of the specimen hampers comparison with *Gabbioceras*.

In *Anagaudryceras* the periodic, collared constrictions, which form broad, flattened, foldlike ribs, become more numerous on the outer whorls. In the present species the outer whorl (plate 2, figure 14) is ornamented with lirae and collars.

Eogaudryceras has trapezoidal initial whorls and rounded cross sections in later whorls. The growth lines, lirae, constrictions and collars are slightly sigmoidal on the flank. Constrictions are variable in prominence; on large shells they are more distinct than on small shells. Collars are normally weakly developed or absent, but in Albian forms, such as in *E. aurarium* (Anderson, 1938) (Murphy, 1967, p. 13, pl. 1, figs. 6–8), strong collars also exist. The present specimens can reasonably well be classified as *Eogaudryceras*, but species comparison is hampered by the poor preservation.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

7.2. Bivalves

Class Bivalvia Linné, 1758
Subclass Palaeotaxodonta Korobkov, 1954
Order Nuculoida Dall, 1889
Superfamily Nuculacea Gray, 1824
Family Nuculidae Gray, 1824
Genus *Palaeonucula* Quenstedt, 1930
Type species *Nucula hammeri* Defrance, 1825, Upper Liassic (Bajocian); Europe.

Palaeonucula peideensis Yu & Li, 1982
Plate 3, figure 1

1982 *Palaeonucula peideensis* Yu et Li (sp. nov.); Li & Yu, pp. 93–94, pl. 3, figs. 21–22.
1997 *Palaeonucula peideensis* Yu et Li; Gu et al., pp. 10–11, pl. 1, figs. 18–19.

Material Four specimens: one left valve (HM17–B11), internal mould, from Chaoyang village in Hulin County; one left valve (EH4–B42) and two right valves (EH4–B41, EH4–B43), internal moulds, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B41	20	--	--
EH4–B42	16	25	0.64
EH4–B43	17	23	0.74

Description Shell small, inflated, subquadrate or suboval. Apical angle about 130°, opisthogyrous. Aequilateral, anterior margin acutely rounded. Posterior margin obtusely rounded or nearly straight, with distinct quadrately rounded postero-ventral angle. Hinge with palaeotaxodont denticles. Inner shell surface ornamented with concentric striae and growth lines. Posterior adductor scar strong and vertically elongated.

Discussion The species resembles *P. triangularis* Duff, 1978 (pl. 1, fig. 13) from the English Lower Oxford Clay (Middle Jurassic), but the Chinese species has a smaller height/length ratio than the English species.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Palaeonucula cf. *makitoensis* (Hayami, 1959)
Plate 3, figure 2

cf. 1959 *Nuculoposis* (*Palaeonucula*) *makitoensis* Hayami, new species, pp. 143–145, pl. 12, figs. 4–6.

1982 *Palaeonucula mediformis* Li et Yu (sp. nov.); Li & Yu, p. 92, pl. 3, figs. 3, 4, 6, 8.

1984 *Palaeonucula makitoensis* Hayami; Gu et al., p. 70, pl. 1, figs. 11–14.

1987 *Palaeonucula makitoensis* Hayami; Gu et al., p. 1, pl. 1, figs. 1, 2.

1997 *Palaeonucula* cf. *makitoensis* Hayami; Gu et al., pp. 7–8, pl. 1, figs. 8–12.

Material Two specimens: one right valve (HM17–B12), internal mould, from Chaoyang village in Hulin County; one right valve (EH4–B12), internal mould, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B12	20	26	0.77
HM17–B12	18	22	0.82

Description Shell medium-sized. Outline subovate or triangularly rounded, slightly inflated. Umbo at the anterior two-thirds to three quarters of the length, opisthogyrous. Anterior margin roundly curved. Postero-ventral margin distinctly truncated by the postero-dorsal margin, leading to a postero-ventral right angle. Antero-dorsal margin straight or slightly convex, postero-dorsal margin slightly concave. Hinge line is not preserved. Posterior

muscular scar strong and vertically elongated. Shell surface ornamented with delicate concentric growth lines.

Discussion *P. makitoensis* Hayami is reported from the Upper Jurassic Mitarai Formation of central Japan (Hayami, 1959, pp. 143–145, pl. 12, figs. 4–6). The Japanese species is much smaller than the present Chinese specimens. Hayami (1959) figured three specimens. The holotype (MM3141, pl. 12, fig. 4) is an internal mould and of relatively smaller height than the second paratype (MM3142, pl. 12, fig. 6). Gu et al. (1997) also figured a small specimen (pl. 1, fig. 12) collected from the Qihulin Formation north of Peide in Mishan, which has a relatively greater shell length than other specimens. Moreover, it has an elongated shell outline like those of *P.* aff. *ishidoensis* (Yabe & Nagao) (Gu et al., 1997, pp. 5–7, pl. 1, figs. 2, 3). The specimens of Gu et al. (1997) were collected from the Qihulin Formation of the Longzhaogou valley in Hulin and from north of Peide in Mishan, respectively. I place the Chinese specimens under open nomenclature because of their much larger size, stronger shell inflation, more numerous palaeotaxodont teeth (anterior hinge 27, posterior hinge eleven; the Japanese species has 20 and nine, respectively), less elongated anterior end, very faintly lower position of the posterior end, and very sharply outlined adductor scars.

Li & Yu (1982) figured eight specimens as *P. mediformis*. The holotype (BH0842, pl. 3, fig. 1) has an obliquely trapezoidal outlines, whereas the paratypes has rounded triangular outline (pl. 3, figs. 3, 4, 6, 8). Gu et al. (1997) referred the paratypes to *P.* cf. *makitoensis*.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Palaeonucula yunshanensis Yu & Li, 1982

Plate 3, figures 3–4

1982 *Palaeonucula yunshanensis* Yu et Li (sp. nov.); Li & Yu, p. 94, pl. 3, figs. 13–16.

1982 *Nuculoma nina* (Borissjak); Li & Yu, p. 90, pl. 4, fig. 17.

1982 *Palaeonucula kaoraensis* Cox; Li & Yu, p. 92, pl. 3, fig. 9.

1984 *Palaeonucula* aff. *makitoensis* Hayami; Gu et al., p. 71, pl. 1, fig. 15.

1984 *Palaeonucula* cf. *stolikzkai* Cox; Gu et al., p. 71, pl. 2, fig. 6.

1997 *Palaeonucula yunshanensis* Yu et Li; Gu et al., pp. 11–12, pl. 1, figs. 20–23.

Material Three specimens: one left valve (EH3–B2), internal mould, and one left valve (EH3–B3), external mould, from north of Dongsheng village in Mishan County; one right valve (EH4–B6), internal mould, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH3–B2	13	18	0.72
EH3–B3	14	17	0.82
EH4–B6	14	18	0.78

Description Small, outline subtriangular or suboval, moderately inflated. Antero-dorsal margin long and curved, meets the short and faintly concave postero-dorsal margin ca. 110° below the umbo. Broadly curved ventral margin merges meeting the posterior margin in a distinct rounded obtuse angle. The anterior margin is broadly rounded. Umbone low, opisthogyrous, situated at the anterior three quarters of the shell length. Anterior hinge has approximately 22 palaeotaxodont teeth, whereas the posterior hinge has eleven palaeotaxodont teeth, which become laterally larger. Inner ventral margin smooth, posterior adductor scar rounded.

Discussion The outline of the present species is similar to that of the paratype of *P. makitoensis* Hayami, 1959 from the Upper Jurassic Mitarai Formation of central Japan. *P. yunshanensis* differs from *P. makitoensis* by its slightly greater convexity, its rounded and obtuse umbone and its slightly broader anterior margin.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Palaeonucula mishanensis Yu & Li, 1982

Plate 3, figure 5

1982 *Palaeonucula mishanensis* Yu et Li (sp. nov.); Li & Yu, p. 93, pl. 4, fig. 12.

1997 *Palaeonucula*(?) *mishanensis* Yu et Li; Gu et al., pp. 13–14, pl. 2, fig. 6.

Material One right valve (EH3–B1), internal mould, from north of Dongsheng village in Mishan County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH3–B1	13	18	0.72

Description Shell of medium size, moderately inflated. Outline subelongated or subovate, inequilateral. Antero-dorsal margin long and nearly straight, postero-dorsal margin short, apical angle 120°. Anterior end slightly elongated and narrowly rounded, posterior end obtusely rounded, with a rounded postero-ventral angle, ventral margin broadly curved. Umbone low, opisthogyrous, projecting over the dorsal margin with deep cavity, and situated at the anterior two-thirds of the length. Anterior and posterior hinge with palaeotaxodont teeth, the exact number of teeth is not clear. Inner ventral margin smooth, inner surface ornamented by widely spaced concentric lines, posterior adductor scar is rounded.

Discussion The holotype of *P. mishanensis* is a very small specimen (9.5 mm long and 6.5 mm high), approximately half the size of the present specimen. The species differs from *P. yunshanensis* Yu & Li in having a subelongate outline, a narrower anterior margin and a more anteriorly located umbone. It differs from *P. menkii* (Roemer) (Arkell, 1927, pp. 33–34, pl. 1, figs. 1, 1a) from the Jurassic of Europe in having a proportionally greater height.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Nuculanacea H. Adams & A. Adams, 1858

Family Nuculanidae H. Adams & A. Adams, 1858

Genus *Mesosaccella* Chavan, 1946

Type species *Nucula foersteri* Müller, 1847 from the Upper Cretaceous of Germany.

Mesosaccella longzhaogouensis Li & Yu, 1982
Plate 3, figure 6

1982 *Mesosaccella longzhaogouensis* Li et Yu (sp. nov.); Li & Yu, p. 100, pl. 1, figs. 9–12.
1982 *Mesosaccella morrisi* (Deshayes), 1853; Li & Yu, p. 101, pl. 1, fig. 4.
1982 ?*Palaeoneilo* cf. *bittneri* Borissjak, 1904; Li & Yu, p. 95, pl. 2, fig. 17, non 14–16.
1984 *Mesosaccella morrisi* (Deshayes); Gu et al., p. 73, pl. 1, figs. 9, 10.
1984 *Palaeoneilo* aff. *belaensis* Cox; Gu et al., p. 75, pl. 2, figs. 8, 10, pl. 4, fig. 7.
1987 *Mesosaccella morrisi* (Deshayes); Gu et al., p. 1, pl. 1, fig. 4.
1997 *Mesosaccella longzhaogouensis* Li et Yu; Gu et al., p. 16–17, pl. 2, figs. 12–16.

Material Two right valves (EH4–B7, EH4–B44), internal moulds, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B7	22	33	0.67
EH4–B44	20	32	0.63

Description Shell large for the genus. Outline suboval to subelliptic, aequilateral. Anterior margin rounded, posterior margin broadly rounded. Both antero- and psotero-dorsal margins slightly concave or nearly straight. Ventral margin broadly curved. Umbo low, situated at the anterior one-third of the shell length. Surface ornamented with fine and dense concentric growth-lines. Hinge series bear palaeotaxodont denticles.

Discussion The specimens agree with the holotype of *Mesosaccella longzhaogouensis* (Gu et al.,1997, pl. 2, fig. 12). They have also similarities to *Palaoneilo qihulinensis* J. Chen & Gu (Gu et al., 1997, pl. 3, fig. 12), but the present specimens have no posterior umbonal sulcus or depression, which is the characteristic feature for the genus *Palaeoneilo*, and for this reason they should be grouped in *Mesosaccella*.
The present species appears similar to the English species *M. morrisi* (Deshayes) (Duff, 1978, pp. 29–30, pl. 1, figs. 22, 24–33; text-fig. 22) but differs in its oval form, its rounded postero-dorsal angle, and relative greater height.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Mesosaccella longa Yu & Li, 1982
Plate 3, figures 7–10

1982 *Mesosaccella longa* Yu et Li (sp. nov.); Li & Yu, p. 100, pl. 1, figs. 13–18.
1982 *Mesosaccella longzhaogouensis* Li et Yu (sp. nov.); Li & Yu (pars), p. 100, figs. 7, 8.
1984 *Palaeoneilo* aff. *belaensis* Cox (pars). Gu et al., p. 75, pl. 2, fig. 9.
1997 *Mesosaccella longa* Yu et Li; Gu et al., pp. 17–18, pl. 2, figs, 17–20.

Material Six specimens: two right valves (EH4–B8, EH4–B48) and one left valve (EH4–B39), internal moulds, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County; three left valves (HM17–B6, HM17–B7, HM17–B13), internal moulds, from Chaoyang village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B8	14	27	0.52
EH4–B39	8	14	0.57
EH4–B48	15	28	0.54
HM17–B6	14	26	0.54
HM17–B7	7	12	0.58
HM17–B13	16	33	0.48

Description Shell medium-sized, elongated, length about twice as large as the height, and rather inflated. Anterior margin acutely rounded, posterior margin largely pointed and slightly bent upwards. Antero-dorsal margin short and straight, postero-dorsal margin long and slightly concave, ventral margin broadly curved. Umbone prosogyrous, blunt and slightly projected, located at the anterior two-fifths of the shell length. Hinge has V-shaped palaeotaxodont denticles, anterior hinge has about 30 teeth, whereas the posterior one has ca. 20, no chondrophore of recilifer present. Shell surface ornamented with fine and dense concentric striations.

Discussion *Mesosaccella longa* differs from *M. longzhaogouensis* in its smaller H/L ratio, and in its postero-dorsal margin, which is bent upwards.
Mesosaccella longa are similar to *Palaeoneilo qihulinensis perlangar* J. Chen & Gu (Gu et al., 1984, pl. 3, fig. 9; Gu et al., 1997, pl. 3, fig. 15), but *M. longa* has no interruption between the anterior and posterior hinge series.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Family Malletiidae H. Adams & A. Adams, 1858
Genus *Palaeoneilo* Hall & Whitfield, 1869
Type species *Nuculites constricta* Conrad, 1842, middle Devonian of New York state, USA.

Palaeoneilo peideensis Li & Yu, 1982
Plate 3, figure 11

1982 *Palaeoneilo peideensis* Li et Yu (sp. nov.), p. 96, pl. 2, figs. 9–10, 12–13.
1997 *Palaeoneilo peideensis* Li et Yu; Gu et al., pp. 19–20, pl. 3, figs. 1–3.

Material Two specimens: one left valve (HM17–B10, internal mould), from Chaoyang village in Hulin County; one left valve (EH4–B45, internal mould), from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B45	14	19	0.74
HM17–B10	16	23	0.70

Description Medium-sized, outline oval to subquadrate. Anterior margin rounded; there is no distinct antero- and postero-ventral angles. Anterior and posterior margins extend roundly upwards meeting the dorsal margin with prominent angles. Ventral margin broadly curved. Dorsal margin triangular with the umbone at nearly central position. Umbonal region low, the prosogyrous umbone is slightly anterior of the median on the dorsal margin. A few palaeotaxodont teeth visible on the posterior hinge. Surface ornamented with fine dense concentric striations. The faint posterior umbonal depression is discernible on the shell surface.

Discussion The outlines of the present specimens are very similar to those of *Rollieria*? *trapezica* (Yu & Li) (Gu et al., 1997, pl. 4, figs. 19–23). The latter species, as stated by Gu et al. (1997, p. 32), has no radial groove and internal septum, both characteristic features of *Palaeoneilo*, nor a small pallial sinus which is one of the diagnistic characters of *Rollieria*, but placing them together in *Palaeoneilo* may be preferable.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Palaeoneilo yunshanensis Li & Yu, 1982
Plate 3, figures 12–13

1982 *Palaeoneilo yunshanensis* Li et Yu (sp. nov.), p. 97, pl. 2, figs. 1–5.
1984 *Palaeoneilo peideensis* J. Chen sp. nov.; Gu et al., p. 78, pl. 3, figs. 16–18.
1997 *Palaeoneilo yunshanensis* Li et Yu; Gu et al., p. 20, pl. 3, figs. 4–8.

