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Clastic facies microfossils from the Chuanlinggou Formation (1800 Ma) near Jixian, North China

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ABSTRACT — Abundant organic-walled microfossils are well preserved in petrographic thin sections of shales from the *c.* 1800 Ma old Chuanlinggou Formation (Changchengian System) near Jixian, North China. The microfossils are compressed parallel to lamination and consist of sphaeromorph acritarchs and filamentous forms. The sphaeromorphs, ranging from 20-200μm in diameter, are more abundant in shales of the base of the Chuanlinggou Formation and assignable to *Kildinosphaera, Leiosphaeridia*, and *Chuaria*. They could represent either prokaryotic or eukaryotic organisms. The filaments, 0.5-24μm wide, are apparently unbranched, non-septate, and originally tubular structures. They occur in shales of the upper part of the formation, and include *Archaeotrichion, Eomycetopsis*, and *Siphonophycus*. The wider filaments probably represent the empty sheaths of the Oscillatoriaceae, whereas the narrower ones could represent either oscillatoriacean filaments to bacterial filaments. Although the Chuanlinggou microbiota seems to be a highly biased sampling of the Proterozoic life toward degradation-resistant taxa, it is among the oldest clastic microbiotas now known.

INTRODUCTION

Precambrian micropalaeontology has advanced remarkably during the last 25 years. In addition to the study of microfossils preserved in stromatolitic cherts, a promising direction in Precambrian micropalaeontology involves the study of microfossils preserved in clastic rocks. This direction was established through the pioneering work of Timofeev (1959, 1966, 1969, 1973; Timofeev *et al.*, 1976). In recent years, the study of clastic facies microfossils in Precambrian rocks has increased immensely (Allison & Moorman, 1973; Amard, 1984; Bloeser & Schopf, 1977; Cloud *et al.*, 1975; Diver, 1980; Ford & Breed, 1973; Hofmann, 1977; Hofmann & Aitken, 1979; Hofmann, Hill & King, 1979; Horodyski, 1980; Horodyski, Donaldson & Kerans, 1980; Javor & Mountjoy, 1976; Knoll & Keller, 1979; Knoll *et al.*, 1981; Moorman, 1974; Peat *et al.*, 1978; Peat, 1984; Vidal, 1974, 1976, 1979, 1981; Vidal & Siedlecka, 1983; Xing Yusheng & Liu Guizhi, 1973; Zhang Zhongying *et al.*, 1981; Zhang Zhongying, 1982). These clastic facies microfossils provide the opportunity to study Precambrian life quite different in appearance from that preserved in stromatolitic cherts. They also have environmental and stratigraphic distributions that are both delimitable and useful, and even document important evolutionary events (Vidal & Knoll, 1983). The present paper reports an assemblage of microfossils from the *c.* 1800 Ma old Chuanlinggou Formation near Jixian, North China. This microbiota represents one of the oldest clastic facies microbiotas now known in the world, and therefore is of fundamental significance.

GEOLOGICAL SETTING AND AGE

In the Yanshan Range a few km north of the famous ancient town of Jixian, about 100km east of Beijing, a 9200m thick section of essentially unmetamorphosed Proterozoic sedimentary rocks is superbly exposed (Figs. 1, 2). This section is structurally located on the north limb of a southeast-trending syncline north of Jixian. Early in 1934, the Chinese geologist Gao Zhenxi and his assistants (Kao *et al.*, 1934) first described and established the Jixian section, and has since been known as a preliminary standard for the Middle and Upper Proterozoic of North China. The Middle and Upper Proterozoic there rests unconformably upon the Archean metamorphosed Qianxi Group composed mainly of amphibolites, pyroxene amphibolites, and hornblende migmatitic gneisses, and disconformably underlies the middle part of the Lower Cambrian Fujunshan Formation containing *Redlichia* and *Palaeolenus*.

