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New data regarding acritarch biostratigraphy from the Early-Middle Cambrian Kaili Formation in Chuandong, Guizhou Province, China

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Abstract

Previous studies had evaluated acritarchs from the Balang and Pingzhai sections of the Early-Middle Cambrian Kaili Formation in east Guizhou, China. The results of these studies suggest that the acritarchs in these sections have potential biostratigraphic significance. More recently, 34 samples collected from 83 m lower part of the Lower-Middle Cambrian Kaili Formation in the Jianshan section of Chuandong, Guizhou Province were prepared for palynological analysis. Analysis of these samples revealed a distinct change in the acritarch assemblages at the bed, which was approximately 46 m above the bottom of the Kaili Formation. These findings suggest a boundary represented by an important alteration of the ecological environment. In addition, the position of the acritarch biostratigraphic change is somewhat higher than the boundary between Cambrian Series 2 and Series 3 based on trilobites found in the same section. This indicates that the distinct change in acritarch assemblages is similar to the change in trilobite assemblages that occurs around the boundary between Cambrian Series 2 and Series 3. Therefore, acritarch biostratigraphy can provide data that can be used to define the base of Cambrian Series 3 in this region, and possibly worldwide.
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Keywords: Acritarchs; Lower-Middle Cambrian Kaili Formation; Jianshan section; Chuandong

1. Introduction

The biostratigraphic significance of acritarchs from Early Paleozoic rocks has a great potential for describing alterations of marine environments. Many Early Paleozoic palynofloras and acritarch zonations have been studied and defined worldwide [1]. In addition, Early-Middle Cambrian acritarch zonations from the East European Platform and the Lublin Slope and Upper Silesia in Poland have been recognized by Volkova [2], Volkova et al. [3] and Moczydłowska [4,5]. Furthermore, Martin and Dean [6–8] described Cambrian acritarchs that corresponded to trilobite zones in eastern Newfoundland, Canada.

In South China, Yao et al. [9] have summarized the lowest Cambrian organic-walled microfossils and the acritarch assemblage from cherts and phosphorites of the basal Cambrian. In addition, it has been reported that the *Asteridium-Heliosphaeridium-Comasphaeridium* zone in South China is similar to the *Asteridum tornatum-Comasphaeridium velvetum* acritarch zone in the East European Platform [4].

During the last decade, acritarch studies of the Balang and Pingzhai sections of the traditional Lower-Middle Cambrian Kaili Formation in eastern Guizhou had been conducted. Although only a small number of moderately diversified acritarchs were obtained from the two sections of the Kaili Formation [10,11], the acritarch assemblages

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contained some significant Cambrian forms that could be used to define the boundary and to compare the sections of the series at the base of Cambrian Series 3 based on the presence of trilobite zones [10,11].

2. Biostratigraphy of the Kaili Formation

The Jianshan section of the Kaili Formation at Chuandong which was evaluated in this study is located approximately 8 km northeast of the Balang section of Taijiang County, Guizhou Province, China (Fig. 1). A representative stratigraphic column of the stratal units of this section from the base of the Kaili Formation upwards towards an interval at 83 m is shown in Fig. 2. The interval is the lower part of the Kaili Formation. This portion of the Kaili Formation covers the Lower and Middle Cambrian boundary, which is defined by trilobite zones. The units are described briefly in the list below:

- 82–83 m. Gray–yellow silty-mudstone. Trilobites: *Oryctocephalus indicus*, *Xingrenaspis xingrenensis*, *X. politus*, *Pagetia taijiangensis*, etc. Acritarchs: *Stictosphaeridium* sp., *Leiosphaeridia* sp. *B.*
- 80–81 m. Gray thin beds of limestone interbeded with calcareous mudstone. Trilobites: *Oryctocephalus indicus, Pagetia taijiangensis, Kaotaia globosa*, etc. Acritarchs: *Synsphaeridium* sp., *Pterospermella* sp.
- 75–79 m. Gray marl, thin beds of argillaceous limestone interbeded with calcareous mudstone. Trilobites: *Oryctocephalus indicus, Metabalangia yupingensis, Probowmania* (*P.*) *balangensis*, etc. Acritarchs: *Leiosphaeridia holtedahlii, L.* sp. fragments of multicellular algae.
- 69–74 m. Gray calcareous mudstone containing local marl. Trilobites: *Oryctocephalus indicus, O.* (*O.*) *latilimbatus, Euarthricocephalus* (*E.*) *taijiangensis*, etc. Acritarchs: *Dictyotidium priscum, Granomarginata prima, Leiosphaeridia bicrura, L. crassa, L. holtedahlii, L. laminarita, L. sp. A, L. sp. C, Lophosphaeridium* sp., *Ooidium* sp., *Ovurum saccatum.*
- 65–68 m. Dark gray mudstone with developed lamellation. Trilobites: *Oryctocephalus indicus, Oryctocephalites* (*Parachangaspis*) *longus, Metabalangia yupingensis, etc. Acritarchs: Leiosphaeridia atava, L. crassa.*
- 55–64 m. Dark gray mudstone, shown as fragments since slacking. Trilobites: *Oryctocephalus indicus, O. latilimbatus, Euarthricocephalus* (*E.*) *taijiangensis, Metarthricocephalus spinosus*, etc. Acritarchs: *Leiosphaeridia holtedahlii*, *L.* sp., tabular cyanobacterial sheaths.
- 45–54 m. Dark gray silty-mudstone, local calcareous Trilobites: *Oryctocrphalus indicus*, *Metabalangia yupingensis*, *Euarthricocephalus* (*E.*) *taijiangensis*, *Xingrenaspis xingrenensis*, etc. Acritarchs: *Cymatiosphaera postii*, *Cristallinium ovillense*, *Dictyotidium priscum*, *Leiosphaeridia atava*, *L. crassa*, *L.* sp. B, *Pterospermella solida*, *Retisphaeridium densum*, *Stictosphaeridium* sp., tabular cyanobacterial sheaths.
- 41–44 m. Gray silty-mudstone with concretions of marl. Trilobites: *Nangaops danzhaiensis, N. brevis*, *Bathynotus kueichouensis*, etc. *Acritarchs: Leiosphaeridia atava*, *L. crassa, Lophosphaeridium tentadium, Synsphaeridium* sp.
- 34–40 m. Gray silty-mudstone with developed lamellation, shown as fragments since slacking. Trilobites: *Parashuiyuella subcylindrica, Protoryctocephalus elongatus, Probowmania* (*Mufushania*) *nakingensis*, etc. Acritarchs: *Leiosphaeridia crassa*.
- 20–33 m. Gray–green silty-mudstone, shown as tabular since weathering. Trilobites: *Olenoides hubeiensis, Ovatoryctocara granulata, Nangaops elongatus*, etc. Acritarchs: *Leiosphaeridia crassa*.
- 17–19 m. Dark gray calcareous mudstone, interbeded with 4–5 thin beds of dark gray argereceous limestone. Trilobites: *Olenoides hubeiensis, Oryctocephalops guizhouensis, Chittidilla* (*Diandongaspidella*) *brevis*, etc. Acritarchs: *Leiosphaeridia crassa*.
- 14–16 m. Dark gray medium-thick limestone, interbeded with shale. Trilobites: *Bathynotus kueichouensis, Olenoides hubeiensis, Balangcunaspis* (*B.*) *transverus*, etc. Acritarchs: *Leiosphaeridia crassa*, tabular cyanobacterial sheaths, unnamed acritarch form.

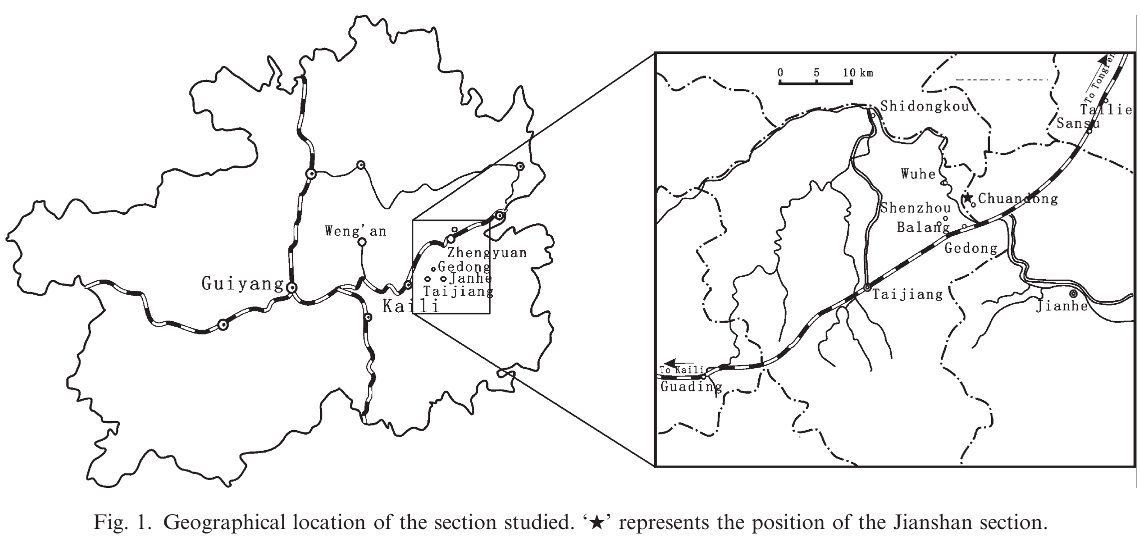

Fig. 1. Geographical location of the section studied. '★' represents the position of the Jianshan section.