Material Three specimens: one left valve (EH4–B3), internal mould, from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County; two left valves (HM17–B8, HM17–B47), internal moulds, from Chaoyang village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B3	9	15	0.60
HM17–B8	10	15	0.67
HM17–B47	6	10	0.60

Description Medium-sized for the genus, moderately inflated, shell elongated, suboval, aequilateral, posteriorly higher. Anterior margin acutely rounded, posterior margin broadly rounded to nearly straight, with a square postero-dorsal angle. Ventral margin broadly rounded. Umbo situated at the anterior one-third to two-fifths of the shell length. The anterior hinge consists of twelve teeth, the posterior of 20 teeth.

Discussion *P. peideensis* Li & Yu, 1982 and *P. peideensis* J. Chen, 1984 are homonyms, because Chen did not know that Li & Yu (1982) have already described *P. peideensis*. However, *P. peideensis* J. Chen, 1984 is conspecific with *P. yunshanensis* Li & Yu, 1982, thus *P. peideensis* J. Chen, 1984 should not be upheld.

The species differs from *P. peideensis* in having an elongated outline.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Subclass Pteriomorphia Beurlen, 1944
Order Pterioida Newell, 1965

Suborder Pteriina Newell, 1965

Superfamily Pectinacea Rafinesque, 1815

Family Entoliidae Korobkov, 1960

Genus *Entolium* Meek, 1865

Type species *Pecten demissus* Phillips, 1829 (=*Pecten disciforne* Schuebler in Zieten, 1833), Jurassic, Europe.

Entolium? *extensum* Yu & Li, 1982

Plate 3, figure 15

1982 *Entolium extensum* Yu et Li (sp. nov.); Li & Yu, p. 114, pl. 9, figs. 1–3.

1982 *Entolium* cf. *demissum* (Phillips), 1829; Li & Yu, pp. 113–114, pl. 6, figs. 1–8.

1982 *Entolium disciforme* (Schuebler), 1883; Li & Yu, p. 114, pl. 6, figs. 11–14.

1982 *Entolium longzhaogouense* Yu et Li (sp. nov.); Li & Yu, pp. 114–115, pl. 9, figs. 4–7.

1982 *Entolium peideense* Li et Yu (sp. nov.); Li & Yu, p. 115, pl. 6, figs. 17–20.

1982 *Entolium yunshanense* Yu et Li (sp. nov.); Li & Yu, pp. 115–116, pl. 6, figs. 9–10.

1982 *Entolium* cf. *nieniexionglaense* Wen, 1976; Li & Yu, p. 116, pl. 6, figs. 15–16.

1984 *Entolium demissum* (Phillips); Gu et al., p. 101, pl. 12, figs. 7–15.

1984 *Entolium* cf. *cingulatum* (Goldfuss); Gu et al., pp. 101–102, pl. 13, figs. 1, 2, 4.

1984 *Entolium*? *hulinense* J. Chen et Gu sp. nov.; Gu et al., pp. 103–104, pl. 11, figs. 1–13.

1984 *Entolium*? aff. *hulinense* J. Chen et Gu sp. nov.; Gu et al., pp. 104–105, pl. 14, figs. 6–8, 9–15.

1987 *Entolium demissum* (Phillips); Gu et al., p. 1, pl. 1, figs. 6–7.

1997 *Entolium extensum* Yu et Li; Gu et al., pp. 78–80, pl. 9, figs. 14–19; pl. 10, figs. 1–9.

Material Ten specimens: three left valves (EH4–B19, EH4–B20, EH4–B36, internal moulds); five left valves (EH4–B4, EH4–B31, EH4–B33, EH4–B34, EH4–B38) and two right valves (EH4–B16, EH4–B35), external moulds, all from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B4	40	40	1.00
EH4–B16	18	15	1.20
EH4–B19	49	39	1.27
EH4–B31	31	--	--
EH4–B33	37	--	--
EH4–B34	25	--	--
EH4–B35	29	27	1.07
EH4–B36	56	51	1.10
EH4–B38	42	37	1.14

Description Shell medium-sized for the genus, pectiniform, equilateral, suborbicular. Height normally greater than the length, the greatest length at about half shell height. Lateral and ventral margins well rounded, shell shoulder rounded. Hinge short and straight. Ears equal to subequal, triangular, with an elevation towards the dorsal and lateral extremities in both valves, their outer angles obtusely rounded, their outer borders meeting the margin of the shell downward on the shoulders at an acute angle in the posterior ear, but much larger in the anterior ear. Umbonal angle between 90° and 123°, seldom smaller than 90°. Umbonal ridges distinct. Surface ornamented with concentric delicate growth lines and periodic riblets. Specimen EH4–B4 (plate 3. Figure 15) also has irregular radial fine threads, but on other specimens no such ornament is visible. On two specimens (EH4–B13, 37, internal moulds) there are irregular radial low, broad but faint plications. Auricles are ornamented with concentric elements. Cardinal crura are clearly seen on internal moulds; the ligament pit has transverse ridges. Muscle scars are not preserved.

Discussion Based on the shell outline the species has been split into several species of *Entolium* by authors before the 1990s. Although the outline varies from obovate to suboricular, the umbonal angles change within a very large range. Gu et al. (1997) revised these species and synonymized them with *E. extensum* Yu & Li (Li & Yu, 1982), which has priority.

Yamani (1983) proposed the genus *Cingentolium* and designated *Pecten cingulatus* (Goldfuss, 1835) as the type species. According to Yamani, the species of *Cingentolium* have concentric striae on both valves, and their inner shell surface is ornamented with radial ribs,

whereas the species of *Entolium* are either smooth on both valves or only the left valves is ornamented with concentric striae. The present specimens have concentric delicate growth lines on both valves and radial thread-like striae on the shell surface. Therefore, it seems that the present specimens could be attributed to *Cingentolium*, but the cardinal area and inner shell surface features are not very well preserved, and further comparison is difficult.

The present specimens differ from *E. demissum* (Phillips) (Arkell, 1930, pp. 91–93) in that the latter has no radial ornament on the shell surface, whereas the present specimens show faint but constant radial surface ornaments.

The present specimens are different from *E. utukokense* Imlay, 1961 from the Albian of northern Alaska, in that *E. utukokense* is much larger (length 41–105 mm); the Chinese specimens have a greatest length of 51 mm (specimen EH4–B36).

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Family Pectinidae Rafinesque, 1815

Genus *Camptonectes* Agassiz in Meek, 1864

Subgenus *Camptonectes* (*Camptonectes*) Agassiz in Meek, 1864

Type species: *Pecten lens* J. Sowerby, 1818; subsequently designated by Stoliczka 1871. Jurassic of Europe.

Camptonectes (*Camptonectes*) *wandaensis* Li & Yu, 1982

Plate 3, figures 14, 16–19

Nomen nudum 1979 *Camptonectes* (*C.*) *wandaensis* Gu sp. nov., pl. 2, figs. 10–14 (no description).

1982 *Camptonectes* (*Boreionectes*) *wandaensis* Gu; Li & Yu, pp. 121–122, pl. 8, figs. 14–18, 19, 19a.

1982 *Camptonectes*? (*Boreionectes*) *minutus* Yu et Li (sp. nov.); Li & Yu, pp. 120–121, pl. 8, figs. 12–13.

1982 *Camptonectes* (*Boreionectes*) *yunshanensis* Yu et Li (sp. nov.); Li & Yu, p.122, pl. 9, figs. 11–15.

1984 *Camptonectes* (*C.*) *wandaensis* Gu sp. nov.; Gu et al., pp. 106–107, pl. 16, figs. 1–11, pl. 17, figs. 1–8, pl. 19, figs. 10–11.

1987 *Camptonectes* (*C.*) *wandaensis* Gu; Gu et al., p. 1, pl. 1, figs. 8–9.

1997 *Camptonectes* (*C.*) *wandensis* Gu; Gu et al., pp. 83–85, pl. 11, figs. 18–20, pl. 12, figs 1–4.

Material Seventeen specimens: three left valves (EH4–B11, EH4–B25, EH4–B27) and four right valves (EH4–B2, EH4–B21, EH4–B22, EH4–B24), internal moulds; two left valves (EH4–B28, EH4–B29) and four right valves (EH4–B5, EH4–B17, EH4–B41, EH4–B46), external moulds, from the Longzhaogou valley, 8 km north of Qianjin village, Hulin County; two left valves (HM17–B5, HM17–B30), internal moulds; one left valve (HM17–B4) and one right valve (HM17–B35), external moulds, from Chaoyang village, Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B2	17	18	0.94
EH4–B5	17	19	0.92
EH4–B11	15	17	0.89
EH4–B17	9	9	1.00
EH4–B21	21	19	1.11
EH4–B22	18	18	1.00
EH4–B24	15	15	1.00
EH4–B25	17	16	1.06
EH4–B29	15	14	1.07
EH4–B41	18	19	0.94
EH4–B46	20	21	0.95
HM17–B4	17	18	0.94
HM17–B5	19	19	1.00
HM17–B30	17	17	1.00

Description Medium-sized for the genus. Outline pectiniform and rounded, very slightly opisthocline. Shell length is nearly equal to or slightly greater than shell height. Inaequilateral, anterior margin broadly rounded, posterior margin acutely rounded. Apical angle 90°–100°. Beak not projected over the hinge margin. Ears unequal, anterior ear much larger. Right

byssal ear sublinguiform with convex antero-dorsal part and concave zone of deep byssal sinus and notch, the two parts being delimited by a sulcate trough; its surface is ornamented with regular concentric striations and six radial striae resulting in a reticulate pattern on the middle part of the ear. Left anterior ear flat and subtrigonal, its dorso-anterior corner being truncated by an angle of nearly 90° or a little larger; its surface is fully decorated with about 20 fine radial riblets crossed by concentric elements. Both posterior ears are flat and subtrigonal with an obtuse dorso-posterior angle; their surfaces are ornamented with fine concentric striae and fine dense radial and divaricate striations which meet the posterior auricular margin vertically. Shell surface with dense, regular, concentric furrows and a few very feeble concentric striations on the interspaces. Somewhat punctate radial riblets are clearly discernible on the marginal shell parts. Gu et al. (1997) stated that there are no radial truncated riblets on the ventral margin, however, the figured specimens have this ornament on the ventral margin.

Discussion *Camptonectes* (*C.*) *wandaensis* differs from the Jurassic *C.* (*C.*) *lens* (Sowerby) and *C.* (*C.*) *auritus* (Schlotheim) (Duff, 1978, pl. 5, figs. 22, 25, text-fig. 22) in that the latter two have a more rounded shell outline and possess regular radial divaricate ornaments which fully cover the shell surface. It differs from the Portlandian *C. lamellosus* (Sowerby) (Dechaseaux, 1936) and *C. suprajurensis* (Buv.) (Spath, 1936) from the Paris Basin and Greenland, respectively. *C. lamellosus* has slightly larger posterior ears and its height is distinctly greater than the length; furthermore, no radial riblets appear on the antero- and postero-margins. *C. suprajurensis* has feeble concentric furrows. The outline of the Japanese species *C. torinosuensis* Kurata & Kimura (Kimura, 1951) from the Torinosu Group is very similar to that of *C.* (*C.*) *wandaensis*, although the Japanese species has no radial riblets or striae on the ears in spite of the concentric ornamentation (Gu et al., 1997).

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Camptonectes (*Camptonectes*) cf. *clathratus* Li & Yu, 1982

Plate 3, figures 20–21

cf. 1982 *Camptonectes* (*Camptonectes*) *clathratus* Li et Yu (sp. nov.), pp. 116–117, pl. 7, figs. 6–8.

1982 *Camptonectes* (*Camptonectes*)? cf. *convexus* Yu et Li; Li & Yu, p. 117, pl. 7, fig. 4; pl. 9, figs. 16–18.

1982 *Camptonectes* (*Camptonectes*) *lens* (Sowerby) (pars); Li & Yu, p. 118, pl. 7, figs. 1, 1a, 2, non 3.

1997 *Camptonectes* (*Camptonectes*) cf. *clathratus* Li et Yu; Gu et al., pp. 87–88, pl. 10, figs. 17–21.

Material Four specimens: one left valve (EH4–B26) and one right valve (EH4–B23), internal moulds, from the Longzhaogou valley, 8 km north of Qianjin village, Hulin County; two left valves (HM17–B9, HM2–B1), internal moulds, from Chaoyang village, Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B23	16	10	1.60
EH4–B26	15	9	1.67
HM2–B1	22	19	1.16
HM17–B9	23	21	1.10

Description Shell small for the genus, pectiniform outline, slightly higher than long. Anterior and posterior margins nearly straight, ventral margin well rounded. Dorsal margin straight. Anterior ear greater than posterior one. The left anterior ear truncated by an almost right angle, the left posterior ear truncated with an obtuse angle.

Apical angle ca. 105°, anterior umbonal ridge slightly more concave than the posterior one.

Discussion The present specimens are slightly higher than long, and differ from the preceding species *Camptonectes (C.) wandaensis* Li & Yu, 1982. The specimens described here are internal moulds with no surface ornament preserved and because of its greater umbonal angle of about 105°, they are referred, although with doubt, to *Camptonectes* (*C.*) *clathratus* Li & Yu, 1982.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Subclass Heterodonta Neumayr, 1884

Order Veneroida H. Adams & A. Adams, 1856

Superfamily Crassatellacea Férussac, 1822

Family Astartidae D'Orbigny, 1844

Subfamily Astartinae D'Orbigny, 1844

Genus *Astarte* Sowerby, 1816

Type species *Venus scotia* Maton & Rockett, 1807, Recent in the seas of Scotland and the Atlantic Ocean.

Astarte? *quadrata* (Yu & Li, 1982)

Plate 3, figure 22

1982 *Astartoides*? *quadratus* Yu et Li (sp. nov.); Li & Yu, p. 134, pl. 16, fig. 7.

1984 *Astarte qihulinensis* J. Chen sp. nov.; Gu et al., pp. 153–154, pl. 34, fig. 7–9, 10(?), 11, 12(?).

1984 *Neocrassina*? sp. 1; Gu et al., p. 156, pl. 34, fig. 5; pl. 35, figs. 23–26.

1984 *Neocrassina*? sp. 2; Gu et al., p. 156, pl. 34, fig. 22.

1997 *Astarte*(?) *quadrata* Yu et Li; Gu et al., pp. 169–171, pl. 22, figs. 2, 21, 23–25; pl. 23, figs. 7–12.

Material Four specimens: one right valve (EH4–B50), internal mould, from the Longzhaogou valley, 8 km north of Qianjin village, Hulin County; one right valve (HM17–B34), internal mould; one left valve (HM17–B3) and one right valve (HM17–B25), external moulds, from Chaoyang village of Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B50	8	10	0.80
HM17–B3	7	8	0.88
HM17–B25	4	5	0.80
HM17–B34	6	7	0.86

Description Shell small to medium-sized for the genus, equivalve, inequilateral, moderately inflated. Outline suborbicular to subelliptic, slightly longer than high. Anterior end narrowly rounded, posterior end broadly rounded, postero-dorsal margin straight, antero-dorsal margin distinctly concave, ventral margin broadly curved. Umbone prosogyrous, situated at the anterior one-third of the shell length. External surface ornamented with ten regular concentric, broadly spaced ridges; there are also delicate concentric striations between the ridges. Hinge structure is not preserved.

Discussion The specimens resemble those of *Astarte*? *quadrata* figured by Gu et al. (1997, pl. 22, figs. 2, 23–25; pl. 23, figs. 7–12) in shell outline and surface ornamentation. These were also collected from the Qihulin formation and should be grouped into the same species. However, as the hinge structure is not preserved their attribution to *Astarte* is doubtful.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Astarte sp.
Plate 3, figure 23

Material Four specimens: one right valve (HM17–B36, internal mould); two left valves (HM17–B37, HM17–B46) and one right valve (HM17–B1), external moulds, all from Chaoyang village, Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
HM17–B1	11	13	0.85
HM17–B36	8	11	0.73
HM17–B37	8	11	0.73
HM17–B46	11	13	0.85

Description Shell medium-sized, outline orbicular or subellipical, equilateral. Anterior and posterior margins rounded, ventral margin broadly curved, symmetrical with dorsal margin. Umbone situated near the middle of the dorsal margin. Shell surface with twelve or more

broadly spaced concentric ridges and irregular delicate growth lines between them. No hinge structure preserved.