The Middle and Upper Proterozoic of the Jixian section is naturally subdivisible into the Changchengian, Jixianian, and Qingbakouan Systems (not groups). According to the decision made by the Meeting of Stratigraphic Classification and Nomenclature of the Upper Precambrian of China held in Beijing 22-24 July 1982, convened by the Committee on Stratigraphy of All-China, these systems have continued to be used as regional chronostratigraphic units throughout the country. The Changchengian System comprising the lower part of the section, is well developed in the Yanshan Range, having a total thickness of 4342m. This system has been subdivided into the following five formations (in ascending order):

1. The Changzhougou Formation: fluvial and shallow-water conglomerates, white quartzose sandstones, and arenaceous shales, with a thickness of 859m.

2. The Chuanlinggou Formation: intertidal and subtidal, black and greyish-green siltstones and shales with sandstone lenses, up to 899m thick.

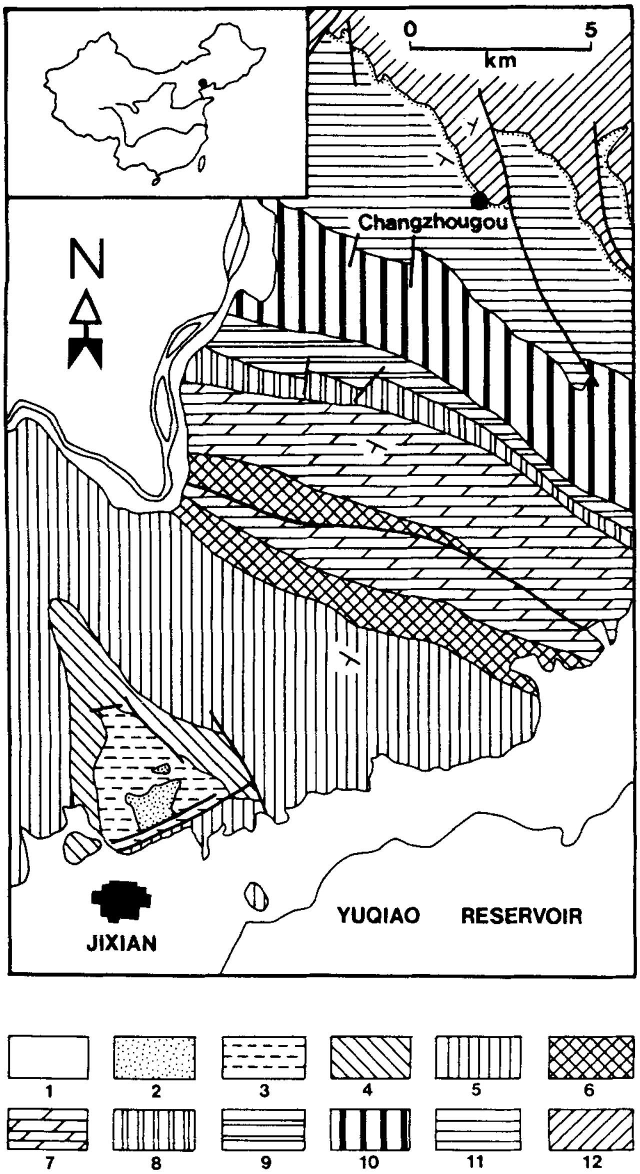


Fig. 1. Location and simplified geological map of the Jixian region, North China. 1 – Quaternary; 2 – Lower Cambrian; 3 – Jingeryu and Xiamaling Formations; 4 – Tieling and Hongshuizhuang Formations; 5 – Wumishan Formation; 6 – Yangzhuang Formation; 7 – Gaoyuzhuang Formation; 8 – Dahongyu Formation; 9 – Tuanshanzi Formation; 10 – Chuanlinggou Formation; 11 – Changzhougou Formation; 12 – Archean.

3. The Tuanshanzi Formation: subtidal to supratidal argillaceous and ferruginous dolomites, sandy dolomites, and dolomitic siltstones and sandstones, with halite casts and stromatolites in the upper part, with a thickness of 518m.

4. The Dahongyu Formation: shallow water quartzose sandstones, arkosic sandstones, sandy dolomites, stromatolitic dolomites, and some brilliant green, K-rich shales, with trachyte lavas and volcaniclastic rocks in the middle part, approximately 480m thick.