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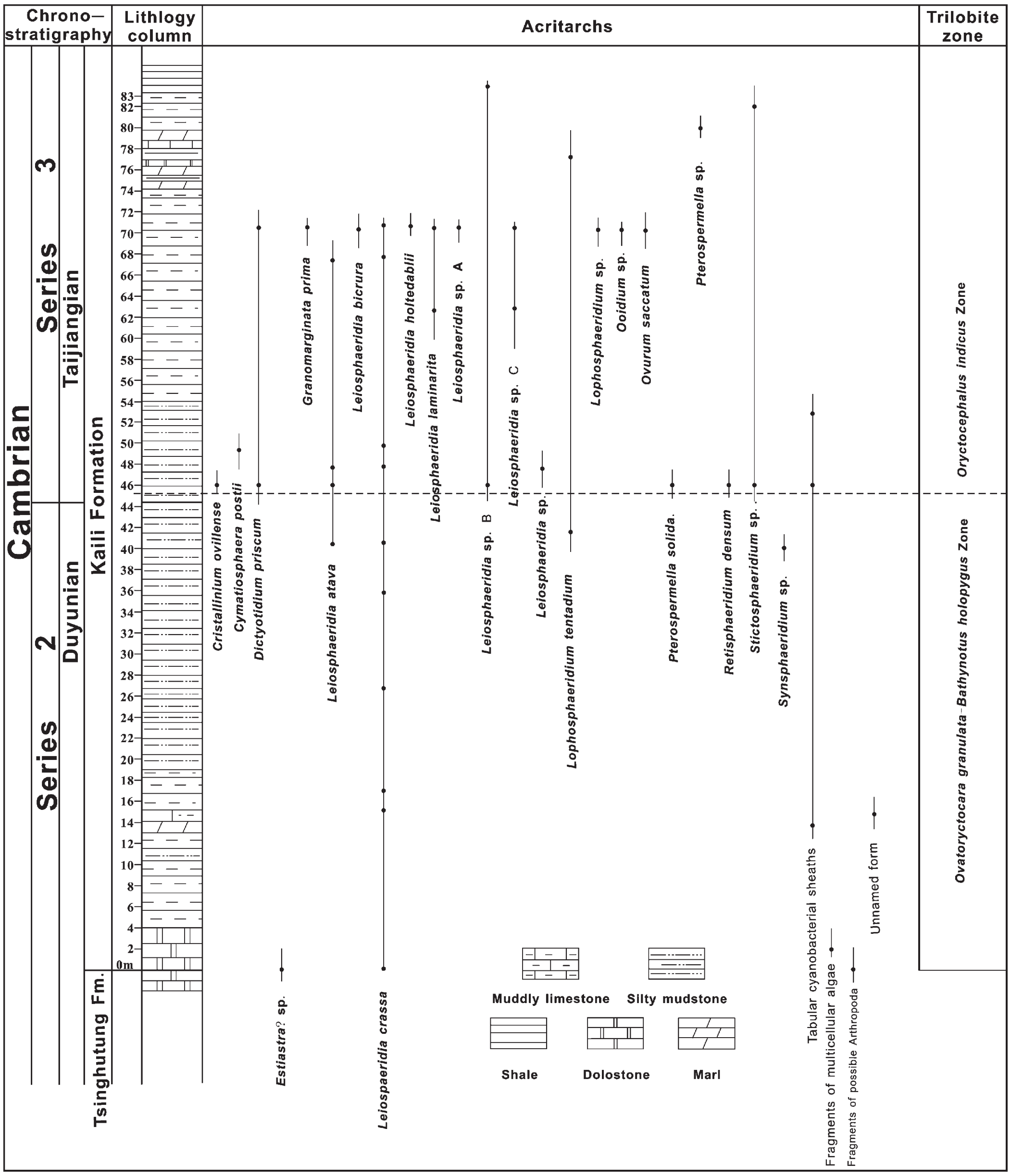

Fig. 2. Stratigraphy and distribution of acritarch taxa in the Early-Middle Cambrian Kaili Formation of the Jianshan Section, Chundong, Guizhou Province, China.

- 6.6–13 m. Dark gray silty-mudstone, interbeded with 2–3 thin beds of black arginaceous limestone. Trilobites: *Nangaops danzhaiensis, Balangcunaspis* (*B.*) *transverus, Kunimingaspis deltoidea*, etc.
- 4.1–6.5 m. Dark gray calcareous mudstone, shown as thin tabular since weathering. Trilobites: *Chittidilla* (*Diandongaspidella*) *brevis, Protoryctocephalus balangensis, Balangcunaspis* (*B.*) *transversus*, etc.
- 3.3–4.0 m. Dark gray dolomitic limestone, interbeded with shale. Trilobites: *Bathynotus kueichouensis, Balang-cunaspis (B.) transversus. Acritarchs: Leiosphaeridia crassa*, fragments of multicellular algae.
- 2.6–3.2 m. Thin beds of arginaceous dolomite. Acritarchs: *Leiosphaeridia crassa*, fragments of multicellular algae.
- 0–2.5 m. Black medium-thick calcareous dolomite. Acritarchs: *Estiastra*? sp., *Leiosphaeridia crassa*.