Discussion The present specimens are similar to those of *Astarte* (*A.*) cf. *diphorma* Li & Yu (Gu et al., 1997, pp. 171–172, pl. 22, figs. 9–15) in outline and ornamentation, but are slightly smaller and have less numerous concentric ridges.
They differ from *Astarte* (*A.*) *diphorma* Li & Yu, 1982 (Gu et al., 1997, pp. 175–176, pl. 22, figs. 4–8) in that the umbone is situated near the middle of the dorsal margin.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Subclass Anomalodesmata Dall, 1889
Order Pholadomyoida Newell, 1965
Superfamily Pholadomyacea Gray, 1847
Family Pholadomyidae Gray, 1847
Genus *Goniomya* Agassiz, 1841
Type species *Mya angulifera* J. Sowerby, 1819, Bathonian, England.

Goniomya peideensis Yu & Li, 1982
Plate 3, figure 24

1982 *Goniomya peideensis* Yu et Li (sp. nov.); Li & Yu, pp. 143–144, pl. 22, figs. 10–12, 12a.
1982 *Goniomya* cf. *literata* (Sowerby), 1819; Li & Yu, p. 143, pl. 22, fig. 9.
1984 *Goniomya* sp. nov.?; Gu et al., pp. 181–182, pl. 46, fig. 9; pl. 47, figs. 9–14.
1984 *Goniomya* sp.; Gu et al., p. 182, pl. 47, fig. 15.
1987 *Goniomya* sp.; Gu et al., pl. 1, figs. 11, 12.
1997 *Goniomya peideensis* Yu et Li; Gu et al., pp. 229–231, pl. 35, figs. 13–19.

Material Eight specimens: one left valve (HM38–B1) and three right valves (HM17–B14, HM17–B19, HM38–B2), internal moulds; one left valve (HM38–B5) and three right valves (HM17–B21, HM17–B23, HM38–B3), external moulds, all from the Chaoyang village, Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
HM38–B1	35	68	0.51

Description Shell large for the genus, equivalve and inequilateral, anterior height much smaller than posterior height. Oblong or elongated elliptic, shell much longer than high. Dorsal margin nearly straight. Anterior margin narrowly rounded, posterior margin broadly rounded. Antero-dorsal angle ca. 130°, postero-dorsal angle slightly larger, ventral margin very broadly rounded. Antero- and postero-ventral angles nearly equal. Umbone situated at the anterior two-fifths of the shell length, orthogyrous or slightly prosogyrous, and protruding slightly above the dorsal margin. Shell surface ornamented with broad, regular and radially plicate V-shaped ribs, which become broader ventrally and their interspaces gradually enlarge. The anterior and posterior parts of the shell carry radial riblets, which intersect the concentric ornament, a feature also visible in the specimen figured by Gu et al. (1997, pl. 35, fig. 19).

Discussion *Goniomya peideensis* differs from *G. suborchiaci* Nagao, 1934 from the Aptian–Albian Miyako Group in Japan (Hayami, 1966, pp. 163–165, pl. 25, figs. 1–13) in that the Japanese specimens are smaller and by the presence of regular U-shaped but never V-shaped broad ribs in the median part of the valve.

The present specimens are similar to the Albian *G. matonabbei* McLearn, 1933 (Imlay, 1961, p. 47, pl. 6, fig. 18) from the Tuktu and Ignek formations of Alaska. The holotype of the latter has nearly the same measurements (66 mm length and 33 mm height) as the specimen figured here. Gu et al. (1997) made no comparison with the Alaskan species. Although the specimen examined by Imlay (1961) is poorly preserved, it might be conspecific with the present material. To clarify this question, study of McLearn´s original material is necessary.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Pandoracea Rafinesque, 1815

Family Thraciidae Stoliczka, 1870

Genus *Thracia* Leach in Sowerby, 1823

Type species *Thracia pubescens* Lam, 1819 (=*Mya pubescens* Pulteney, 1799), Recent, Atlantic Ocean.

Thracia rotundata (Sowerby, 1836)
Plate 3, figure 25

1836 *Panopea rotundata* J. de C. Sowerby in Fitton, pp. 129, 337, pl. 13, fig. 2. (Not seen.)
1909 *Thracia rotundata* (Sowerby); Woods, pp. 241–242, pl. 39, figs. 10a, 10b.
1982 *Thracia orbiculata* Yu et Li (sp. nov.); Li & Yu, pp. 145–146, pl. 21, figs. 5–9.
1982 *Thracia parvula* Yu et Li (sp. nov.); Li & Yu, p. 146, pl. 20, fig. 10.
1982 *Thracia scythica* Eichwald, 1869 (pars); Li & Yu, p. 146, pl. 20, figs. 14, 15, non 16.
1982 *Thracia shokawensis* Hayami, 1959 (pars); Li & Yu, pp. 146–147, pl. 21, figs. 1–4, 10, non 11, 12.
1982 *Thracia* cf. *shokawensis* Hayami, 1959 (pars); Li & Yu, p. 147, pl. 20, figs. 3, 5, 6, non 1, 2, 4.
1982 *Thracia suborbiculata* Yu et Li (sp. nov.) (pars); Li & Yu, p. 147, pl. 20, figs. 7,8,12,13, non 9.
1984 *Thracia depressa* (J. de C. Sowerby); Gu et al., pp. 183–184, pl. 47, figs. 1–4, 6, 7, non 5.
1984 *Thracia aff. depressa* (J. de C. Sowerby); Gu et al., p. 184, pl. 48, figs. 15–22 .
1984 *Thracia shokawensis* Hayami (pars); Gu et al., pp. 185–186, pl. 48, figs. 10, 13, non 7–9, 11, 12.
1987 *Thracia shokawensis* Hayami; Gu et al., p. 1, pl. 1, fig. 10.
1987 *Thracia depressa* (J. de C. Sowerby); Gu et al., p. 2, pl. 3, fig. 17.
1997 *Thracia rotundata* (J. de C. Sowerby); Gu et al., pp. 238–240, pl. 37, figs. 11–19.

Material One crushed left valve, external mould (HM17–B2) from Chaoyang village, Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
HM17–B2	23	28	0.82

Description Shell medium-sized for the genus. The crushed shell is roundly rectangular to suborbicular in outline. Anterior part higher and broader, antero-ventral margin more or less rounded, posterior end broadly rounded. Postero-dorsal angle truncated. Umbo prominent, placed near the median of shell length above the dorsal margin. Postero-umbonal ridge distinctly extends to the postero-ventral angle and separates a clear posterior area. Shell surface ornamented with concentric ribs and lines.

Discussion The figured specimen has the same shell outline and features as that of Gu et al. (1997, pl. 37, fig. 15) from the same locality. The present specimen differs from *T. phillipsi* Römer in being smaller and having a higher posterior margin and a distinct postero-dorsal angle. The specimen is very similar to two specimens of *Thracia* (*T.*) *depressa* (J. de C. Sowerby) reported by Duff (1978, pl. 13, figs. 13, 23) from the late middle Callovian *Eryminoceras coronutum* Zone and from the late early Callovian *Sigaloceras calloviense* Zone of England. However, it differs from the English species by its smaller size and distinctly truncated postero-dorsal angle. The specimen has the same suborbicular outline as the specimen of *Thracia rotundata* (J. de C. Sowerby) reported by Woods (1909, pl. 39, fig. 10) from the Hythe beds (Aptian) of southern England.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; Aptian of England.

Thracia sp.

Plate 3, figure 26

Material One left valve (EH4–B1), internal mould, and one left valve (EH4–B47), external mould, from the Longzhaogou valley, 8 km north of the Qianjin village, Hulin County.

Measurements (mm)

Specimen No.	H (height)	L (length)	H/L
EH4–B1	27	41	0.66
EH4–B47	27	40	0.68

Description Left valve slightly smaller than the right one. Outline elongated oval. Anterior end narrowly rounded, no antero-ventral or antero-dorsal angle, whereas the posterior end is

broader with almost right-angled rounded postero-dorsal angle and a somewhat obtusely rounded postero-ventral angle. Ventral margin broadly curved. Beak opisthogyrous, situated slightly behind the median. The postero-umbonal ridge distinctly separates a posterior area. Shell surface ornamented with concentric folds and lines.

Discussion In the present specimens no granular ornamentation is preserved, whereas the specimens described by Gu et al. (1997, pp. 241–242, pl. 38, figs. 19–22) show a distinct granular ornament on the surface and also a more acute anterior margin.

The present specimens resemble *Thracia* sp. as described by Woods (1909, pp. 243–244, pl. 40, figs. 7–9) from the Upper Greensand (Albian) of England. However, Gu et al. (1997, p. 242) insisted that their specimens represent a new Early Cretaceous species. They differentiated the Chinese specimens from the English specimens only by their smaller size.
The present specimens are conspecific with the specimen described by Li and Yu (1982, p. 145, pl. 19, fig. 2) as an affinity of the Upper Jurassic *T. fukushimensis* Tamura, 1960 from the Some Group of Japan, on the basis of morphologic characters. However, they differ from *T. fukushimensis* in having an elongated oval form, a smaller height/length ratio and a more distinct postero-umbonal ridge.

Gu et al. (1984, pp. 184–185, pl. 48, figs. 1–6) described a species as closely related to *T. depressa* (J. de C. Sowerby) reported by Duff (1978) from the lower Oxford Clay (Middle Jurassic) of England. However, the English specimen has a relatively greater height and consequently a less elongated oval form.

The present specimen is similar to specimens of *T. robinaldina*? (d´Orbigny) from the Lower Greensand (Aptian–lower Albian) of England (Woods, 1909, p. 242, pl. 40, figs. 1–3), but the later are smaller and more inflated than the crushed Chinese specimens.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

7.3. Radiolarians

Phylum Protozoa
Class Reticularia
Order Polycystida
Suborder Spumellariina
Superfamily Spongodiscacea Haeckel, 1881, emended Pessagno, 1971, 1973
Subsuperfamily Pseudoaulophacilae Riedel, 1971, emended Pessagno, 1971
Family Orbiculiformidae Pessagno, 1973
Genus *Orbiculiforma* Pessagno, 1973
Type species *Orbiculiforma quadrata* Pessagno, 1973

Orbiculiforma sp.
Plate 4, figures 1–2

Material Two broken specimens (EH4–R1, EH4–R2) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. diameter	Diameter of central cavity
EH4–R1	250	139
EH4–R2	220	108

Description Test large, thin, polygonal in outline with seven sides. Central cavity very shallow with a diameter approximately half the size of test diameter. Meshwork is not preserved.

Discussion The two specimens have the same seven-sided outline as *Orbiculiforma mutangula* Pessagno, 1977, and the same ratio of central cavity to test diameter. The Chinese specimens are poorly preserved, their meshwork is not preserved.
Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Family Sponguridae Haeckel, 1862, emended Pessagno, 1973
Subfamily Archaeospongopruninae Pessagno, 1973
Genus *Archaeospongoprunum* Pessagno, 1973
Type species *Archaeospongoprunum venadoensis* Pessagno, 1973

Archaeospongoprunum? sp.
Plate 4, figures 3a–b

Material One broken specimen (EH4–R3) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang Province, northeastern China.

Measurement Length of polar spine: 442 μm.

Description The specimen is a (small) part of the central chamber with a long polar spine. Central chamber ornamented with irregular polygonal pore frames. Polar spine tetraradiate in axial section with four massive, rounded ridges alternating with four narrow grooves.

Discussion Only a very small part of the test is preserved with a long polar spine, so that the present specimen is assigned with doubt to *Archaeospongoprunum*.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Sphaerallacea Haeckel, 1881, emended Pessagno, 1977a
Family Pantanelliidae Pessagno, 1977b
Genus *Praeconocaryomma* Pessagno, 1976
Type species *Praeconocaryomma universa* Pessagno, 1976

Praeconocaryomma? sp.
Plate 4, figures 4–5

Material Two specimens EH4–R4, R5 from the Longzhaogou valley, 8 km north of the Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurement Maximum diameter: 194 μm.

Description Cortical shell subspherical, with numerous large mammae.

Discussion The detailed structures on and between the mammae are not preserved, which are diagnostic characters for the species identification.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Suborder Nassellariina Ehrenberg, 1875
Superfamily Cyrtoidea Haeckel, 1862
Subsuperfamily Eucyrtidilae Ehrenberg, 1847
Family Archaeodictyomitridae Pessagno, 1976, emended 1977b
Genus *Archaeodictyomitra* Pessagno, 1976, emended 1977b
Type species *Archaeodictyomitra squinaboli* Pessagno, 1976

Archaeodictyomitra cf. *vulgaris* Pessagno, 1977
Plate 4, figures 15a–b

cf. 1977 *Archaeodictyomitra vulgaris* Pessagno n. sp., p. 44, pl. 6, fig. 15.
cf. 1988 *Archaeodictyomitra vulgaris* Pessagno; Thurow, p. 398, pl. 6, fig. 19.
cf. 1989 *Archaeodictyomitra vulgaris* Pessagno; Tumanda, p. 36, pl. 7, figs. 1, 4.

Material One poorly preserved specimen (EH4–R15) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R15	226	107

Description Test acutely conical, with five postero-abdominal chambers. Cephalis conical, thorax, abdomen and postero-abdominal chambers trapezoidal with feeble constrictions. Costae throughout. Postero-abdominal chambers with approximately 11 continuous costae visible in lateral view. Relic pores between costae are not preserved.

Discussion The specimen has weak constrictions. These are also clearly seen on Tumanda's (1989) specimens from the Manokawa Formation (Barremian) of Japan, but are less distinct on Pessagno's type specimens from the Lower Cretaceous of California. The latter specimens have a perfectly conical test and nearly the same number of costae, but because relic pores between the costae are not seen in the Chinese specimen, it is left under open nomenclature.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China. *A. vulgaris* Pessagno has been described from the Lower Cretaceous in California, and the Barremian of Japan.

Family Xitidae Pessagno, 1977
Genus *Novixitus* Pessagno, 1977
Type species: *Novixitus mclaughlini* Pessagno, 1977

Novixitus? sp.
Plate 5, figures 3a–b

Material One poorly preserved specimen (EH4–R19) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R19	261	163

Description Test elongated conical, with seven segments. Cephalis and thorax conical, smooth, imperforate, without apical horn; there are no pores between cephalis and thorax. Abdomen trapezoidal, perforated with irregular polygonal pore frames. Postero-abdominal chambers trapezoidal to cylindrical in outline with strong polygonal pore frames, and irregularly spaced large tubercles on the circumference ridges. Pore frames in three to four transverse rows per chamber. Tubercles on the initial postero-abdominal chamber distinct, but on later chambers small or indistinct. Final chamber with constricted narrow end.

Discussion The specimen is questionably assigned to *Novixitus* Pessagno because the outer layer of the networks is not well developed, and the irregular large tubercles are only seen on the initial postero-abdominal chambers; on later chambers they disappear, and the inter-tubercle bars are poorly developed. However it is also difficult to assign it to other known genera such as *Parvicingula* Pessagno, 1977 and *Foremania* Empson-Morin, 1981, because it differs from *Parvicingula* in having three or four rows of pore frames per postero-abdominal chamber, in lacking strong circumferential ridges and lacking the cephalis horn. It differs from *Foremania* in having weaker circumferential ridges lacking regular small nodes.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Genus *Xitus* Pessagno, 1977
Type species: *Xitus plenus* Pessagno, 1977

Xitus cf. *spicularius* (Aliev, 1965)
Plate 5, figure 4

cf. 1965 *Dictyomitra spicularia* sp. nov.; Aliev, p. 39, pl. 6, fig. 9.
cf. 1977b *Xitus spicularius* (Aliev); Pessagno, p. 56, pl. 9, fig. 7; pl. 10, fig. 5.