5. The Gaoyuzhuang Formation: peritidal to subtidal carbonates, mainly cherty dolomites and stromatolitic dolomites, and minor manganiferous dolomites, siltstones and sandstones, up to 1596m thick.

The overlying Jixianian System resting conformably upon the Gaoyuzhuang Formation, is chiefly made up of carbonates interbedded with small amount of sandstones and shales, with a total thickness of 4507m. This system comprises four formations (in ascending order): the Yangzhuang Formation (dolomites with minor limestones), the Wumishan Formation (siliceous dolomites with abundant cherty bands), the Hongshuizhuang Formation (black and green shales), and the Tieling Formation (dolomites and limestones). The Qingbaikouan System resting disconformably upon the Tieling Formation, comprises the lower Xiamaling Formation (shales with siltstones) and the upper Jingeryu Formation (limestones, shales, glauconitic and arkosic sandstones), with a total thickness of 371m.

Based on studies at the Laboratory of Isotope Geology of the Kweiyang Institute of Geochemistry, Academia Sinica (Zhong Fudao, 1977) and the Tianjin Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences (Chen Jinbiao *et al.*, 1980; Sun Dazhong & Lu Songnian, 1985), numerous radiometric dates from strata within the Jixian section have been obtained on various units. Indeed, these dates (see Fig. 2) provide some useful information about the absolute ages of the Middle and Upper Proterozoic strata there. It should be noted that there are pitfalls in viewing certain of these dates as unequivocal ages. For example, the inaccuracy of K-Ar age determinations on glauconites still remains a crucial problem common to Precambrian geochronometry. The microfossil-bearing Chuanlinggou Formation has yielded a whole-rock Pb-Pb isochron age of 1922 Ma, and a U-Pb model age of 1910 Ma. In addition, there are two K-Ar ages of 1817 and 1875 Ma on phlogopite from an intrusive porphyritic dyke cutting the formation near the village of Liuzhuangzi (Hofmann & Chen Jinbiao, 1981). Thus, the age of the Chuanlinggou Formation can be estimated as falling between 1900 and 1800 Ma.