Conformity. Tsinghutung Formation: Gray and thin-bed dolomites.

3. Materials and methods

A total of 35 samples were collected, of which 34 were collected from surface rocks in the Jianshan section from 0 to 83 m above the base of the Kaili Formation, and one was collected from the underlying Tsinghutung Formation. All samples were collected in Chuandong, Jianhe (former Taijiang), Guizhou, China, and were processed using conventional palynological techniques

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[12,13]. Thirty of the samples yielded acritarchs and other palynomorphs. All filtrated organic residues were fixed using glycerol jelly as a mounting medium, and then observed and photographed under a transmitted light microscope (Leitz Wetzlar Diaplan). All specimens obtained here were deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

4. Microfossil material

Palynomorphs including acritarchs, cyanobacterial sheaths, fragments of multicellular algae and possible metazoan remains were obtained from 29 of the Kaili Formation samples collected from the Jianshan section at Chuandong, Guizhou Province. In addition, acritarchs were found in the sample collected from the underlying Tsinghu-

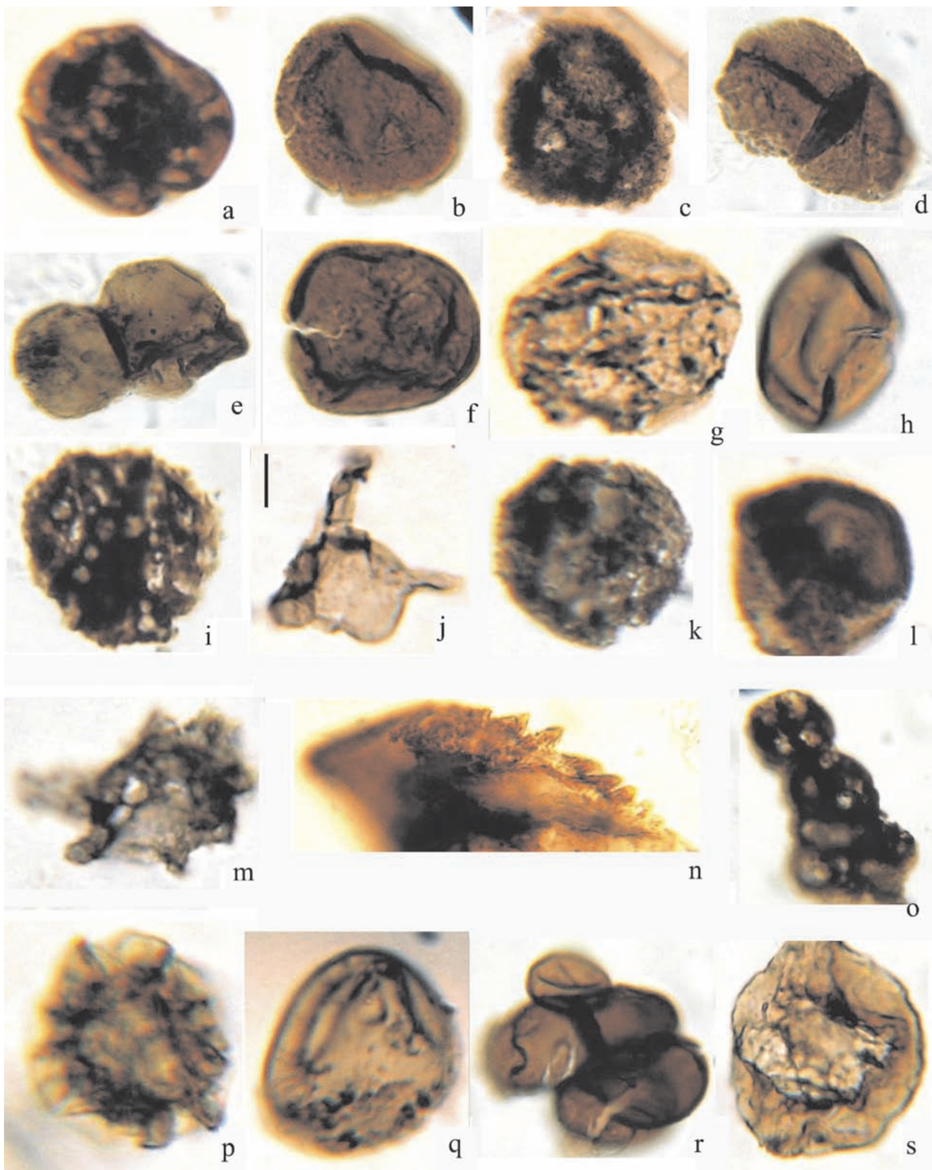

Fig. 3. The acritarchs from the Jianshan section of the interval from 0 to 83 m above the base of the Kaili Formation (>200 m in thickness), Chungdon, Jianhe (formally Taijiang), Guizhou, China. All specimens are from the Kaili Formation, with exception of j, m from the underlying Tsinghutung Formation. (a, h, and l) *Leiosphaeridia crassa* (Naumova) emend. Jankauskas, 1989. (a) GJCJ-71; (h) GJCJ-15.2; l, GJCS-0; (b and f) *Leiosphaeridia laminarita* (Timofeev) emend. Jankauskas, 1989. (b) GJCJ-71; (f) GJCJ-71; (c) *Leiosphaeridia holtedahlii* (Timofeev) emend. Jankauskas, 1989, GJCJ-71; d, and e are *Leiosphaeridia* sp. A. (d) GJCJ-71; (e) GJCJ-71; (g and k) *Lophosphaeridium