Material One poorly preserved specimen (EH4–R20) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R20	342	142

Description Test elongated conical. Cephalis triangular, smooth, with a broken apical horn. Thorax and abdomen trapezoidal, with transversal aligned pores, and thick hexagonal pore frames. Postero-abdominal chambers cylindrical, ornamented with two-layer networks, the inner layer consisting of hexagonal pore frames, the outer layer of irregular tubercles and inter-tubercle rays.

Discussion It seems reasonable to accommodate this specimen within *Xitus* because of the presence of a cephalic apical horn, and a two-layer network test structure. The outline is similar to that of *Xitus spicularius,* but the larger pores, coarser pore frames, and irregular tubercles distinguish it from *Xitus spicularius.*

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China. *Xitus spicularius* is reported from the Albian of northeastern Azerbaijan, and Albian of the California.

Xitus? sp.
Plate 5, figures 5–6

Material Two specimens (EH4–R21, R22) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R21	309	150
EH4–R22	257	139

Description Test elongated conical. Cephalis triangular, smooth, with an apical horn. Thorax and abdomen trepazoidal, ornamented with three rows of pores per segment and proportionally thicker longitudinally arranged bars. Postero-abdominal chambers ornamented with two-layer networks. The inner layer consists of polygonal pores and pore frames. The outer layer consists of irregular tubercles and inter-tubercle bars.

Discussion The present specimens have a two-layer network and a well developed apical horn, and could be accommodated in the *Xitus*, although the outline of the test is proportionally wider than that of *X*. cf. *spicularius* described above. It is similar to *X*. *plenus* Pessagno (1977b, pl. 9, figs. 15, 21, 22, 26) from the upper Albian of California. But the poor preservation makes further comparison impossible.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Family Theoperidae Haeckel, 1881, emend. Riedel, 1967b, Takemura, 1986
Genus *Stichomitra* Cayeux, 1897
Type species: *Stichomitra bertrandi* Cayeux, 1897.

Stichomitra cf. *tosaensis* Nakaseko & Nishimura, 1981
Plate 4, figures 9–11

cf. *Nomen nudum* 1979 *Stichomitra tosaensis* n. sp. Nakaseko & Nishimura; Nakaseko et al, p. 24, pl. 7, fig. 11 (no description).
cf. 1981 *Stichomitra tosaensis* n. sp. Nakaseko & Nishimura, p. 162, pl. 11, fig. 3.
cf. 1994 *Stichomitra tosaensis* Nakaseko & Nishimura; O'Dogherty, p. 146, pl. 18, figs. 1–7, non. 8.

Material Three specimens (EH4–R9, R10, R11) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R9	213	119
EH4–R10	257	155
EH4–R11	224	148

Description Shell acutely conical, with approximately five postero-abdominal segments. Cephalis large, knob-like or dome-shaped, poreless and smooth. The first row of thoracic pores are vertically elliptical with strong pore frames in between, the other thoracic pores are smaller, sub-circular and arranged in three irregular transverse rows. The abdomen has three rows of small circular pores, which are arranged in transverse rows. There is no node on the stricture between the thorax and the abdomen. The postero-abdominal segments have three to four rows of larger circular pores and pore frames, which are spaced in regular transverse

rows. Strong strictures develop on the postero-abdominal segments, small nodes are not confined to the strictures, but occur also on the individual segments.

Discussion The specimens do not show the internal structure of their cephalis, but with the large dome-shaped cephalis and the well developed circumferential ridges indicate, they could be assigned to *S. tosaensis* Nakaseko & Nishimura, which has been reported from the late Albian to Cenomanian (*Holocryptocanium barbui-H. geysersensis* assemblage) of the Suzaki Formation, (Shimanto belt, Southwest Japan) (Nakaseko et al., 1979). O'Dogherty (1994) figured eight specimens, which showed a modification of the apical portion, leading from a long knob-like cephalis to a shorter acutely conical cephalis. However, his specimen figured in pl. 18, fig. 8 seems not to belong to this species because of the occurrence of a small apical horn.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China. *Stichomitra tosaensis* is reported from the Albian–Cenomanian of Japan, Italy and Spain.

Stichomitra sp. 1

Plate 4, figures 12–14

Material Three specimens (EH4–R12, R13, R14) from the Longzhaogou valley, 8 km north of Qianjin village of Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R12	>223	132
EH4–R13	257	153
EH4–R14	>233	155

Description Shell conical, with six segments. Cephalis large, broadly conical, or subspherical. Thorax and abdomen trapezoidal, with irregularly placed circular pores and strong pore frames. The initial postero-abdominal chamber trapezoidal, and later postero-abdominal chambers nearly cylindrical. Postero-abdominal chambers decorated with circular pores, which are larger than those of the thorax and abdominal chamber test; the pores are spaced in three regular transverse rows in the initial postero-abdominal chambers, and in four

rows in the later chambers. Pore frames are irregular polygonal. The initial postero-abdominal chambers have indistinct circumferential ridges carrying weakly developed tubercles; weakly developed inter-nodal bars extend diagonally across the surface. The later postero-abdominal chambers lack tubercles and circumferential ridges, which makes it difficult to identify the position of the joint.

Discussion This species differs from *Stichomitra* cf. *tosaensis* by having a broadly conical test, conical cephalis, weakly developed circumferential ridges, and the irregular nodes and distinct diagonally spaced inter-nodal bars.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Stichomitra sp. 2
Plate 5, figures 7

Material One specimen (EH4–R23) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R23	315	165

Description Test incompletely preserved, elongated conical, with four postero-abdominal chambers. Cephalis is broken, but apparently small. Thorax and abdomen are well perforated, trapezoidal in outline. Postero-abdominal chambers trapezoidal. Constrictions weakly developed. Thick hexagonal pore frames placed in transverse rows, approximately four rows of pores on the postero-abdominal chambers. The final postero-abdominal chamber is reduced in width, rendering the test a spindle-shaped outline. There are weak circumferential ridges in the middle of the postero-abdominal chambers, as well as regularly developed weak nodes.

Discussion *S. communis* (Squinabol, 1903) has slightly narrower chambers, stronger constrictions, and stronger nodes developed on the circumferential ridges than the specimen described here.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Stichomitra? sp. 3
Plate 5, figures 1–2

Material Two broken specimens (EH4–R17, R18) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R17	192	108
EH4–R18	>204	113

Description Test conical, approximately seven segments. Cephalis rounded, conical, without apical horn. Thorax and abdomen trapezoidal, with irregular pores and pore frames. Postero-abdominal chambers trapezoidal in outline. Postero-abdominal chambers carrying three transverse rows of pores and polygonal pore frames. Circumferential ridges with regular small tubercles, which are connected by diagonal bars.

Discussion The specimens differ from species of *Foremania* by having diagonal bars between the tubercles. The Chinese specimens lack an apical horn on the cephalis, and have three regular rows of transverse pores and pore frames on the postero-abdominal chambers, characters that indicate that can not be assigned to *Xitus* Pessagno, 1977.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Stichomitra sp. 4
Plate 4, figure 16a–b

Material One poorly preserved specimen (EH4–R16) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R16	271	143

Description Test conical apically and cylindrical distally. Cephalis, thorax and abdomen expanding rapidly in width and length. Cephalis conical, smooth and lacking horn. Thorax and abdomen trapezoidal in outline. Cephalis and thorax smooth, lacking pores, but there are indistinct pores in their joint. Abdomen with irregular pores and pore frames. Width of postero-abdominal chambers increasing slowly with adding of the chambers, which renders the postero-abdominal chambers a cylindrical outline. Indistinct circumferential ridges situated in the middle part of the later chambers. Initial postero-abdominal chamber with longitudinal tubercles, which disappear in the later chambers. The test surface is ornamented with hexagonal pore frames.

Discussion In comparison with *S*. aff. *Tosaensis* Nakaseko & Nishimura, 1979, the specimen has a conical instead of a knob-like cephalis and weakly developed circumferential ridges.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Stichomitra? sp. 5
Plate 5, figures 8–9

Material Two specimens (EH4–R24, R25) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R24	225	157
EH4–R25	318	167

Description Test broadly conical, with eight segments, postero-cephalis chambers trapezoidal apically, becoming cylindrical distally. Cephalis triangular, smooth, except for pores, and lacking a horn; thorax and abdomen trapezoidal with irregularly placed circular pores and strong pore frames. Initial postero-abdominal chamber trapezoidal, but distal postero-abdominal chambers nearly cylindrical. Postero-abdominal chambers decorated with circular pores, which are larger than those of the thorax and abdominal chamber test; the pores are spaced in three regular transverse rows in the initial postero-abdominal chambers, and in four rows in the later chambers. Pore frames irregular polygonal. Postero-abdominal chambers with distinct circumferential ridges and tubercle-like enlargements.

Discussion The specimens are assigned to *Stichomitra* with doubt because of the development of the circumferences. But the lack of information about the inner structure of the cephalis makes it difficult to assign it to *Amphipyndax*.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Stichomitra sp. 6
Plate 5, figure 10

Material One specimen (EH4–R26) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R26	>340	205

Description Test large, broadly conical, with four chambers. Cephalis conical, encased in thorax, poreless, without apical horn. Postero-cephalic chamber trapezoidal, notably increases in width and slightly in height, final chamber becomes cylindrical in outline. Pores of the postero-cephalis chambers are circular, with polygonal pore frames.

Discussion The specimen is similar to *S. japonica* (Nakaseko & Nishimura) O'Dogherty, 1994 (pl. 16, figs. 1–6) from the early Aptian of Italy and the late Albian-Cenomanian (*Holocryptocanium barbui–H. geysersensis* assemblage) of the Suzaki Formation (Shimanto belt, Southwest Japan). However, the Chinese specimen is larger, about twice as large as the Italian species, its constrictions are weaker, and the pores on the postero-cephalic chambers are arranged fairly regularly in transverse rows.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Stichomitra sp. 7
Plate 5, figures 11–12

Material Two specimens (EH4–R27, R28) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R27	283	146
EH4–R28	221	123

Description Shell elongated conical, apically acute conical, distally cylindrical. Cephalis, thorax and abdomen not visible, enclosed in sediments, postero-abdominal chambers cylindrical in outline and ornamented by circular pores and strong polygonal pore frames placed in transverse rows. Tubercles and circumferential ridges on the postero-abdominal chambers lacking.

Discussion The species is similar to *Stichomitra mediocoris* (Tan, 1927) (O'Dogherty, 1994, pp. 142–144), but the pores are smaller and the pore frames on postero-abdominal chambers thicker. As initial parts of the test (cephalis, thorax and abdomen) are not preserved, it is difficult to make detailed comparisons.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Gen. et sp. indet.

Plate 4, figure 6

Material One specimen (EH4–R6) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China

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Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R6	210	185

Description Specimen subspherical to ellipsoidal, surface smooth, no meshwork preserved.

Discussion Although no surface meshwork is seen, the ellipsoidal outline indicates that this form could be referred to *Holocryptocanium* Dumitrica, 1970. A definite determination will require study of the internal structure, which is not preserved in the Chinese specimen.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Gen. et sp. indet.

Plate 4, figures 7–8

Material Two specimens (EH4–R7, R8) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R7	158	142
EH4–R8	90	76

Description Test subspheric to ellipsoidal, its surface decorated with regularly hexagonal pore frames with a diameter of 4.2 μm.

Discussion The specimens are similar to the Japanese species *Holocryptocanium barbui* Dumitrica, 1970, from the Toma Formation (Barremian–Aptian) (Kato & Iwata, 1989, pl. 4, fig. 10), but the Chinese specimens are preserved with no internal structures, and with smaller pore frames (4.2 μm in diameter). It is very interesting that Kato & Iwata (1989) assigned two specimens from the Toma and Kaimei formations (Albian) to *H. barbui* despite their different surface ornaments: the specimen from the Toma Formation has regular polygonal pore frames on the test surface, whereas the specimen from the Kaimei Formation has a smooth surface with very small pores.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Nassellaria gen. et sp. indet.

Plate 5, figures 13–14

Material Two specimens (EH4–R29, R30) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (μm)

Specimen No.	Max. length	Max. width
EH4–R29	200	133
EH4–R30	>221	143

Description Test conical, with five segments, outline of cephalis not preserved, thorax and abdomen trapezoidal in outline, final chamber inflated. Test has a two-layer structure, where the inner layer consists of round or elliptical pores and polygonal pore frames and the outer layer of irregular tubercles. There are no circumferential ridges.

Discussion The specimens are preserved with no cephalis, but the two layer test suggests that they may be assigned to *Amphipyndax* Foreman, or *Tethyseta* Dumitrica, although there are no circumferential ridges on their tests.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

7.4. Agglutinated foraminifers

Order Foraminiferida Eichwald, 1830
Suborder Textulariina Delage & Hérouard, 1896
Superfamily Ammodiscacea Reuss, 1862
Family Astrorhizidae Brady, 1881
Subfamily Rhizammininae Rhumbler, 1895
Genus *Bathysiphon* Sars, 1872
Type species *Bathysiphon filiformis* Sars, 1872; Norway, Recent.

Bathysiphon sp.
Plate 6, figure 4

Material Two specimens (EH4–F1, 2) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Length	Max. Diameter
EH4–F1	0.24	0.06

Description Test tube form without constrictions; surface smooth, agglutinated grains inconspicuous.

Discussion The Chinese specimens have much thinner tubes than those of the known species, such as *Bathysiphon brosgei* Tappan, 1957 and *Bathysiphon vitta,* Nauss, 1947.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Family Ammodiscidae Reuss, 1862
Subfamily Ammodiscinae Reuss, 1862
Genus *Ammodiscus* Reuss, 1862
Type species *Ammodiscus infimus* Bornemann, 1874; Europe, Jurassic.

Ammodiscus rotalarius Loeblich & Tappan, 1949
Plate 6, figures 1–3

1949 *Ammodiscus rotalarius* Loeblich & Tappan, n. sp., p. 247, pl. 46, fig. 1.
1960 *Involutina cretacea* (Reuss); Takayanagi, p. 67, pl. 1, figs. 10a–12.
1962 *Ammodiscus rotalarius* Loeblich & Tappan; Tappan, pp. 131–132, pl. 30, figs. 5–8.
1980 *Ammodiscus rotalarius* Loeblich & Tappan; Sliter, pl. 1, fig. 8.
1980 *Ammodiscus rotalarius* Loeblich & Tappan; Haig, pp. 96–97, pl. 2, figs. 3–4; pl. 9, fig. 5.

Material Three specimens (HM17–F1–3) from Chaoyang village, and one specimen EH4–F3 from the Longzhaogou valley, 8 km north of the Qianjin village, Hulin County, Heilongjiang Province, northeastern China.

Measurements (mm)

Specimen No.	Max. Diameter
HM17–F1	0.23
HM17–F2	0.25
HM17–F3	0.35

Description Test small, discoidal, proloculum followed by long tubular second chamber, increasing gradually in size; test finely agglutinated; aperture formed by the open end of the tubular chamber.

Discussion Takayanagi (1960) figured *Involutina cretacea* (Reuss) with finely agglutinated test wall, but the genus *Involutina* has calcareous tests, so the specimens of Takayanagi should be assigned to *Ammodiscus* under the present species.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; middle Albian of Love County, Oklahoma, U.S.A.; Albian of Alaska; Upper Miyakoan (Albian)–Upper Urakawan (Santonian) of Japan; Aptian–Albian, site 416 in eastern North Atlantic.

Genus *Glomospirella* Plummer, 1945

Type species *Glomospira umbilicata* Cushman & Waters, 1927; Texas U.S.A., Upper Carboniferous.

Glomospirella? sp.

Plate 6, figure 5

Material One fragmentary specimen (EH4–F4) from the Longzhaogou valley, 8 km north of the Qianjin village of Hulin County, Heilongjiang Province, northeastern China.

Measurements (mm)

Specimen No.	Max. Diameter
EH4–F4	0.51

Description Test large, compressed, discoidal, irregularly planispirally coiled, tubular second chamber increase rapidly; wall finely agglutinated.