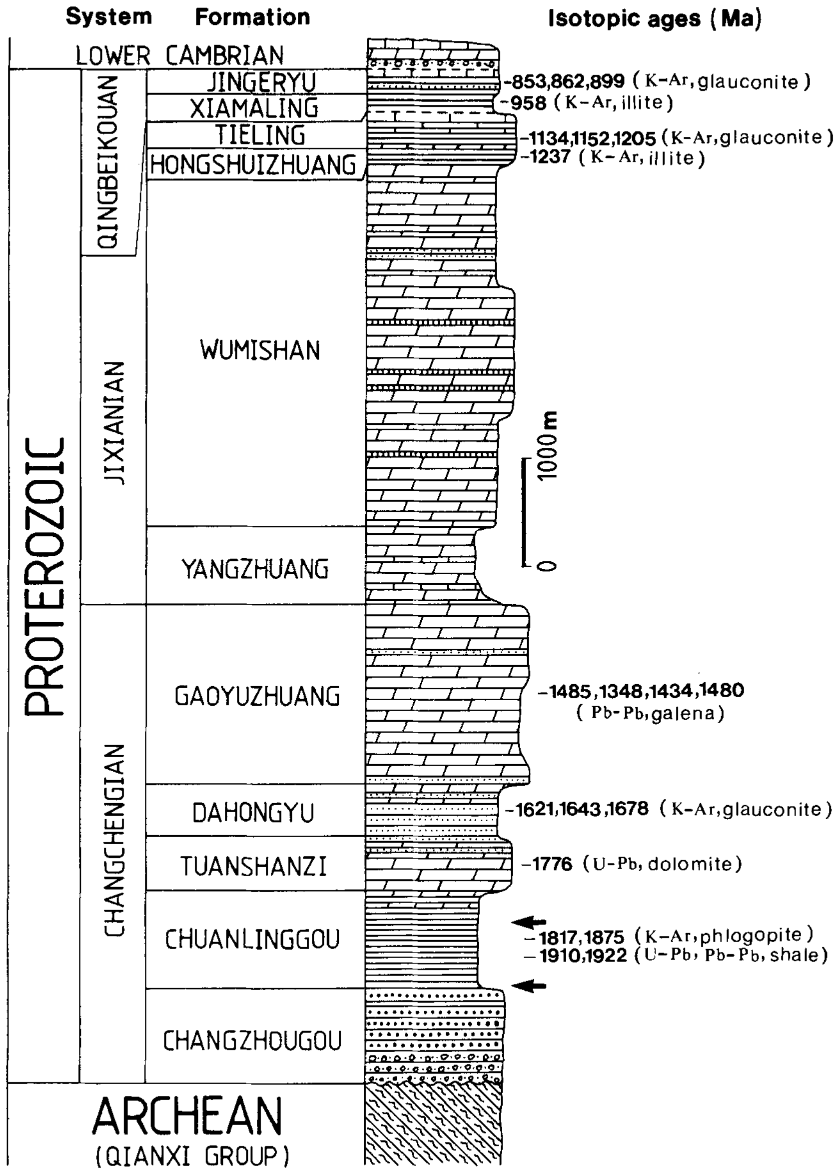


Fig. 2. Generalised lithostratigraphic column of the Proterozoic, Jixian region, North China. The arrows indicate the fossiliferous levels studied. Radiometric dates from Sun Dazhong & Lu Songnian (1985) and Hofmann & Chen Jinbiao (1981).

PALAEONTOLOGY

Abundant microfossils have been discovered in petrographic thin sections cut parallel to lamination from shales of the Chuanlinggou Formation alongside the path from Qingshanling to Tuanshanzi, about 3-5km southwest of Changzhougou. There are two fossiliferous levels within the formation. The first occurs only about 6-9m above the base of the formation, whereas the second is in the upper part of the formation, both consisting of dark greyish-green shales and shaly siltstones. Examination of thin sections shows that all these microfossils are enclosed by the argillaceous matrix of the shale and are compressed parallel to lamination; none are three-dimensionally preserved. In thin sections cut perpendicular to lamination, the microfossils appear only as very thin dark streaks. They are, thus, indigenous to the shale and syngenetic with its deposition.

The Chuanlinggou microbiota consists of two broad categories of microfossils, namely sphaeromorphs and filaments. The sphaeromorphs are organic-walled microfossils referred to the acritarchs (Downie, Evitt & Sarjeant, 1963). They are numerically abundant and well preserved in the first fossiliferous level of the Chuanlinggou Formation. Fossil filaments, on the contrary, are found in the second fossiliferous level of the formation, along with a few poorly preserved sphaeromorphs. Both sphaeromorphs and filaments occur isolated and scattered on the bedding planes of the shale, rather than in mat-like aggregates. It appears that they were transported into their present positions with other detritus. Based on their attitudes in shales and varied preservation, most of them might have been washed around for some time before being deposited. The microfossils are light-brown to dark-brown in colour, suggesting moderate to higher thermal alteration (Staplin, 1977). Postdepositionally introduced features, such as imprints of mineral grains and deformation caused by pyrite crystal growth can be seen in preserved microfossils.

It should be mentioned that the presence of acid-resistant, organic-walled microfossils in the Chuanlinggou Formation obtained using maceration techniques was first established by Xing Yusheng & Liu Guizhi (1973). Nine genera and nineteen species of microfossils were formally described, among these three genera and 12 species being restricted to this formation in the Jixian region. They concluded that this microfossil assemblage was characterised by very small sphaeromorph acritarchs (less than 10μm in diameter) which dominate, while larger sphaeromorphs over 30μm across were very scarce. It is puzzling that most of the microfossils described by them have not as yet been detected in petrographic thin sections. Moreover, all the sphaeromorph acritarchs observed in thin sections are larger than 20μm in diameter, and most of them are between 40-200μm across. It seems that Xing Yusheng & Liu Guizhi's conclusion is not warranted by present evidence. The reason for the striking difference between the microfossils obtained from maceration and those from petrographic thin sections is uncertain. Although in macerates larger acritarchs may be easily damaged during processing, the possibility of a contaminative origin for smaller acritarchs cannot be excluded. However, further study is needed to test whether these small sphaeromorphs in macerates are primary.