tentadium* Volkova, 1979. (g) GJCJ–77; (k) GJCJ–42; (i) *Leiosphaeridia* sp., GJCJ-42; (j and m) are *Estiastra*? sp., (j) GJCS-0; (m) GJCS-0; (n and f) fragments of possible Arthropoda, GJCS-0; o, *Synsphaeridium* sp., GJCJ-42; (p) *Cymatiosphaera postii* (Jankauskas, 1976) Jankauskas, 1979, GJCJ-50; (q) *Ooidium* sp., GJCJ-71; (r) *Ovulum saccatum* Jankauskas, 1975, GJCJ-71; (s) *Leiosphaeridia bicrura* Jankauskas, 1976, GJCJ-71. Scale bar is 6 μm for (a, g, and r); 7 μm for (k and l); 8 μm for (i); 10 μm for (f, m, p, and s); 11 μm for (b, h, and q); 12 μm for (e and j); 13 μm for (c); 14 μm for (d); 15 μm for (n); 27 μm for (o).

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tung Formation, which is very close to the base of the Kaili Formation. As shown in Fig. 2, most of the acritarch taxonomic forms listed herein are sphaeromorphs, which are normally named as leiospheres. The morphological features of these specimens such as the formation of the vesicles, wall thickness, folds, and number of excystment openings differed from one another (see Figs. 3–5). Furthermore, although their biostratigraphic significance is limited, the difference in their first appearance in the stratigraphic column could reflect a distinct deposited environment and possible biological affinity. With the exception of some known leiosphaerid forms, including *Leiosphaeridia atava* and *L. crassa*, several new forms, provisionally named *Leiosphaeridia* sp. A, B, C in this paper, appeared to be indigenous to the formation. Additionally, a few other Lower-Middle Cambrian familiar acritarch genera, such as *Lophosphaeridium, Dictyotidium, Cymatiosphaera, Cristallinium, Granomarginata, Ooidium, Pterospermella* and *Retisphaeridium*, were found in the rock samples collected from slightly higher units of the Kaili Formation. Moreover, cyanobacterial sheaths, fragments of multicellular algae and possible metazoan (Arthropoda?) remains