Discussion The discoidal test suggests that the specimen could be referred to the genus *Glomospirella*.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Lituolacea de Blainville, 1827

Family Haplophragmoididae Maync, 1952

Genus *Cribrostomoides* Cushman, 1910

Type species *Lituola subglobosum* Sars, 1871

Cribrostomoides? *nonioninoides* (Reuss, 1863)

Plate 6, figures 6–11

1863 *Haplophragmium nonioninoides* Reuss, p. 30, pl. 1, figs. 8a, b.

1938 *Haplophragmoides* D8; Hecht, pl. 3a, figs. 52–69; pl. 3b, row 5; pl. 4a, rows 1–3, 5; pl. 4b, row 3, figs. 33–46; pl. 5a, figs. 14–20; pl. 5b, figs. 38–40; pl. 6a, figs. 45–53.

1938 *Haplophragmoides* D9; Hecht, pl. 2a, figs. 46–54; pl. 2b, row.

1959 *Haplophragmoides* cf. *chapmani* Crespin; Groch, p. 117, pl. 12, figs. 17–18.

1960 *Haplophragmoides* cf. *chapmani* Crespin; Groch, p. 127, pl. 5, fig. 9.

1980 *Labrospira nonioninoides* (Reuss, 1863); Haig, p.104, pl. 3, figs. 12–19.

1990 *Haplophragmoides nonioninoides* (Reuss); Weidich, p. 88, pl. 36, figs. 19–20.

1994 *Haplophragmoides nonioninoides* (Reuss, 1863); Meyn & Vespermann, pl. 1, figs. 1–8.

1995 *Cribrostomoides nonioninoides* (Reuss, 1863); Holbourn & Kaminski, p. 448, pl. 5, fig. 1.

Material Six distorted specimens (HM17–F4–9) from Chaoyang village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. Diameter
HM17–F4	0.64
HM17–F5	0.53
HM17–F6	0.50
HM17–F7	0.77
HM17–F8	0.54
HM17–F9	0.61

Description Test free, planispiral, slightly asymmetrical, periphery rounded, chamber size increasing gradually as added, eight chambers in the final whorl; wall finely to coarsely agglutinated; aperture not preserved.

Discussion The species was previously placed in *Haplophragmoides*, but because of the areal slit aperture it was assigned by Haig (1980) to the Holocene genus *Labrospira*. Meyn & Vespermann (1994) reclassified it again as of the genus *Haplophragmoides*, and Holbourn & Kaminski (1995) assigned it to *Cribrostomoides.* Although the Chinese specimens have no aperture preserved, according to the test shape and arrangement of chambers, they could belong to this genus.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; Aptian–early Albian of Northwest Germany; Barremian–Albian of the western Carpathians; Aptian–Albian of Australia; Valanginian–Barremian of DSDP site 263, Indian Ocean.

Genus *Asanospira* Takayanagi, 1960
Type species *Lenticulina*? *teshioensis* Asano, 1950

Asanospira nakagawaensis (Asano, 1950)
Plate 6, figures 12–15

1950 *Lenticulina nakagawaensis* sp. nov. Asano, p. 21, pl. 3, figs. 15a–b.
1960 *Asanospira nakagawaensis* (Asano); Takayanagi, p. 75, pl. 2, figs. 9a, b.

Material: Four complete, well-preserved specimens (HM17–F10–12, HM38–F1) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

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Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of Chambers in final whorl
HM17–F10	0.30	0.22	0.08	7
HM17–F11	0.39	0.27	0.09	7
HM17–F12	0.31	0.24	--	7

Description: Test planispiral, involute, compressed, slightly asymmetrical; periphery subacute; chambers distinct, slightly inflated, seven in the last whorl, increasing gradually in size as added. Borders of each chamber clear, with narrow lobes extending toward umbilicus. The last chamber slightly evolute in some specimens. Sutures depressed, distinct, gently curved backward; wall finely agglutinated, surface smooth; aperture a low slit at base of the apertural face of the last chamber.

Discussion The present specimens are more compressed than the Japanese holotype of *Asanospira nakagawaensis* (Asano, 1950) (Takayanagi, 1960, pl. 2, figs. 9a, b) from the

Middle Yezo Group. The holotype has a maximum diameter of 0.44 mm, a minimum diameter of 0.33 mm and a maximum thickness of 0.17 mm.

The Chinese specimens resemble *Haplophragmoides linki* Nauss, 1947 (Hemleben & Troester, 1984, pl. 2, fig. 22.) in side view, but *H. linki* has a broadly rounded instead of subacute periphery (Nauss, 1947).

A. nakagawaensis resembles *Haplophragmoides gigas minor* Nauss, 1947 (p. 338, pl. 49, figs. 10a–b), (its holotype has a maximum diameter of 0.4 mm, and a maximum thickness of 0.14 mm), from the lower–middle Aptian Mannville Formation in the Western Interior of Canada. The Canadian species possesses the same features, such as the narrow, rounded angled periphery, a curved, depressed suture, and a smooth test surface (Haig, 1980), although it has more chambers (8–11) in the last whorl than the Chinese specimens.

The Chinese specimens are very similar to *Haplophragmoides falcatosuturalis* Neagu, 1990 (p. 250, pl. 4, figs. 16–20) from the lower Cenomanian of the eastern Carpathians of Romania in having a lobate and moderately acute periphery, curved, depressed sutures, and a very finely agglutinated, smooth test wall. However, the Carpathian species has 6-8 chambers in the last whorl and a lenticular shape instead of a compressed test. The holotype has a maximum diameter of 0.46 mm, a minimum diameter of 0.38 mm, and a thickness of 0.25 mm.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; Uppermost Miyakoan (lower Cenomanian)–Lower Urakawan (Coniacian) of Teshio, and Turonian in the Obira area, Uppermost Miyakoan (lower Cenomanian) to the Upper Urakawan (Santonian) of the Otoinep-Saku, Oyubari and Mombetsu areas, in Japan.

Genus *Haplophragmoides* Cushman, 1910
Type species *Nonionina canariensis* d´Orbigny, 1839

Haplophragmoides concavus (Chapman, 1892)
Plate 6, figures 16–18, 21a–b

1892 *Trochammina concava*; Chapman, p. 327, pl. 6, fig. 14a, b.
1940 *Haplophragmoides concava* (Chapman); Tappan, pp. 95–96, pl. 14, figs. 7a–c.
1951 *Haplophragmoides concavus* (Chapman); Bartenstein & Brand, pl. 1, figs. 24–25.
1959 *Haplophragmoides concavus* (Chapman); Geroch, pl. 12, figs. 5a–5c.

1966 *Haplophragmoides concavus* (Chapman, 1892); Bartenstein et al., p. 138, pl. 1, figs. 64–71, 76–78.

1990 *Haplophragmoides concavus* (Chapman); Weidich, p. 87, pl. 7, figs. 2, 11, 19; pl. 36, figs. 5–6.

1995 *Haplophragmoides concavus* (Chapman, 1892); Holbourn & Kaminski, p. 448, pl. 5, fig. 3.

Material: Two specimens (EH4–F5–6) from the Longzhaogou valley, 8 km north of Qianjin village, and two specimens (HM17–F13–14) from Chaoyang village, Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of Chambers in final whorl
EH4–F5	0.59	0.47	--	5
EH4–F6	0.38	0.32	--	5
HM17–F13	0.44	0.29	0.14	5
HM17–F14	0.41	0.31	0.15	5

Description Test free, planispiral, involute, biumbilicate, umbilicus depressed, chambers subtriangular, each chamber with an inflated lobe extending toward umbilicus. Outer parts thin, compressed like a keel; chamber size increases rapidly as added, five chambers in the final whorl; sutures radial, or very slightly curved; peripheral margin subangular; aperture interialmarginal; test wall finely to coarsely agglutinated.

Discussion The strongly compressed specimen (plate 6, figures 16a–b), coarsely agglutinated, is closest to the type of *H. concavus* (Chapman) in having an involute test, and five chambers in the final whorl. The other specimens are finely agglutinated, well preserved with lens-shaped tests. Here I place them together under the species *H. concavus* (Chapman).

The Chinese specimens resemble the specimen of *Haplophragmoides* cf. *walteri* figured by Hemleben & Troester (1984, p. 519, pl. 3, fig. 6) from the Hole 534A in the Atlantic in chamber arrangement and chamber shapes, although the latter has five chambers in the last whorl, and a smaller test diameter of 0.29 mm. It differs from *H. rota* Nauss, 1947 which is usually depressed in the centre parts and with a broadly rounded periphery view.

The species differs from *Asanospira teshioensis* (Asano) by having more inflated chambers, subacute periphery, and fewer chambers in the final whorl.

It resembles *Haplophragmoides menitens* Krasheninnikov, 1974 (p. 636, pl. 2, figs. 3a, b, 4a, b) in the number of chambers in the final whorl, although the latter species has more inflated chambers, and a more rounded periphery.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; Gault (Albian) of England; upper Albian of northern Texas; Valanginian–Albian of the western Carpathians; lower Cretaceous of the northern Calcareous Alps.

Haplophragmoides multiformis Akimets, 1966
Plate 6, figures 19–20, 22a–b; plate 7, figure 11

1966 *Haplophragmoides multiformis* Akimets sp. nov., pp. 336–338, pl. 1, figs. 4a, b, 5–7.
1990 *Haplophragmoides multiformis* Akimets; Weidich, pp. 87–88, pl. 7, figs. 8–10, 12, pl. 36, figs. 7–8, 15–16.

Material Five specimens (HM17–F15, 16, 30–32) from Chaoyang village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of chambers in final whorl
HM17–F15	0.32	0.29	--	4
HM17–F16	0.25	0.23	--	3
HM17–F30	0.39	0.33	0.11	4
HM17–F31	0.43	0.36	0.11	4

Description Test free, planispiral, biumbilicate, involute, strongly compressed; sutures distinct, radiate; chambers triangular, chamber size increasing gradually as added, three to four chambers in the final whorl; periphery lobular; aperture not preserved.

Discussion The Chinese specimens are strongly compressed with much thinner peripheral edges than those of *Haplophragmoides multiformis* Akimets from the northern Calcareous

Alps (Weidich, 1990). However, because of the number of chambers in the final whorl, and their similar arrangement, they are considered conspecific.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; lower cretaceous of Belarus and northern calcareous Alps.

Haplophragmoides neocomiana (Chapman, 1894)
Plate 7, figure 6

1894 *Haplophragmium neocomianum*; Chapman, p. 695, pl. 34, fig. 2.
1946 *Haplophragmoides neocomiana* (Chapman); Ten Dam, p. 571, pl. 87, fig. 5.

Material One complete, strongly compressed specimen (HM17–F18) from Chaoyang village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm).

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of chambers in final whorl
HM17–F18	0.34	0.28	--	9

Description Test free, strongly involute and compressed; suture indistinct; chamber increasing slowly in size as added, nine chambers in the final whorl; wall finely agglutinate; aperture not preserved.

Discussion The species resembles the middle Volgian *Haplophragmoides* aff. *neocomiana* (Løfaldli & Thusu, 1979, pl. 46, fig. 6) in test outline, but the poor preservation of the latter makes further comparison impossible.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; Lower Cretaceous of England; Lower Cretaceous of Netherlands.

Haplophragmoides sp.

Plate 7, figures 7a–c

Material One complete, poorly preserved specimen (HM17–F17) from Chaoyang village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of chambers in final whorl
HM17–F17	0.35	0.27	0.11	10

Description Test free, planispiral, involute, compressed, umbilicate; chambers triangular, chamber size increasing gradually as added, approximately ten chambers in the final whorl; sutures radial, or very slightly curved; aperture not preserved; test wall coarsely agglutinated.

Discussion The specimen differs from *Haplophragmoides walteri* (Grzybowski) (Yasuda, 1986) by having a rounded instead of a subacute periphery.

It is very similar to the middle Bathonian–Callovian *Haplophragmoides infracalloviensis* Dain, 1948 (Morris et al., 1989, p. 230, pl. 6.3.10, figs. 10–11), but the latter has wider umbilicus.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Family Lituolidae de Blainville, 1825

Subfamily Ammomarginulininae Podobina, 1978

Genus *Ammomarginulina* Wiesner, 1931

Type species: *Ammomarginulina ensis* Wiesner, 1931

Ammomarginulina? sp.

Plate 7, figures 1–2

Material Two poorly preserved specimens (EH4–F7, EH4–F8) from the Longzhaogou valley, 8 km north of Qianjin village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. length
EH4–F7	0.58
EH4–F8	0.52

Description Test elongate, compressed; early portion enrolled and planispiral, later portion discoiling and rectilinear with indistinct sutures; wall coarsely agglutinated, aperture not preserved.

Discussion The number of chambers in the coiling portion is not clear, which makes species identification difficult.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Genus *Recurvoides* Earland, 1934
Type species: *Recurvoides contorturs* Earland, 1934

Recurvoides sp.
Plate 7, figures 9a–c

Material One specimen (HM17–F20) from Chaoyang village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of Chambers in final whorl
HM17–F20	0.35	0.26	0.12	5

Description Test free, compressed, streptospiral; peripheral contour elongate, peripheral margin subangular and slightly lobular; ventral side involute; umbilicus lacking; spiral side eccentric, earlier chambers not visible; aperture not preserved.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Spiroplectamminacea Cushman, 1927
Family Spiropletamminidae Cushman, 1927
Genus *Spiroplectammina* Cushman, 1927
Type species: *Textularia agglutinans* d´Orbigny var. *biformis* Parker & Jones, 1865

Spiroplectammina sp.
Plate 7, figures 3–5

Material Three poorly preserved specimens (EH4–F9–11) from the Longzhaogou valley, 8 km north of Qianjin village, Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. length
EH4–F9	0.48
EH4–F10	0.19
EH4–F11	0.29

Description Test elongate, oval in section, enlarging gradually with growth, early stage planispiral coils, later biserial; biserial portion has four pairs of chambers; sutures straight and oblique in the biserial portion; the early planispiral coil narrower than the succeeding biserial portion; wall agglutinated; aperture is not visible.

Discussion The Chinese specimens have poorly preserved early coils; the number of the last coil is unclear. Although the early planispiral coil is narrower than the succeeding biserial portion, the walls are not finely agglutinated, and the sutures are not distinct on the test surface. These features indicate that the specimens cannot be assigned to *Quasispiroplectammina* Loeblich & Tappan.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

Superfamily Trochamminacea Schwager, 1877

Family Trochamminidae Schwager, 1877

Subfamily Trochammininae Schwager, 1877

Genus *Trochammina* Parker & Jones, 1859

Type species *Nautilus inflatus* Montagu, 1808

Trochammina depressa Lozo, 1944

Plate 7, figures 12a–c

1944 *Trochammina depressa* sp. nov.; Lozo, p. 552, pl. 2, figs. 4a, b, 5.

1949 *Trochammina depressa* Lozo, 1944; Loeblich & Tappan, p. 256, pl. 49, figs. 1a–2.

1981 *Trochammina depressa* Lozo, 1944; McNeil & Caldwell, p. 168, pl. 13, figs. 8a–c.

1990 *Trochammina depressa* Lozo, 1944; Weidich, p. 99, pl. 9, fig. 4.

1995 *Trochammina depressa* Lozo, 1944; Holbourn & Kaminski, p. 450, pl. 5, fig. 5.

Material One poorly preserved specimen (HM17–F24) from the Chaoyang village of Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of Chamber in final whorl
HM17–F24	0.37	0.29	0.10	5

Description Test free, small, trochospiral; ventral side with five, involute, triangular, gradually increasing chambers, suture radial; spiral side poorly preserved, inner whorls difficult to discern; wall finely agglutinated; aperture not preserved.

Discussion The specimen figured here closely resembles *Trochammina depressa* Lozo from the upper Albian Kiamichi Formation of northern Texas, although it is not as compressed as the holotype (0.02 mm thick).