Sphaeromorph acritarchs in petrographic thin sections of the investigated formation are between 20-200μm in diameter. Based on their morphological features, at least some taxa can be easily recognised, although their identifications in this paper are provisional pending formal taxonomic treatment of the microfossils. The most common and prominent acritarchs (Pl. 1, figs. 1, 2) closely resemble *Kildinella* Timofeev (1963) 1966. They are circular to oval (originally spherical), single-walled organic vesicles. The vesicles, 38-85μm across, are thin, robust, and highly flexible, and display well developed clear and sharp lanceolate folds. Their external texture seems to be scabrous in appearance because of sediment compaction, but observations at high magnification, particularly under oil immersion, show that the original surface is psilate to finely granulate. It should be noted that the genus *Kildinella* has recently been thought by Lindgren (1982) to be congeneric with *Leiosphaeridia* Eisenack. The type species of *Kildinella (K. hyperboreica)* was thus transferred to *Leiosphaeridia*; the new taxonomic combination being *L. asperata* (Naumova) Lindgren 1982. The remaining species of *Kildinella* were later transferred by Vidal (in Vidal & Siedlecka, 1983) to the new genus *Kildinosphaera* Vidal; the type species being *K. chagrinata* (= *Kildinella sinica* Timofeev). According to the diagnosis of *Kildinosphaera*, the Chuanlinggou specimens are

Explanation of Plate 1

Structurally preserved sphaeromorph acritarchs and filamentous microfossils in petrographic thin sections of shales from the 1800 Ma old Chuanlinggou Formation (Changchengian System) near Jixian, North China. All specimens are strongly flattened parallel to lamination. Single bar scale is 10μm long; double bar scale 50μm long. Thin section number and the registration number for the Palaeobotany Collection, Nanjing University are given for each specimen.

Figs. 1, 2. *Kildinosphaera* sp.: fig. 1, JChu-116, B8518; fig. 2, JChu-120, B8519.

Fig. 3. *Leiosphaeridia* sp. JChu-115, B8520.