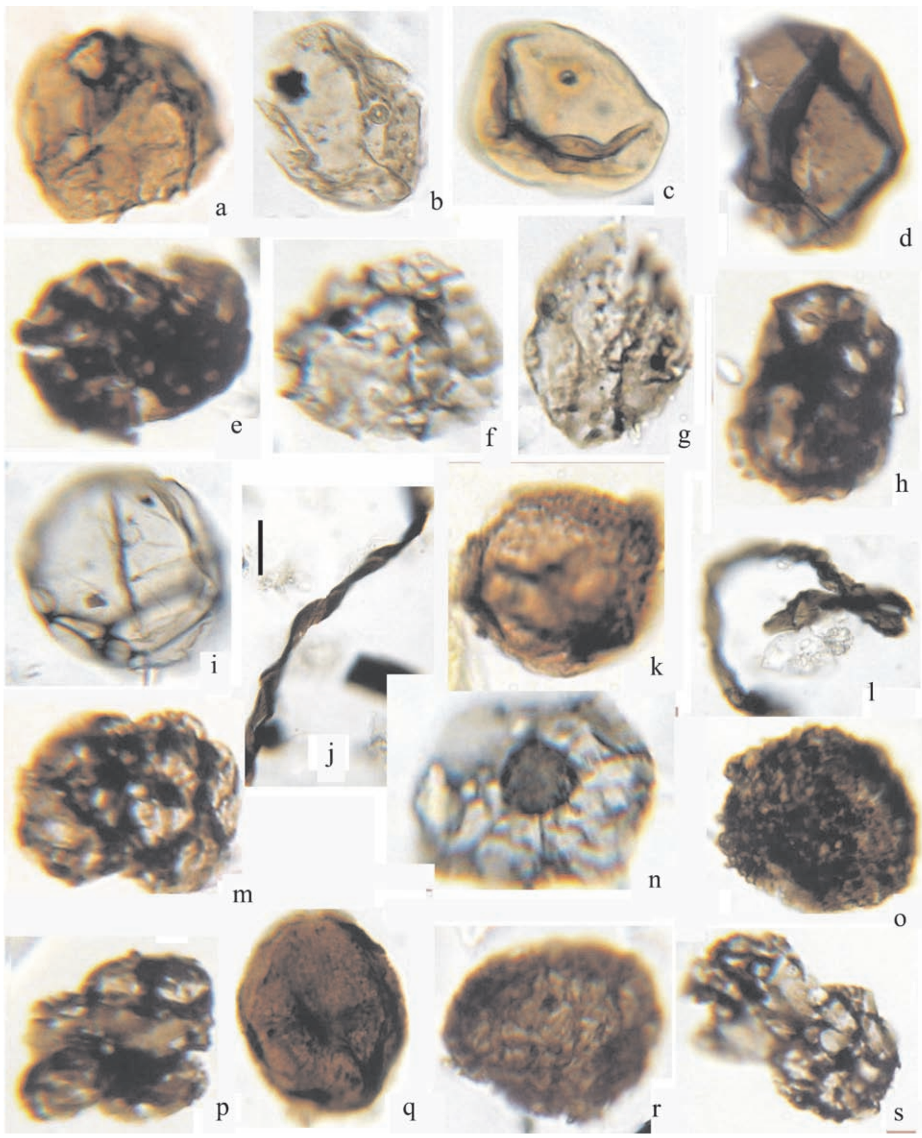

Fig. 4. The acritarchs from the Jianshan section of the interval from 0 to 83 m above the base of the Kaili Formation (<200 m in thickness), Chungdon, Jianhe (formally Taijiang), Guizhou, China. All specimens are from the Kaili Formation. (a) *Leiosphaeridia laminarita* (Timofeev) emend. Jankauskas, 1989, GJCJ-27; (b and c) *Leiosphaeridia* sp. B. (b) GJCJ-85 and (c) GJCJ-46.5; (d, e, and h) *Leiosphaeridia crassa* (Naumova) emend. Jankauskas, 1989. (d) GJCJ-3; (e) GJCJ-36; (h) GJCJ-41; (f and g) *Leiosphaeridia atava* (Naumova) emend. Jankauskas, 1989. (f) GJCJ-46.5; (g) GJCJ-48; (i) *Stictosphaeridium* sp., GJCJ-46.5; (j and l) Tubular cyanobacterial sheaths. (j) GJCJ-53; l, GJCJ-46.5; (k) *Granomargenata prima* Naumova, 1960, GJCJ-71; (m) *Leiosphaeridia* sp., GJCJ-42; (n) *Pterospermella solida* (Volkova) Volkova, 1979, GJCJ-46.5; (o) *Dictyoditium priscum* Kirjanov and Volkova, 1979, GJCJ-71; (p and s) *Synsphaeridium* sp. (p) GJCJ-41; (s) GJCJ-39; (q) *Leiosphaeridia bicrura* Jankauskas, 1976, GJCJ-71; (r) *Dictyoditium priscum* Kirjanov and Volkova, 1979, GJCJ-46.5. Scale bar is 6 μm for (a); 7 μm for (k and m); 8 μm for (f, g, h, r, and s); 9 μm for (d, e, and p); 11 μm for (i); 12 μm for (b, c, and q); 14 μm for (o); 16 μm for (n); 30 μm for (j and l).

