

Early Cambrian eodiscoid trilobites of the Yangtze Platform and their stratigraphic implications^{*}

YANG Aihua, ZHU Maoyan^{**}, ZHANG Junming and LI Guoxiang

(Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China)

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Abstract Analysis of the taxonomy and stratigraphic distribution of the Early Cambrian eodiscoid trilobites of the Yangtze Platform indicates that species of *Tsuniyidiscus* and *Hupeidiscus* can be used for biostratigraphic correlation. *T. actis* occurs only in the lower Qiongzhusian. *T. armatus* occurs in the lower and middle Qiongzhusian, while *T. niutitangensis* and *T. tingi* occur mainly in the middle and upper Qiongzhusian, with only *T. tingi* extending upward into the lower Canglangpuian. *H. orientalis* first appears in the upper Qiongzhusian, reaching peak abundance in the lower Canglangpuian and becoming extinct above the *Drepanuroides* Zone. Biostratigraphic and lithostratigraphic correlations indicate that the limestone in the lower part of the Mingxinsi Formation, the Upper Member of Jiumenchong Formation, and the upper part of the Middle Member of the Huangbailing Formation, can be correlated with each other as *Hupeidiscus*, an index fossil of the lower Canglangpuian is abundant in all these units. The lower part of the Niutitang and Jiumenchong formations in eastern Guizhou, which mainly represent Qiongzhusian strata, can be correlated with the Lower Member of the Huangbailing Formation. The basal part of the Niutitang Formation, which may be equivalent to the Upper Meishucunian Shiyantou Formation in eastern Yunnan, is very condensed. Well-preserved sponge faunas and non-mineralized fossils in the lower part of the Niutitang and Hetang formations are not older than Qiongzhusian in age.

Keywords: eodiscoids, trilobites, black shale, stratigraphy, Early Cambrian, Yangtze Platform, South China.

Lower Cambrian black shales are well developed in the transitional region of the Yangtze Platform. However, because of the rarity of index fossils, subdivision and stratigraphic correlation of these shales remain controversial^[1-6]. Eodiscoid trilobites are abundant in certain parts of the black shales, but trilobite specialists are in disagreement over the taxonomy and stratigraphic distribution of these fossils. Consequently, the usefulness of these trilobites to the correlation of the Lower Cambrian black shales of the Yangtze Platform and beyond has been limited.

Based on the results of recent investigations on the Niutitang and Jiumenchong formations of eastern Guizhou Province and the Huangbaling Formation of southern Anhui Province, we here revise the taxonomy and clarify the stratigraphic distribution of the Lower Cambrian eodiscoids of the Yangtze Platform. In addition, we use these fossils to develop a new set of stratigraphic correlations of the Lower Cambrian black shales.

1 Synopsis of stratigraphic sections

1.1 Eastern Guizhou Province

Longshancun section: This section is located at Yonghe, Weng'an County, Guizhou Province (Fig. 1 ④). Here the Neoproterozoic-Lower Cambrian sequence is well exposed. The Lower Cambrian succession

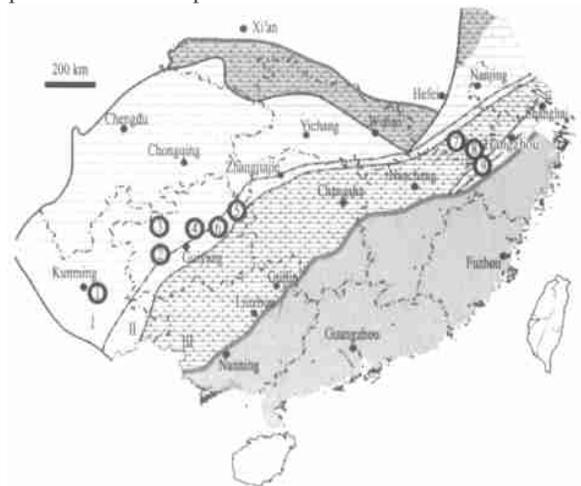


Fig. 1. Geographic maps showing the locations of investigated sections, note the section numbers are the same as in Fig. 2.