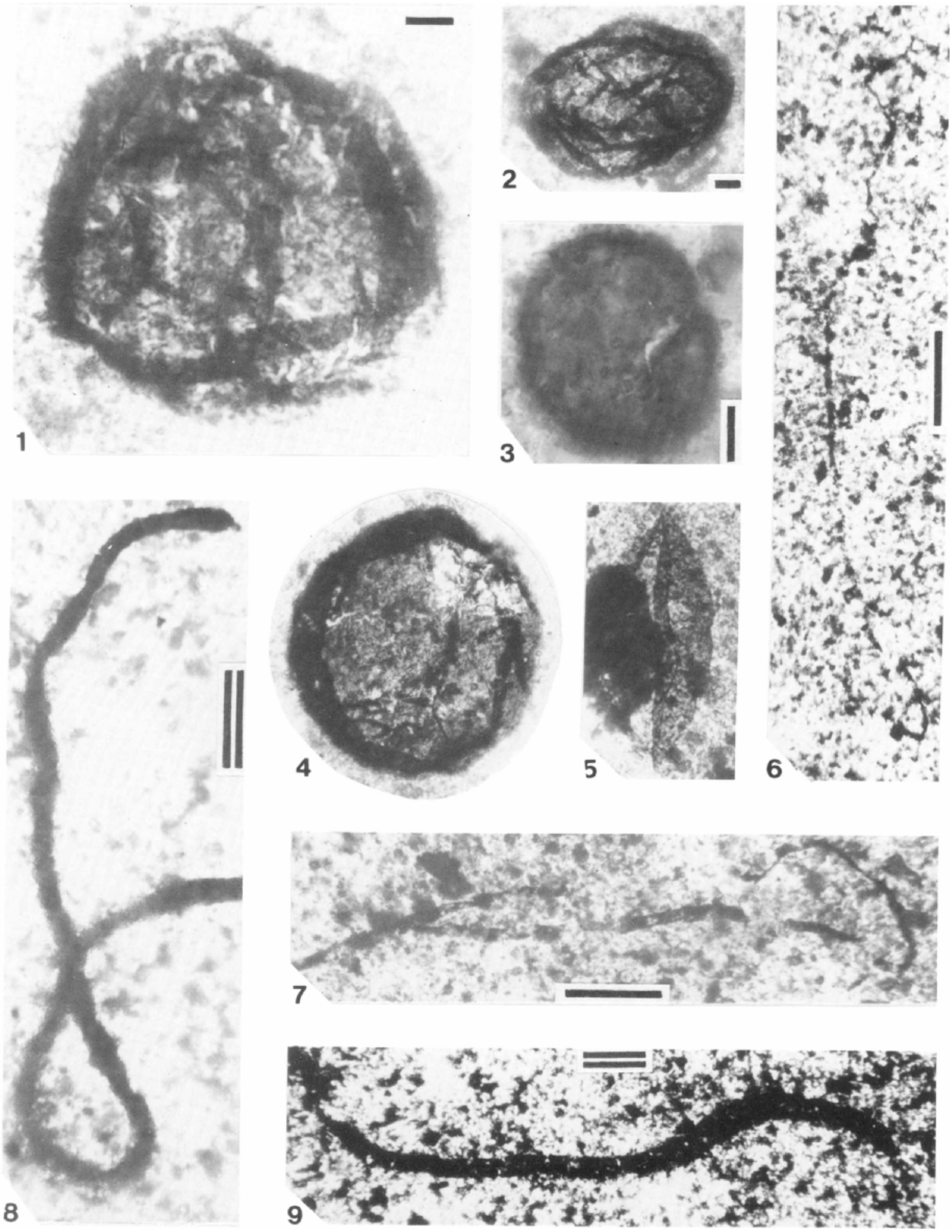
Fig. 4. *Chuaria circularis* Walcott. JChu-106, B8521.

Fig. 5. Boat-shaped sphaeromorph assignable to *Leiosphaeridia* Eisenack. JChu-124, B8522.

Fig. 6. *Archaeotrichion* sp. JChu-002, B8523.

Fig. 7. *Eomycetopsis* sp. JChu-010, B8524.

Figs. 8, 9. *Siphonophycus* spp.: fig. 8, JChu-008, B8525; fig. 9, JChu-006, B8526.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assignable to this new genus. I identify the present material only at the genus level, awaiting further collecting and study of additional material.

Some large, ellipsoidal to fusiform acritarchs (Pl. 1, fig. 5) encountered in petrographic thin sections are single-walled vesicles, commonly half to a quarter as wide as long, mostly in excess of 100μm in length. They have a smooth to shagreen surface texture with a few folds and wrinkles arranged in a linear pattern. A long spit-like "opening" occurs along the longitudinal axis of the vesicles. In gross morphology, shape of vesicles, wall texture, smooth surface, and arrangement of folds, they are indistinguishable from those described by Peat *et al.* (1978, fig. 5, o-s) from shales of the Roper Group (1300-1400 Ma), Northern Territory, Australia. Peat *et al.* (1978) interpreted these fossils as thin empty valves of Disphaeromorph acritarchs, the original sphere falling apart by a median split, then curling up, and eventually giving rise to Netromorph-like bodies. Similar boat-shaped fossils have been named under different genera, such as *Lancettopsis* (Mädler, 1963), *Leiosphaeridia* (Eisenack, 1958; Vanguestaine, 1967), and *Macroptycha* (Timofeev, 1973). Recently, Yan Yuzhong (1982) erected a new genus named *Schizofusa* with two new species for the Chuanlinggou fossils, and placed them in the Netromorphitae. Later Luo Qiling *et al.* (1985) transferred Yan Yuzhong's species to *Leioarachnitum sinitum* (Yan) and *L. apertum* (Yan) respectively. I am not convinced, however, that these acritarchs, as suggested by both Yan Yuzhong and Luo Qiling *et al.*, represent a complete flattened sphere with a complicated ventral and dorsal structure. An alternative interpretation is that they are only simple rolled valves. As pointed out by Peat *et al.* (1978), many of the larger sphaeromorphs open by median splits, and microfossils of this type could be easily mistaken for Netromorphs. It seems reasonable that *Leiosphaeridia* Eisenack is a preferable genus for the Chuanlinggou fossils. Specific identification of the fossils, however, awaits further study.