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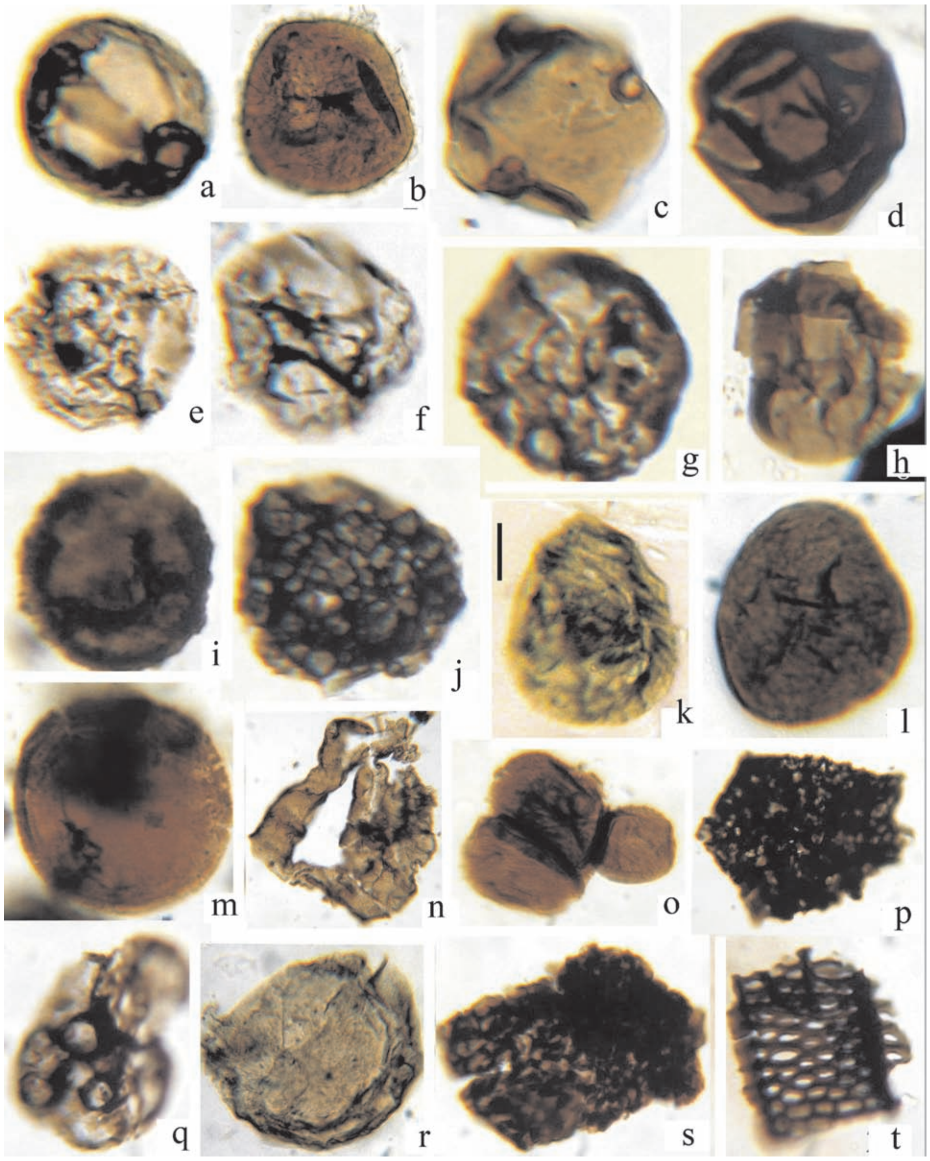

Fig. 5. The acritarchs from the Jianshan section of the interval from 0 to 83 m above the base of the Kaili Formation (>200 m in thickness), Chungdon, Jianhe (formally Taijiang), Guizhou, China. All specimens are from the Kaili Formation, with exception of (g) from the underlying Tsinghutung Formation. (a,c) *Leiosphaeridia crassa* (Naumova) emend. Jankauskas, 1989. (a) GJCJ-17.5; (c) GJCJ-15.2; (b) Unnamed acritarch form, GJCJ-15.2; (d–h) *Leiosphaeridia atava* (Naumova) emend. Jankauskas, 1989. (d) GJCJ-41; (e) GJCJ-46.5; (f) GJCJ-46.5; (g) GJCS-0; (h) GJCJ-46.5; (I and l) *Leiosphaeridia laminarita* (Timofeev) emend. Jankauskas, 1989. (i) GJCJ-63; l, GJCJ-71; (j) *Dictyotidium priscum* Kirjanov and Volkova, 1979, GJCJ-46.5; (k) *Leiosphaeridia* sp., GJCJ-48; (m and o) *Leiosphaeridia* sp. C; (m) GJCJ-63; (o) GJCJ-71; (n) Tabular cyanobacterial sheaths, GJCJ-15.2; (p, s, and t) fragments of multicellular algae. (p) GJCJ-50; (s) GJCJ-3; (t) GJCJ-3; (q) *Synsphaeridium* sp., GJCJ-41; (r) *Stictosphaeridium* sp. GJCJ-83. Scale bar is 8 μm for (d, f, g, and i); 9 μm for (a, c, e, and k); 10 μm for (h and q); 11 μm for (j); 12 μm for (l); 13 μm for (m, p, and t); 14 μm for (s); 21 μm for (b); 22 μm for (r).

were observed. However, almost no acanthomorph specimens were found in the samples collected from the Kaili Formation.

5. Discussion

Acritarchs are organic-walled microfossils which are usually used to study Paleozoic marine ecology and biostratigraphy. However, much more information regarding the environmental distribution and taxonomy of acritarchs is needed to recognize the full potential of their biostratigraphy [1].

The currently available acritarch assemblages of the Lower and Middle Cambrian boundary are comparable to those from the East European Platform [1,3,4,14]. However, many Lower and Middle Cambrian acritarch assemblages that are known to exist elsewhere in the world are somewhat different from those found in the East European Platform. For example, some characteristic acritarch forms, such as *Baltisphaeridium cerinum*, *Dictyotidium birvetense* and *Skiagia ciliosa*, which have been found in the

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Early-Middle Cambrian of the Amadeus Basin in Australia [15], are not seen in the Lower-Middle Cambrian acritarch assemblages of the East European Platform [3,4,14]. More recently, Raevskaya [16] discussed the diversity and distribution of Cambrian acritarchs from both the Siberian and the East European Platform. She proposed that the conspicuous difference in the acritarch assemblages found in the Siberian and East European Platforms were primarily caused by palaeolongitudinal positions, which could result in different environmental deposits.