Crespin (1963, pp. 61–62, pl. 17, figs. 11–21) and Haig (1980, p. 117, pl. 6, figs. 5–7) referred specimens from Queensland to this species, but their figured specimens have more chambers in the final whorl than the holotype of *T. depressa*. Therefore, they should not be assigned to this species.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; lower Cretaceous of North Texas; lower Cretaceous of the northern Calcareous Alps; Aptian–Albian of DSDP Site 263 in Indian Ocean.

Trochammina umiatensis Tappan, 1957
Plate 7, figures 13–14

1957 *Trochammina umiatensis* sp. nov.; Tappan, p. 214, pl. 67, figs. 27–29.
1962 *Trochammina umiatensis* Tappan, p. 156, pl. 38, figs. 5–8.
1980 *Trochammina umiatensis* Tappan; Sliter, pl. 4, figs. 1–2, 6–7.

Material Two specimens (HM17–F23, 25) from the Chaoyang village of Hulin County, Heilongjiang Province, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of Chambers in final whorl
HM17–F23	0.47	0.41	--	5
HM17–F25	0.53	0.46	--	6

Description Test free, trocoid, spiral low, periphery lobular and rounded; chambers inflated, increasing slowly in size, few in number, three to five in the final whorl; sutures distinct, depressed, radial; wall finely to coarsely agglutinated; aperture not preserved.

Discussion The present specimens resemble those of Sliter (1980) in the number and arrangement of the chambers. However, in the Chinese specimen the early chambers on the spiral side are not clearly distinguishable, as a result of poor preservation.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China; Albian of Alaska; Aptian–Albian of DSDP Site 416, eastern North Atlantic.

Trochammina sp.

Plate 7, figures 8, 10

Material: Two specimens (HM17–F21, 22) from Chaoyang village in Hulin County, Heilongjiang, northeastern China.

Measurements (mm)

Specimen No.	Max. diameter	Min. diameter	Max. thickness	No. of Chamber in final whorl
HM17–F21	0.37	0.32	0.19	--
HM17–F22	0.44	0.38	0.20	--

Description: Test free, trochospiral; spiral side concave with a low umbilicus; ventral side convex with a close umbilicus; sutures slightly depressed, indistinct; the number of chambers in the final whorl is not clear, periphery rounded; test wall medium- to fine-grained, occasionally with coarser grains as large as 0.1 mm (plate 7, figure 10a); aperture not preserved.

Discussion: The specimens resemble *Trochomina quinqueloba* Geroch (1959, pl. 12, figs 1–3) from the Polish Carpathian Flysch (Valanginian–Aptian), but the indistinct sutures make the tracing the chambers of the early and final whorls difficult; further comparison is not possible.

Stratigraphical and geographical occurrence Barremian–Aptian of Heilongjiang, northeastern China.

8. Conclusions

1. The ammonite fauna, consisting of *Pseudohaploceras* cf. *nipponicum* Shimizu, 1931, *Eogaudryceras* (*Eogaudryceras*) *yunshanense* (Liang, 1982), indicates a late Early Cretaceous geological age (Barremian–Aptian).
2. The bivalve fauna consists chiefly of long-ranging genera and endemic species. The occurrence of *Thracia rotundata* (J. de C. Sowerby, 1836) suggests an Aptian age.
3. The radiolarian fauna consists of ten genera and 17 species. The occurrence of *Novixitus* sp., *Xitus* cf. *spicularius* (Aliev, 1965), *Stichomitra* cf. *tosaensis* Nakaseko & Nishimura, 1981, *Archaeodictyomitra* cf. *vulgaris* Pessagno, 1977 suggests an Early Cretaceous age.
4. The agglutinated foraminifer fauna consists of ten genera and 16 species, suggesting an Early Cretaceous age (Hauterivian–Albian).
5. Based on the biostratigraphical evidence from the ammonites fauna, the bivalves fauna and microfossils, the Qihulin Formation is assigned a Barremian–Aptian age.

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11. Explanation of Plates

Plate 1

All figures are ×1 except for special explanation.

Pseudohaploceras cf. *nipponicum* Shimizu, 1931

Figure 1, EH4–27, external mould; Figure 2, 019, internal mould; Figure 3, EH4–28, internal mould; Figure 4, EH4–31, internal mould; Figure 6, EH4–8, internal mould; Figure 7, EH4–26, internal mould of the aperture; all from the Qihulin Formation of the Longzhaogou Group; Longzhaogou valley, 8 km north of Qianjin village, Hulin County.

Figure 5, TT10–1, internal mould, from the Qihulin Formation of the Longzhaogou Group; Test trench No. 10, north of Dongsheng village, Hulin County.

Figure 8, HM17–3, internal mould, from the Qihulin Formation of the Longzhaogou Group; Chaoyang village, Hulin County.

Pseudohaploceras sp. 1

Figure 9, EH4–3, internal mould, from the Qihulin Formation of the Longzhaogou Group; Longzhaogou valley, 8 km north of Qianjin village, Hulin County.

Figure 10, HM17–6: a, internal mould, b, counterpart; Figure 11, EH4–13, internal mould; Figure 12, EH4–12: a, internal mould, b, counterpart; all from the Qihulin Formation of the Longzhaogou Group; Chaoyang village, Hulin County.

Plate 1

Plate 2

All figures are ×1 except for special explanation.

Pseudohaploceras sp. 1

Figure 1, EH3–1, internal mould, from the Qihulin Formation of the Longzhaogou Group; Dongsheng village, Mishan County.

Figure 2, EH4–10, internal mould; Figure 3, EH4–14, internal mould showing the suture lines, ×2.5; both from the Qihulin Formation of the Longzhaogou Group; Longzhaogou valley, 8 km north of Qianjin village, Hulin County.

Figure 4, enlargement (×2.5) of the suture line of specimen EH4–12 (plate 1, Figure 12b).

Psuedohaploceras sp. 2

Figure 5, EH4–1, internal mould; Figure 6, EH4–9: a, internal mould, b, counterpart; Figure 7, EH4–2, internal mould; Figure 8, EH4–4, internal mould; Figure 9, EH4–5, internal mould; all from the Qihulin Formation of the Longzhaogou Group; Longzhaogou valley, 8 km north of Qianjin village, Hulin County.

Figure 10, HM38–8: a, external mould, b, counterpart; Figure 11, HM38–1, external mould, both from the Qihulin Formation of the Longzhaogou Group; Chaoyang village, Hulin County.

Eogaudryceras (*Eogaudryceras*) *yunshanense* (Liang, 1982)

Figure 12, HM38–3, external mould; Figure 13, HM2–1: a, internal mould, b, counterpart; Figure 14, HM39–1, external mould; all from the Qihulin Formation of the Longzhaogou Group; Chaoyang village, Hulin County.

Plate 2

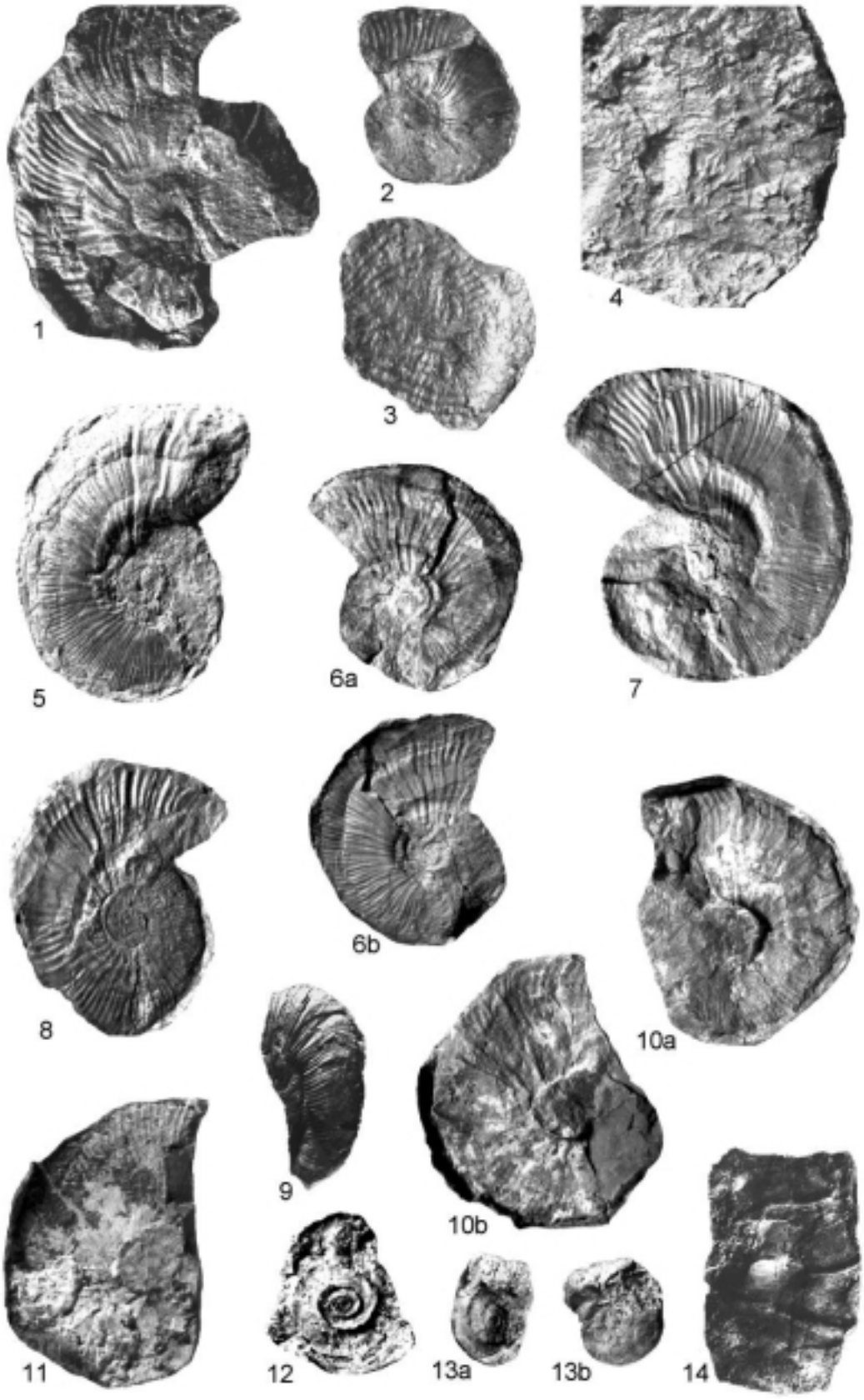

Plate 3

Scale bars are 5 mm long.

Palaeonucula peideensis Yu & Li, 1982
Figure 1, HM17–B11, left valve, internal mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian

Palaeonucula cf. *makitoensis* (Hayami, 1959)
Figure 2, HM17–B12, right valve, internal mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Palaeonucula yunshanensis Yu & Li, 1982
Figure 3, EH3–B2, left valve, internal mould, from the Qihulin Formation in northern Peide, Mishan County.
Figure 4, EH4–B6, right valve, internal mould, from the Qihulin Formation in Longzhaogou valley, Qianjin village, Hulin County, Barremian–Aptian.

Palaeonucula mishanensis Yu & Li, 1982
Figure 5, EH3–B1, right valve, internal mould, from the Qihulin Formation in northern Peide, Mishan County, Barremian–Aptian.

Mesosaccella longzhaogouensis Li & Yu, 1982
Figure 6, EH4–B7, right valve, internal mould, from the Qihulin Formation in Longzhaogou valley, Qianjin village, Hulin County, Barremian–Aptian.

Mesosaccella longa Yu & Li, 1982
Figure 7, EH4–B8, right valve, internal mould, from the Qihulin Formation in Longzhaogou valley, Qianjin village, Hulin County, Barremian–Aptian.
Figure 8, HM17–B6, left valve, internal mould; Figure 9, HM17–B13, left valve, internal mould; Figure 10, HM17–B7, left valve, internal mould, all from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Palaeoneilo peideensis Li & Yu, 1982
Figure 11, HM17–B10, left valve, internal mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Palaeoneilo yunshanensis Li & Yu, 1982
Figure 12, HM17–B8, left valve, internal mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.
Figure 13, EH4–B3, left and right valves, internal moulds, from the Qihulin Formation in Longzhaogou valley, Qianjin village, Hulin County, Barremian–Aptian.

Entolium? *extensum* Yu & Li, 1982
Figure 15, EH4–B4, left valve, external mould, from the Qihulin Formation in Longzhaogou valley, Qianjin village, Hulin County, Barremian–Aptian.

Camptonectes (*C.*) *wandaensis* Li & Yu, 1982
Figures 14 and 18, HM17–B4, left valve, external mould and its enlargement, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Figures 16 and 17, EH4–B5, right valve, external mould and its enlargement; Figure 19, EH4–B2, right valve, internal mould, both from the Qihulin Formation in the Longzhaogou valley, Qianjin village, Hulin County, Barremian–Aptian.

Camptonectes (*C.*) cf. *clathratus* Li & Yu, 1982
Figure 20, HM2–B1, left valve, internal mould; Figure 21, HM17–B9, left valve, internal mould, both from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Astarte? *quadrata* Yu & Li, 1982
Figure 22, HM17–B3, left external mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Astarte sp.
Figure 23, HM17–B1, right valve, external mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Goniomya peideensis Yu & Li, 1982
Figure 24, HM38–B1, left valve, internal mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Thracia rotundata (J. de C. Sowerby, 1836)
Figure 25, HM17–B2, left valve, external mould, from the Qihulin Formation in Chaoyang village, Hulin County, Barremian–Aptian.

Thracia sp.
Figure 26, EH4–B1, left valve, internal mould, from the Qihulin Formation in the Longzhaogou valley in Qianjin village, Hulin County, Barremian–Aptian.

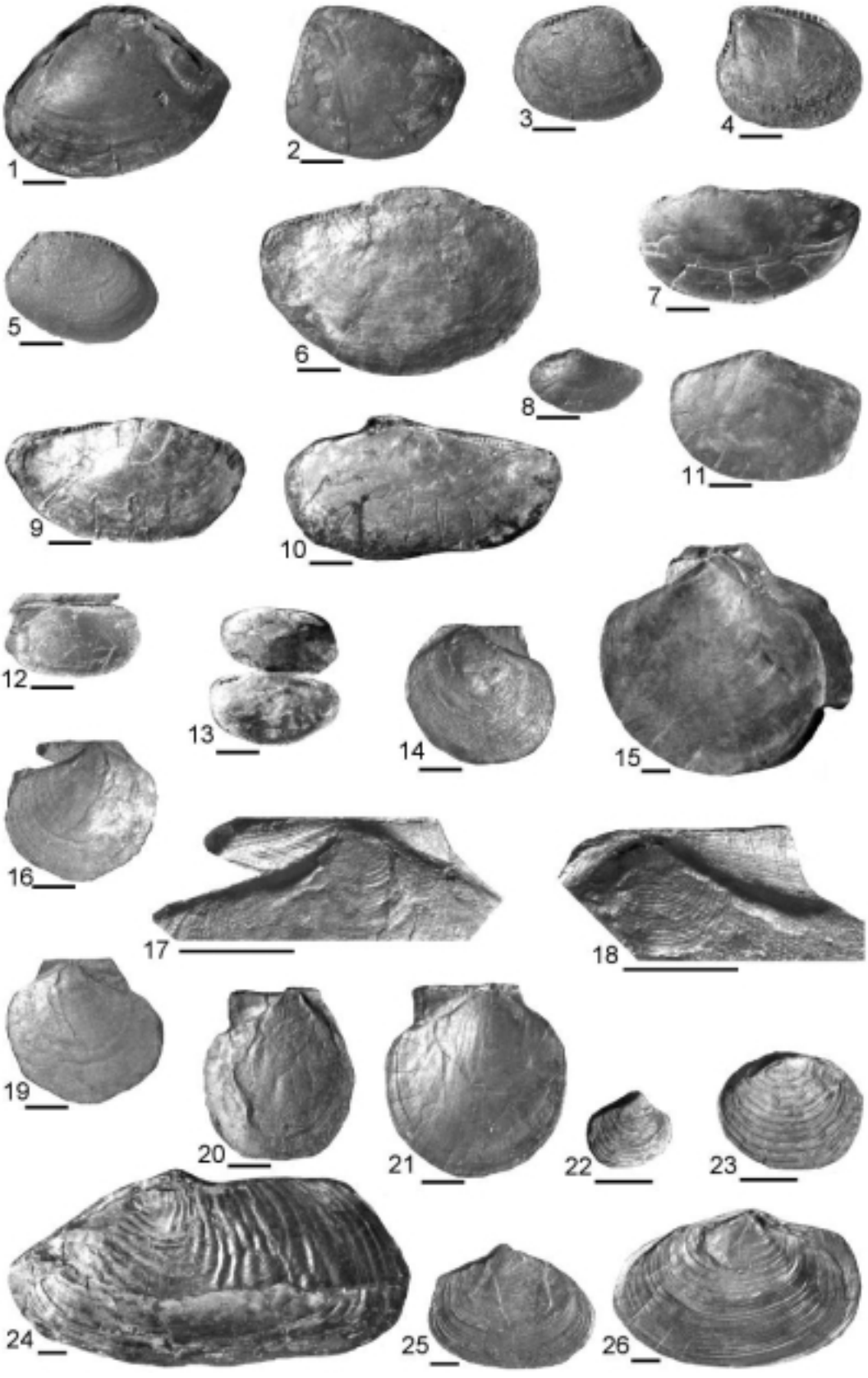
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Plate 4

Scale bars are 100 μm long except where otherwise indicated. All specimens are from the Qihulin Formation of the Longzhaogou Group exposed in the Longzhaogou valley, in Qianjin village, Hulin County, Heilongjiang, northeastern China.