Microscopic specimens of *Chuaria circularia* Walcott (Pl. 1, fig. 4) are recognisable in petrographic thin sections by their large size (Chuanlinggou range = 85-200μm) and thick, psilate to shagreen wall, which is often textured by irregularly or concentrically arranged wrinkles. They also occur at the base of the Chuanlinggou Formation. *C. circularis* is an acritarch species which has been discussed by a number of authors (Ford & Breed, 1973; Vidal, 1974, 1976, 1979, 1981; Vidal & Siedlecka, 1983; Hofmann, 1977; Hofmann & Aitken, 1979; Hofmann & Chen Jinbiao, 1981). The species may occasionally reach megascopic dimensions. Megascopic carbonaceous compressions assignable to *Chuaria* Walcott and *Tyrasotaenia* Gnilovskaya have been reported from a shaly siltstone bed near the top of the Chuanlinggou Formation in the Yanshan Range north of Jixian (Hofmann & Chen Jinbiao, 1981).

A few smaller sphaeromorphs with smooth or shagreen surface (Pl. 1, fig. 3) are comparable with *Protoleiosphaeridium* Timofeev, 1960. As *Protoleiosphaeridium* ranges within the diagnosis of *Leiosphaeridia*, the former has been treated as a synonym of the latter by Downie & Sarjeant (1963) and Lindgreen (1981, 1982). These sphaeromorphs also occur at the base of the Chuanlinggou Formation. Sphaeromorphs from the upper part of the formation, however, are in poor state of preservation, which precludes the assignment of them to particular taxa.

The Chuanlinggou filaments come from the upper part of the formation. They are apparently unbranched, non-septate, and originally tubular structures that were compressed during compaction of the surrounding clastic sediment. These filaments occur isolated, ranging from 0.5-24μm wide, up to 1300μm long. They are dark brown to black in colour; surface texture seems to be psilate to granulate. Although the size distribution of filaments has not been made, the large size range of these filaments indicates that several taxa of filamentous microfossils are present. Most common filaments are between 8-14μm wide (Pl. 1, fig. 8) and between 3-6μm wide (Pl. 1, fig. 7), which could be assigned to *Siphonophycus* sp. and *Eomycetopsis* sp. respectively. Larger *Siphonophycus* filaments (Pl. 1, fig. 9) up to 24μm wide have also been encountered, but are rare and in a poor state of preservation. In all known specimens none of the trichomes are preserved. Thread-like filaments narrower than *Eomycetopsis* are less common in the Chuanlinggou shales, which are here referred to *Archaeotrichion* sp. (Pl. 1, fig. 6).