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^{**} To whom correspondence should be addressed. E-mail: myzhu@nigpas.ac.cn

consists (in ascending order) of the Niutitang, Mingxinsi and Jindingshan formations. The Niutitang Formation is composed of black shales and disconformably overlies the upper dolomite member of the Dengying Formation. *Tsunyidiscus niutitangensis* has been found in the lower and middle parts of

the Niutitang Formation (the lowest occurrence of this trilobite is 16.8m above the Dengying dolomite). The Mingxinsi Formation, which consists mainly of limestone with trilobites and archaeocyathids, conformably overlies the Niutitang Formation (Fig. 2(4)).

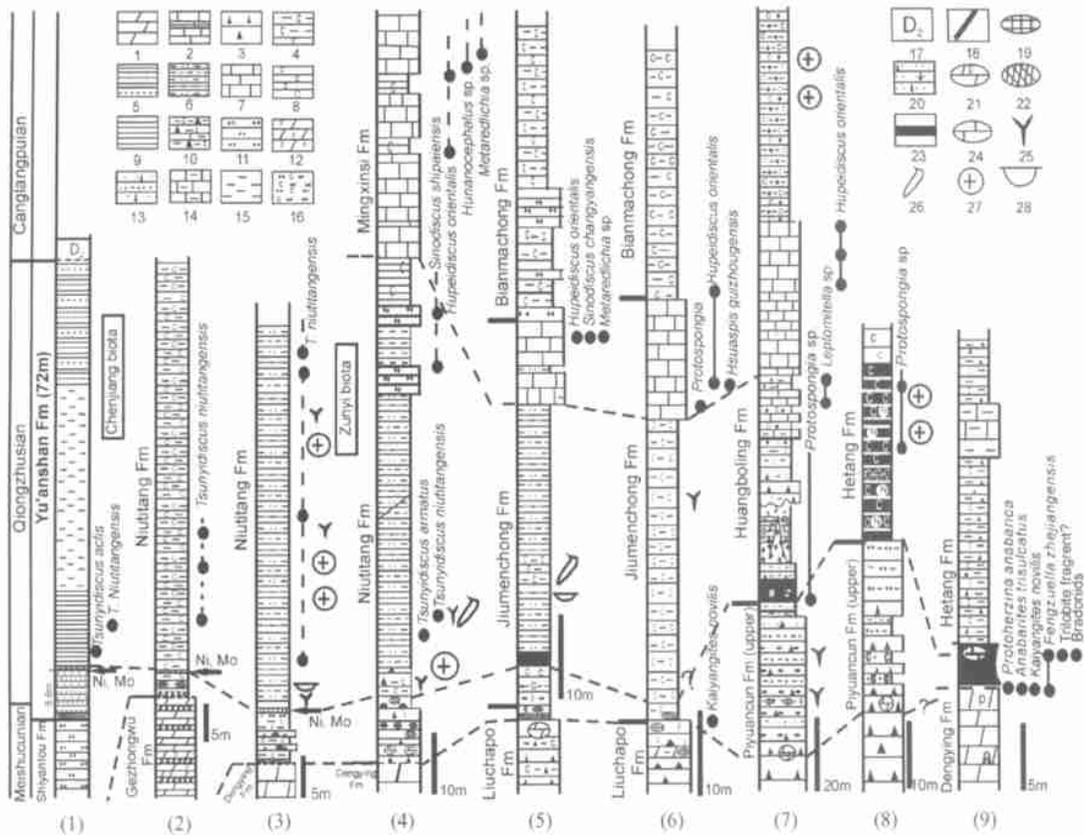


Fig. 2. Stratigraphic correlations of the Lower Cambrian black shales of South China (fossil occurrences in each section are based on our own new data). 1, dolomite; 2, limestone with intercalations of black shale; 3, silicstone; 4, carbonaceous mudstone; 5, siltstone and mudstone; 6, siliceous mudstone; 7, limestone; 8, carbonaceous shale; 9, black shale; 10, carbonaceous silty mudstone; 11, siltstone; 12, phosphatic dolomite; 13, interbeds of siliceous siltstone and muddy siltstone; 14, muddy limestone; 15, mudstone; 16, carbonaceous siltstone; 17, Middle Devonian; 18, fault; 19, barite; 20, siliceous siltstone; 21, phosphatic dolomitic concretions; 22, phosphatic concretions; 23, stone coal; 24, limestone concretions; 25, spicule; 26, rhabdopleurids; 27, complete sponges; 28, bivalved arthropods. (1) Meishucun section, Jinning County, Yunnan; (2) Gezhongwu section, Zhi jin County, Guizhou; (3) Songlin section, Zunyi County, Guizhou; (4) Longshacun section, Weng'an County, Guizhou; (5) Huanglian section, Songtao County, Guizhou; (6) Wuhe section, Taijiang County, Guizhou; (7) Pangwangan section, Dongzhi County, Anhui; (8) Lantian section, Xiuning County, Anhui; (9) Wujialing section, Jiangshan County, Zhejiang.