Orbiculiforma sp.
Figure 1, EH4–R1.

Figure 2, EH4–R2.

Archaeospongoprunum? sp.
Figure 3, EH4–R3: a, shows the enlarged part of the central chamber.

Praeconocaryomma? sp.
Figure 4, EH4–R4.
Figure 5, EH4–R5.

Gen. et sp. indet.
Figure 6, EH4–R6.

Gen. et sp. indet..
Figure 7, EH4–R7, scale bar is 10 μm long.
Figure 8, EH4–R8.

Stichomitra cf. *tosaensis* Nakaseko & Nishimura, 1981
Figure 9, EH4–R9.
Figure 10, EH4–R10.
Figure 11, EH4–R11.

Stichomitra sp. 1
Figure 12, EH4–R13.
Figure 13, EH4–R12.
Figure 14, EH4–R14.
Archaeodictyomitra vulgaris Pessagno
Figure 15, EH4–R15.

Stichomitra sp. 4
Figure 16, EH4–R16.

Plate 4

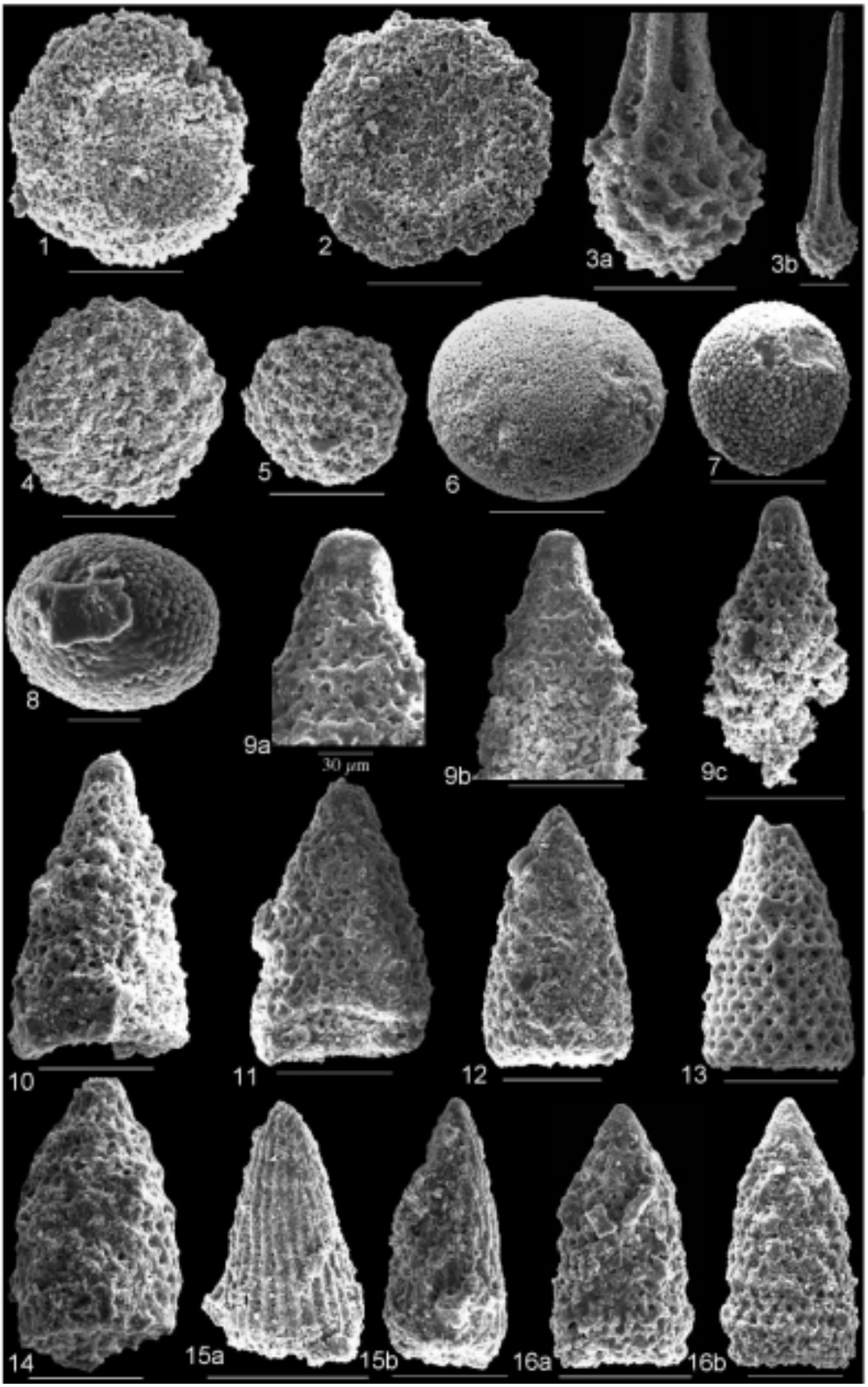


Plate 5

Scale bars are 100 μm long except where otherwise indicated. All specimens are from the Qihulin Formation of the Longzhaogou Group exposed in the Longzhaogou valley, in Qianjin village, Hulin County, Heilongjiang, northeastern China.

Stichomitra? sp. 3
Figure 1, EH4–R17.
Figure 2, EH4–R18.

Novixitus? sp.
Figure 3, EH4–R19.

Xitus cf. *spicularius* (Aliev)
Figure 4, EH4–R20.

Xitus? sp.
Figure 5, EH4–R21.
Figure 6, EH4–R22.

Stichomitra sp. 2
Figure 7, the same specimen and its enlargement, EH4–R23.

Stichomitra? sp. 5
Figure 8, EH4–R25.
Figure 9, EH4–R24.

Stichomitra sp. 6
Figure 10, EH4–R6.

Stichomitra sp. 7
Figure 11, EH4–R27.
Figure 12, EH4–R28.

Nassellaria Gen. et sp. Indet.
Figure 13, EH4–R29.
Figure 14, EH4–R30.

Plate 5

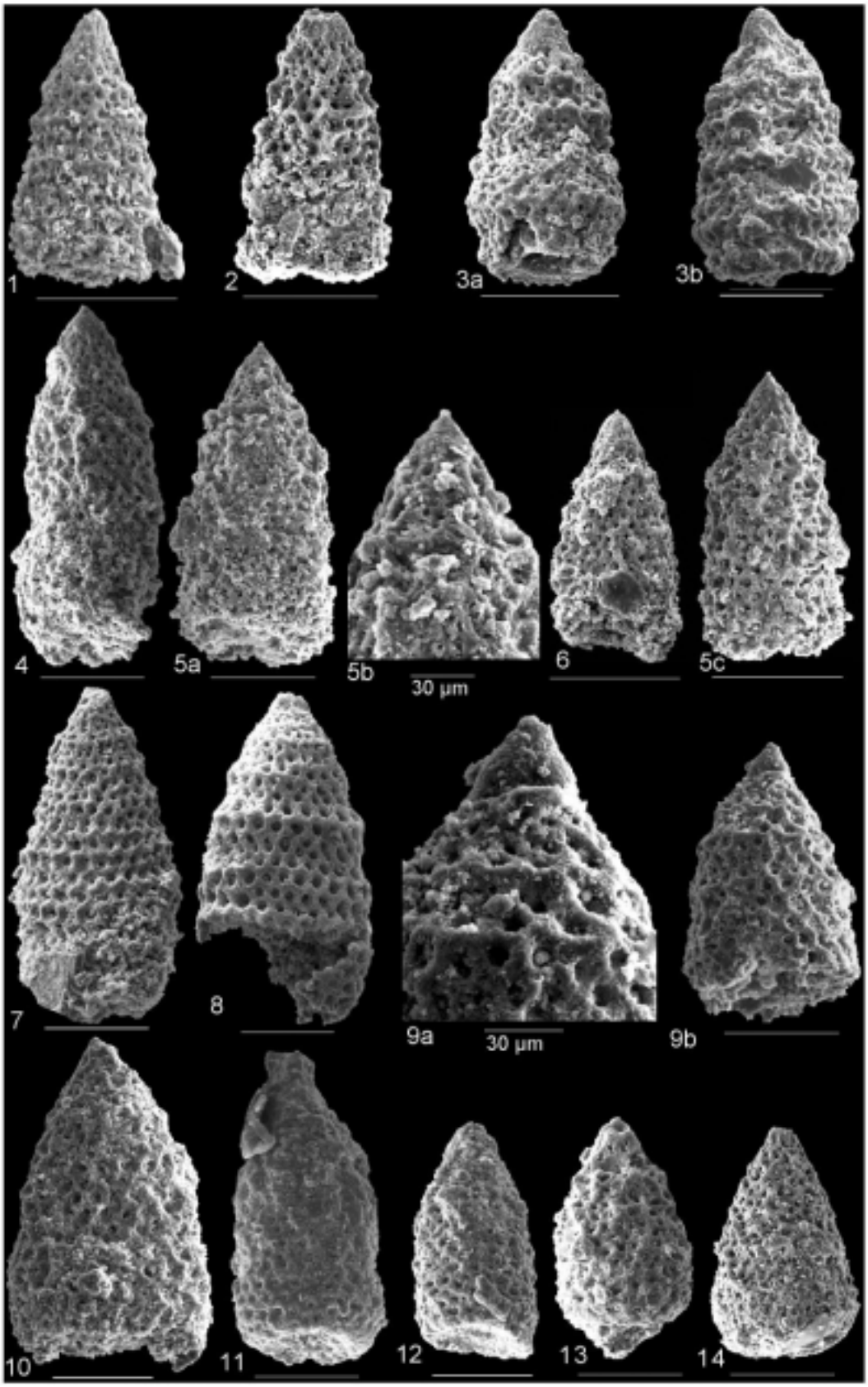


Plate 6

Scale bars are 100 μm long.

Ammodiscus rotalarius Loeblich & Tappan, 1949
Figure 1, HM17–F1: a side view, SEM; b, side view, transmitted-light microscope.
Figure 2, HM17–F2: a, side view, SEM; b, side view, transmitted-light microscope.
Figure 3, HM17–F3, aperture view. All from the Qihulin Formation of the Longzhaogou Group, north of Chaoyang village, Hulin County, Barremian–Aptian.

Bathysiphon sp.
Figure 4, EH4–F1, side view. Qihulin Formation of the Longzhaogou Group of the Longzhaogou valley of Qianjin village, Hulin County, Barremian–Aptian.

Glomospirella? sp.
Figure 5, EH4–F4, side view. Qihulin Formation of the Longzhaogou Group of the Longzhaogou valley of Qianjin village, Hulin County, Barremian–Aptian.

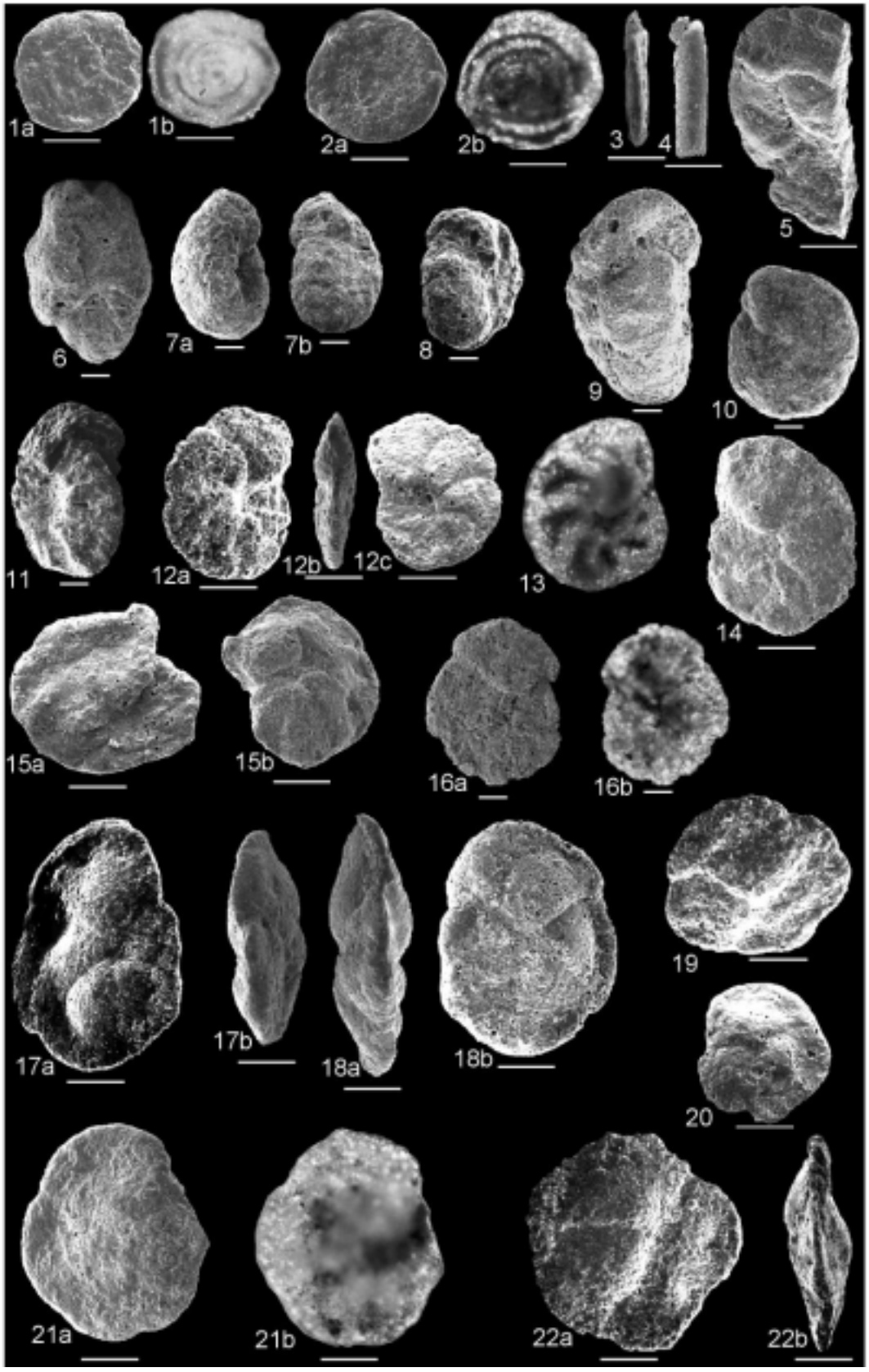
Cribrostomoides? *nonioninoides* (Reuss, 1863)
Figure 6, HM17–F4, side view.
Figure 7, HM17–F5: a, side view; b, aperture view.
Figure 8, HM17–F6, aperture view.
Figure 9, HM17–F7, aperture view.
Figure 10, HM17–F8, side view.
Figure 11, HM17–F9, aperture view. All form Qihulin Formation of Longzhaogou Group, north of Chaoyang village, Hulin County, Barremian–Aptian.