DISCUSSION AND SUMMARY

The Chuanlinggou microbiota consists of dominant sphaeromorph acritarchs and filamentous microfossils. The sphaeromorphs include *Kildinosphaera, Leiosphaeridia*, and *Chuaria*. According to Vidal & Knoll (1983) and Vidal & Siedlecka (1983), *Kildinosphaera* was thought to be abandoned cyst-like vesicle resulting from non-motile stages of prasinophycean green algae. Lindgren (1981) discussed in detail the botanical affinities of *Leiosphaeridia* and concluded that this genus seemed to be one of heterogeneous composition, without possible implication to taxonomy of modern algae. As for *Chuaria*, it is generally agreed that this is a fossil alga probably related to the green algae although this is far from universally accepted. Precambrian acritarchs could represent reproductive cysts of marine planktonic algae (Vidal, 1976; Vidal & Knoll, 1983; Knoll, 1984), but some of them may also represent vegetative stages of the algal life cycle (Lindgren, 1981). It cannot be excluded that some sphaeromorphs in question were probably cyanobacterial. For now, it is difficult to assign the Chuanlinggou sphaeromorphs to any groups of plants with certainty. In the Chuanlinggou filaments, wider flattened tubes made of *Siphonophycus* and *Eomycetopsis* are best interpreted as preserved empty sheaths of oscillatoriacean cyanobacteria (Hofmann & Aitken, 1979; Zhang Zhongying, 1982), whereas the narrower ones made of *Archaeotrichion* could represent collapsed or deflated filaments of *Eomycetopsis* or filamentous bacteria (Hofmann, 1976; Hofmann & Aitken, 1979). In addition to the above-mentioned microfossils, some large, irregular scraps (several hundred microns across or even more) of carbonised organic matter with probably cellular organisation have also been detected in petrographic thin sections. These fossil fragments could hardly be other than eukaryotic.

It should be noted that the Chuanlinggou microbiota, as well as other Proterozoic clastic facies microbiotas, probably represents a highly biased sampling of the Proterozoic life. As pointed out by Horodyski *et al.* (1980), only those elements that were exceptionally resistant to degradation and diagenetic alteration would be preserved in shales. It thus seems possible that the Chuanlinggou microbiota is not representative of the original microbial community from which it was derived. However, such microbiotas document important Precambrian evolutionary events whose record is not observable in the stromatolitic chert, and are potentially useful for intercontinental biostratigraphic correlation.

The Chuanlinggou sphaeromorphs are morphologically comparable with those described from Middle and Upper Proterozoic shales in the Soviet Union (Timofeev, 1966, 1969, 1973), the North Atlantic region (Vidal, 1974, 1976, 1979, 1981; Vidal & Siedlecka, 1983), Australia (Peat *et al.*, 1978), N.W. Scotland (Zhang Zhongying *et al.*, 1981; Zhang Zhongying, 1982), Canada (Hofmann & Aitken, 1976) and the United States (Horodyski, 1980). It is known that *Kildinosphaera, Leiosphaeridia*, and *Chuaria* are common elements in most Late Riphean assemblages. The discovery of *Chuaria circularis* Walcott from the base of the Chuanlinggou Formation deserves special mention, for previous reports of *Chuaria* and similar fossils are all from geographically widely distributed sequences about 1100-600 Ma old throughout the world except in the Yanshan Range north of Jixian (Hofmann & Chen Jinbiao, 1981), and the use of these organisms as characteristic fossils of the Upper Proterozoic in world-wide correlation has been proposed by several authors. The Chuanlinggou filaments are remarkably similar to those preserved in shales of the *c.* 1400 Ma lower Belt Supergroup in the Little Belt Mountains, Montana (Horodyski, 1980), the *c.* 1200 Ma Dismal Lakes Group in Northwest Territories, Canada (Horodyski et al., 1980), and the *c.* 800 Ma Torridon Group in N.W. Scotland (Zhang Zhongying, 1982). As mentioned above, the Chuanlinggou Formation has been dated at *c.* 1800 Ma. On present palaeontological evidence, this formation is likely to be of Upper Riphean age, or not older than 1400 Ma. This means that the isotopic age obtained on the Chuanlinggou Formation is much older than that expected from the fossils. It is suggested that more careful isotopic age determinations on the formation need to be undertaken. If this age is reliable, the newly-discovered Chuanlinggou microbiota does extend the stratigraphic range of some previously well known microorganisms indicative of the upper Riphean back by several hundred million years. Furthermore, as result of the discovery of larger sphaeromorphs (up to 200μm in diameter) from the Chuanlinggou Formation, the commonly accepted view that the apparent trend of size increase of microfossils appeared in Precambrian time (Schopf, 1977; also see Tylor, 1981) also seems to be questionable.

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