Acritarchs obtained from the Kaili Formation of the Jianshan section are dominated by leiospheres. This finding is similar to the previously described acritarch assemblages from the lower-middle portions of the Balang and the Pingzhai sections of the Kaili Formation, which are located in the same area of east Guizhou Province as the Jianshan section. The aspect of acritarch assemblages from the lower part of the Kaili Formation is dominated by leiospheres. The results of a previously conducted study of the sediment of the Kaili Formation in Gedong of Taijiang suggested that the shelf environment was formed at a water depth of 90–200 m [17]. When compared with the known acritarch assemblages of the Kaili Formation in Taijiang and Danzhai areas [10,11], the morphologies or the acritarchs were less diverse than those obtained from the Jianshan section of the Kaili Formation. This finding indicates that the deposited water of the Kaili Formation in the Chuandong area was a little shallower than that of the Kaili Formation in the Jianhe (former Taijiang) and Danzhai areas.

At the genus level, some acritarch forms found in the Jianshan section, such as *Cristallinium, Cymatiosphaera, Granomarginata, Dictyotidium, Lophosphaeridium, Ooidium*, and *Pterospermella*, are comparable to those from the Early-Middle Cambrian strata in the East European Platform. In addition, it should be noted that more diversified acritarchs occur in the samples collected from >46 m above the base of the Kaili Formation than in the samples collected from the bed (<46 m) (see Fig. 2). For example, *Cristallinium ovillense*, *Dictyotidium priscum*, *Retisphaeridium densum, Pterospermella solida, Leiosphaeridia* sp. B, and *Stictosphaeridium* sp. first appear in samples collected from the bed of 46.5 m above the base of the Kaili Formation. Furthermore, more acritarch forms, including *Granomarginata prima, Leiosphaeridia bicura, L.* sp. A, *Lophosphaeridium sp., Ooidium* sp., and *Ovurum saccatum*, initially occur at 71 m above the base of the Kaili Formation. Taken together, these findings indicate that the boundary of acritarch stratigraphic distribution for the studied interval of the Kaili Formation is at the bed, which is located approximately 46 m above the base of the Kaili Formation. According to trilobite data collected from the Jianshan section, the bed at 44.5 m above the base of the Kaili Formation is the base of Cambrian Series 3 [18]. Therefore, the suggested boundary marked by the acritarch biostratigraphy is nearly consistent with the base of Cambrian Series 3 defined by the trilobite zones. Cambrian Series 3 is characterized by the trilobite *Oryctocephalus indicus* zone, whereas Lower Cambrian Series 2 is characterized by the trilobite *Ovatoryctocara glanunata–Bathynotus holopycus* zone [18].

Previously, some acritarch assemblages for the Lower-Middle Cambrian Kaili Formation of both the Balang section and the Pingzhai section were summarized [11]. Specifically, the Lower Cambrian *Cymatiosphaera* cf. *cristata–Fimbriaglomerella membrancea* assemblage and the Middle Cambrian *Cristallinium–Micrhystridium–Pterospermella* assemblage in the Balang section in the Taijiang area differ significantly from the Lower Cambrian *Leiosphaeridia–Tasmanites* and the Middle Cambrian *Retisphaeridium–Micrhystridium tentatium* assemblage in the Pingzhai section in Danzhai area. Although the acritarch assemblages from the two sections are not that similar to each other, it should be noted that the Middle Cambrian acritarch assemblages from both the Baland section and the Pingzhai section are characterized by much higher diversity than those from the Lower Cambrian. Similarly, the acritarch assemblage in Cambrian Series 3 is much more diversified than that of Cambrian Series 2 in the Jianshan section of the Kaili Formation. Taken together, these findings suggest that a remarkable change in both ecological conditions and the depositional environment occurred between the time at which Cambrian Series 2 and Cambrian Series 3 were formed in east Guizhou. This scenario is supported by the extinction of some trilobite genera near the base of Cambrian Series 3. In addition, there is a distinct increase in trilobite genera and species above the base of Cambrian Series 3 in the Wuliu-Zhengjiayan section of the Kaili Formation, with only half of the 12 genera being able to cross the boundary between Cambrian Series 2 and Cambrian Series 3 in that section. A similar situation is also seen in the Jianshan section of the Kaili Formation (to be published). Overall, the results of this study indicate that acritarch biostratigraphy can help to define the boundary between Cambrian Series 2 and Cambrian Series 3, as well as provide significant data, enabling the alteration of ecology in the region to be better understood.

Acknowledgments

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