Asanospira nakagawaensis (Asano, 1950)
Figure 12, HM17–F10, SEM: a, c, side views; b, aperture view.
Figure 13, HM38–F1, transmitted-light microscope, side view.
Figure 14, HM17–F11, SEM, side view.
Figure 15, HM17–F12, SEM: a–b, side views. All form Qihulin Formation of Longzhaogou Group, north of Chaoyang village, Hulin County, Barremian–Aptian.

Haplophragmoides concavus (Chapman, 1892)
Figure 16, EH4–F5: a, SEM, side view; b, transmitted-light microscope, side view.
Figure 17, EH4–F6, SEM: a, side view; b, aperture view. Both from Qihulin Formation of Longzhaogou Group of the Longzhaogou valley of Qianjin village, Hulin County, Barremian–Aptian.
Figure 18, HM17–F13, SEM: a, aperture view; b, side view.
Figure 21, HM17–F14: a, SEM, side view; b, transmitted-light microscope, side view. Both from Qihulin Formation of Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Haplophragmoides multiformis Akimets, 1966
Figure 19, HM17–F15, SEM, side view.
Figure 20, HM17–F16, SEM, side view.
Figure 22, HM17–F30: a, side view; b, aperture view. All from Qihulin Formation of Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Plate 6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21b
22a
22b

Plate 7

Scale bars are 100 μm long.

Ammomarginulina? sp.
Figure 1, EH4–F7: a, SEM, side view; b, transmitted-light microscope.
Figure 2, EH4–F8, SEM, side view. Both from the Qihulin Formation of the Longzhaogou Group of the Longzhaogou valley of Qianjin village, Hulin County, Barremian–Aptian.

Spiroplectammina sp.
Figure 3, EH4–F9: a, SEM, side view; b, transmitted-light microscope, side view.
Figure 4, EH4–F10, SEM, side view.
Figure 5, EH4–F11: a, SEM, side view; b, transmitted-light microscope, side view. All from the Qihulin Formation of the Longzhaogou Group of the Longzhaogou valley of Qianjin village, Hulin County, Barremian–Aptian.

Haplophragmoides neocomiana (Chapman)
Figure 6, HM17–F18, SEM, side view. The Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Haplophragmoides sp.
Figure 7, HM17–F17: a, SEM, side view; b, SEM, aperture view; c, transmitted-light microscope. The Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Trochammina sp.
Figure 8, HM17–F21: a, SEM, spiral view; b, SEM, aperture view; c, SEM, ventral view.
Figure 10, HM17–F22; a, SEM, ventral view; b, aperture view. Both from the Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

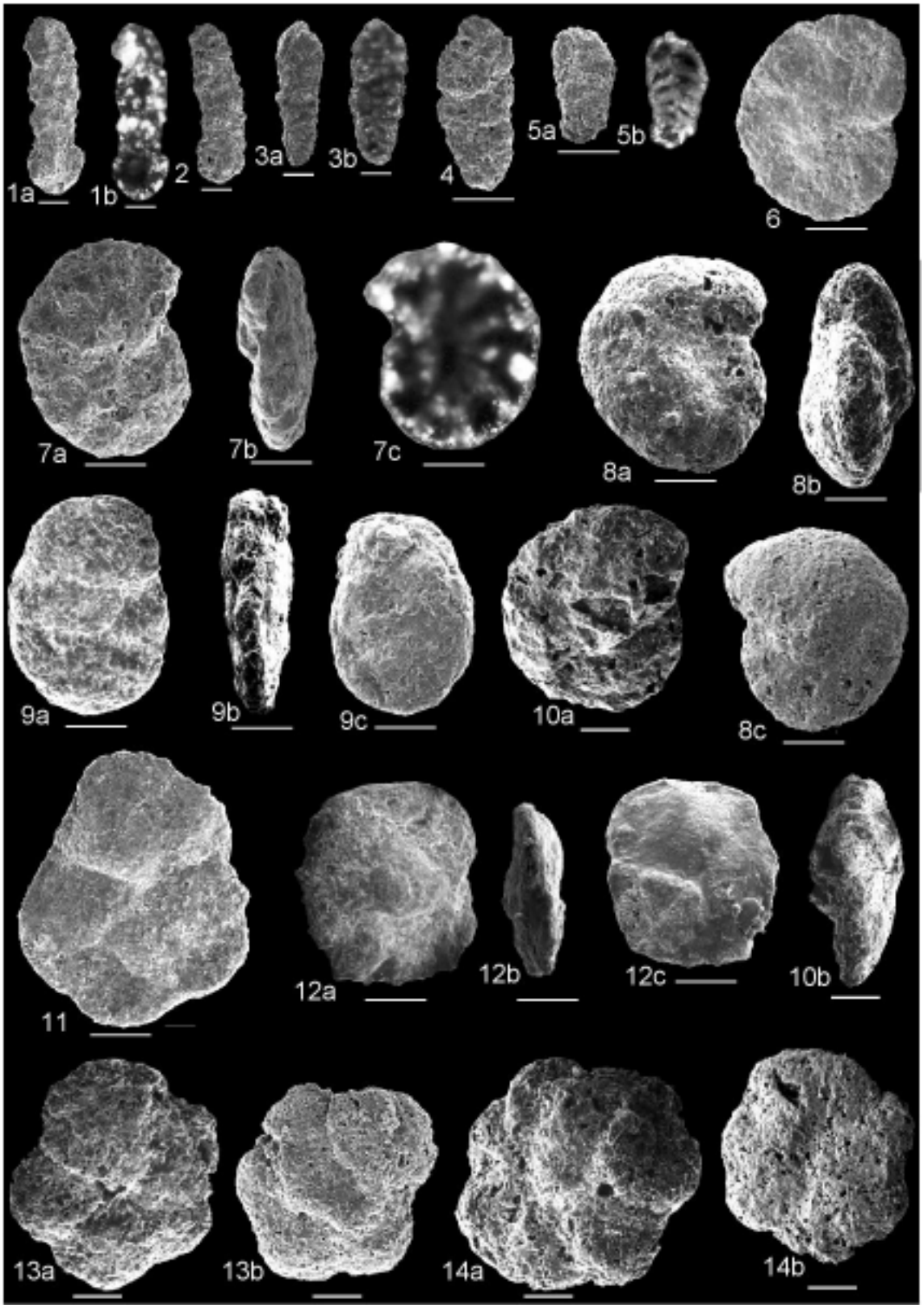
Recurvoides sp.
Figure 9, HM17–F20: a, c, SEM, side views; b, SEM, aperture view. The Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Haplophragmoides multiformis Akimets, 1966
Figure 11, HM17–F31, SEM, side view. The Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Trochammina depressa Lozo, 1944
Figure 12, HM17–F24: a, SEM, spiral view; b, SEM, aperture view; c, ventral view. The Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Trochammina umiatensis Tappan, 1957
Figure 13, HM17–F23: a, SEM, ventral view, b, spiral view.
Figure 14, HM17–F25: a, SEM, spiral view; b, SEM, ventral view. Both from the Qihulin Formation of the Longzhaogou Group of Chaoyang village, Hulin County, Barremian–Aptian.

Plate 7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10a
8c
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12b
12c
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13b
14a
14b

12. Appendix

The fossils in the following descriptions of sections are based on own data.

12.1. Dongsheng section

The description of the Qihulin Formation is as follows (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986):

9. Greyish medium-grained sandstone intercalated with thin-bedded mudstone. 62.9 m
8. Black mudstones yielding ammonites *Pseudohaploceras* sp. 2 (EH3–1), bivalves *Palaeonucula mishanensis* Yu & Li, *P. yunshanensis* Yu & Li. 32.4 m
7. Pale grey medium-grained sandstone. 92.4 m
6. Black mudstone intercalated with thin-bedded siltstones and fine-grained sandstone. 129.3 m
5. Pale grey medium- and fine-grained sandstone intercalated with greyish brown thin-bedded siltstone. 70.7 m
4. Pale grey siltstone and fine-grained sandstone interbedded with medium- and coarse-grained sandstone. 26.7 m
3. Pale grey, light grey medium- and coarse-grained sandstone intercalated with fine-grained sandstone. 25.7 m
2. Grey and dark grey siltstones and fine-grained sandstone interbedded with medium-grained sandstone. 68.3 m
1. Greyish green siltstones interbedded with grey fine-grained sandstone and thin coal seams. 29.3 m

——————conformity——————

Peide Formation

12.2. Longzhaogou section

The Research team on Mesozoic coal-bearing formations in eastern Heilongjiang (1986) measured the section in Longzhaogou. The description is as follows:

8. Interbeddings of dark grey siltstones and mudstones and dark fine-grained sandstone, with medium-grained sandstone. 28.3 m
7. Dark grey and black mudstones with two beds of tuff, yielding ammonites *Pseudohaploceras* cf. *nipponicum* Shimizu, *Pseudohaploceras* sp. 1, *Pseudohaploceras* sp. 2; bivalves *Palaeonucula peideensis* Yu & Li, *Palaeonucula* cf. *makitoensis* (Hayami,

1959), *Palaeonucula yunshanensis* Yu & Li, *Mesosacella longzhaogouensis* Li & Yu, *Mesosacella longa* Yu & Li, *Palaeoneilo peideensis* Li & Yu, *Palaeoneilo yunshanensis* Li & Yu, *Entolium extensum* Yu & Li, *Camptonectes* (*Camptonectes*) *wandensis* Gu, *Camptonectes* (*Camptonectes*) cf. *clathratus* Li & Yu, *Astarte quadrata*, *Thracia* sp. 32.8 m

6. Interbeddings of mudstones and siltstones. 65 m
5. Dark grey siltstones and pale grey fine-grained sandstone with black mudstones, yielding plant fossils. 50.9 m
4. Yellowish grey and dark grey siltstones and fine-grained sandstone intercalated with dark yellow medium-grained sandstone, gritstones, coal seams and carbonaceous mudstones, yielding plant fossils. 57 m
3. Dark yellow and yellow gritstones, gravel-bearing sandstone and dark yellow and grey fine-grained sandstone with siltstones. 61.2 m
2. Interbeddings of dark grey medium-grained sandstone and grey fine-grained sandstones, intercalated with coal seams and carbonaceous mudstones, yielding plant fossils. 59. 8 m
1. Interbeddings of dark grey siltstones, pale grey medium-grained sandstone and dark grey fine-grained sandstone, yielding plant fossils. 73.8 m

----------conformity / disconformity?----------

Peide Fm

12.3. Chaoyang section

The description of the Qihulin Formation is as follows (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986):

Lower Yunshan Formation

----------fault----------

Qihulin Formation

11. Dark grey and black thick-bedded mudstones with yellow-green tuffaceous siltstones and fine-grained sandstone, yielding marine bivalves *Palaeonucula peideensis* Yu & Li, *Palaeonucula* cf. *makitoensis* (Hayami), *Mesosacella longa* Li & Yu, *Palaeoneilo yunshanensis* Li & Yu, *Camptonectes* (*Camptonectes*) *wandensis* Gu, *Camptonectes* (*Camptonectes*) cf. *clathratus* Li & Yu, *Astarte quadrata* Yu & Li, *Astarte* sp., *Goniomya peideensis* Yu & Li, *Thracia rotundata* (J. de C. Sowerby) and ammonites (bed HM2) *Eogaudryceras* (*Eogaudryceras*) *yunshanense* (Liang), (beds HM17, HM38, HM39)

Pseudohaploceras cf. *nipponicum* Shimizu, *Pseudohaploceras* sp. 1, *Pseudohaploceras* sp. 2, *Eogaudryceras* (*Eogaudryceras*) *yunshanense* (Liang). 245.1 m

10. Yellow-green to grey-green siltstones, fine-grained sandstone and dark grey and black mudstones with grey-green thin-bedded crystallinoclastic and glass-clastic ignimbrites. 149.7 m
9. Dark green and dark grey siltstones and fine-grained sandstone. 25.6 m
8. Interbeddings of dark yellow and yellow-green medium-fine grained sandstone and dark grey siltstones and mudstones, with thin coal beds. 33.2 m
7. Pale grey and dark yellow gritstones and medium-grained sandstone intercalated with black mudstones, carbonaceous mudstones and coal. 30.9 m
6. Interdeddings of dark yellow fine-grained sandstone and black siltstones and mudstones with coal beds. 22.1 m
5. Yellow-green medium- to fine-grained sandstone with dark green siltstones, fine-grained sandstone and dark grey carbonaceous mudstones. 57.5 m
4. Yellow-green and dark green medium- and fine-grained sandstone with dark yellow siltstones, dark grey mudstones, carbonaceous mudstones and coal beds, yielding plant fossils. 58.9 m
3. Dark yellow medium-coarse grained sandstone with fine-grained sandstone. 9.7 m
2. Interbeddings of dark grey mudstones and dark yellow, yellow-green siltstones and fine-grained sandstone with carbonaceous mudstones and coal beds. 33.1 m
1. Dark yellow and dark green gravel-bearing gritstones with thin-bedded medium- and fine-grained sandstone. 15.9 m

----------conformity/ disconformity----------

Peide formation

12.4. Farm Yunshan sections

12.4.1. Test trench No. 1 section

The description of the Qihulin Formation of the test trench No. 1 is as following (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986):

Lower Yunshan Formation

----------conformity----------

Qihulin Formation

7. Greyish black mudstones intercalated with grey thin-bedded siltstones. 79.7m

6. Greyish green fine-grained sandstone intercalated with greyish green medium-grained sandstone and coal seams. 174.3 m
5. Greyish green fine-grained sandstone intercalated with greyish green middle-grained sandstone. 135.2 m
4. Grey siltstones intercalated with fine-grained sandstone and thin coal seams. 220.8 m
3. Greyish green fine-grained sandstone intercalated with grey siltstones and coal seams. 121.1 m
2. Greyish green fine-grained sandstone intercalated with grey siltstones. 186.9 m
1. Greyish green coarse-grained sandstone intercalated with greyish green middle-grained sandstone. 41.5 m

----------conformity ----------

Peide formation

12.4.2. Test trench No. 2 section

The description of the Qihulin Formation of Test trench No. 2 is as following (Research team on the Mesozoic coal-bearing formations in eastern Heilongjiang, 1986) (figure 5.2):

Lower Yunshan Formation

----------conformity----------

Qihulin Formation

5. Greyish black siltstones intercalated with greyish yellow fine-grained sandstone. 101.5 m
4. Greyish black mudstones intercalated with siltstones. 50.7 m
3. Grey tuffaceous fine-grained sandstone. 12.2 m
2. Dark gray siltstones, black mudstones. 41.5 m
1. Grey siltstones, greyish green fine-grained sandstone intercalated with greyish black mudstones and coal seams. 60 m

----------fault----------

Peide Formation

Résumé

Li, Gang was born on March 9 of 1967 in Qiqihar, Heilongjiang, China, and Chinese citizen.

August 1974- July 1979 visited Primary School No. 2 of Heavy Machine Company No. 1 of China in Qiqihar.

August 1979-July 1985 visited Middle School No. 5 of Heavy Machine Company No. 1 of China in Qiqihar.

September 1985-July 1990 studied palaeontology and biostratigraphy in the geological department of Peking University in Beijing for the BSc degree.

September 1990-July 1993 studied Early Cretaceous conchostracans from South Shaanxi and West Henan for the MSc degree in the Nanjing Institute of Geology and Palaeontology, Academia Sinica.

July 1993-October 1995 worked as scientific assistant in the Nanjing Institute of Geology and Palaeontology, Academia Sinica.

February 1996-present, doctoral student in Geologisch-Paläontologisches Institute of Heidelberg University, supervised by Prof. Dr. Peter Bengtson. (DAAD scholarship for five years)