Huanglian section: This section is located on the eastern limb of the dissected Songtao Anticline (Fig. 1 ⑤). Here the Lower Cambrian successions are well exposed and consist of the (uppermost Proterozoic) Liuchapo and the basal Cambrian Jiumenchong, Bianmachong, Balang and Qingshudong formations^[7]. The Jiumenchong Formation conformably overlies the Liuchapo Formation, which consists of black silicites (cherts) and phosphatic siliceous shales. The Jiumenchong Formation is subdivided into two members. The lower member consists of black shale yielding bivalved arthropods (*Sunella*) and tubular fossils

(*Sphenothallus*) 15 m above the base of the formation. The upper member consists of dark gray argillaceous limestone with trilobites, including *Hupeidiscus* sp., *Sinodiscus changyangensis* and *Metaredlichia* sp.^[7] (Fig. 2(5)).

Wuhe section: This section is exposed along the Qingshui River from Wuhe to Gedong, Taijiang County, Guizhou Province (Fig. 1 ⑥). The Lower Cambrian succession consists of the Liuchapo, Jiumenchong, Bianmachong, Balang and Tsinghsutung formations. The lithology of the Jiumenchong Formation is similar to that of the

same formation in the section at Huanglian. *Hupeidiscus orientalis* (Fig. 3(a), (b)) and *Hsüaspis guizhouensis*

occur in the limestone at the topmost part of the Jiumen-chong Formation (Fig. 2(6)).

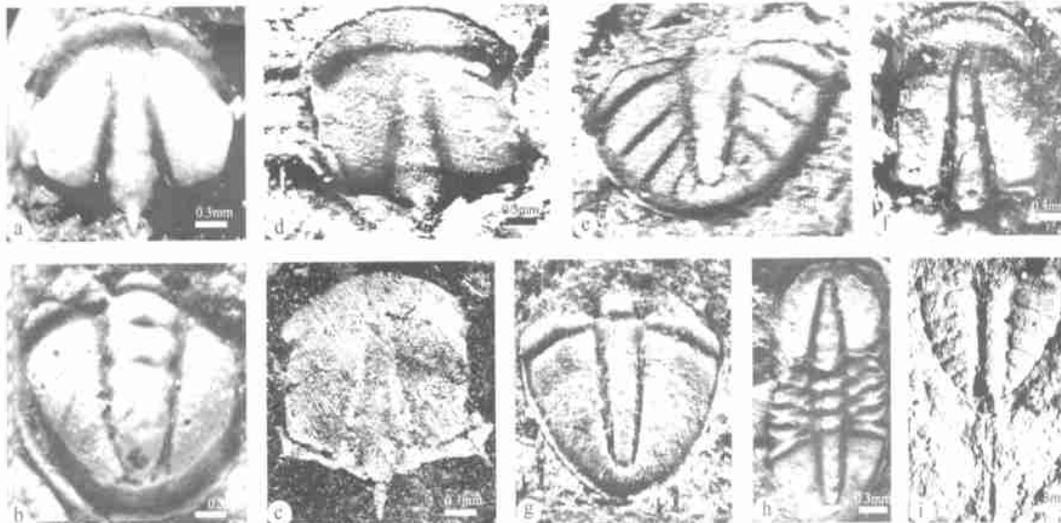


Fig. 3. (a) ~ (c) *Hupeidiscus orientalis* (Chang, 1953). (a), (b) from the upper part of the Jiumen-chong Formation in the Wuhe section near Taijiang County, Guizhou; (c) from the base of Bianmachong Formation in Bageng section near Taijiang County, Guizhou; (a) cranidium, GT VI-14; b. pygidium, GT VI-15. (c) cranidium, GTV-1b. (d), (e) *Tsunyidiscus niutitangensis* (Chang, 1966) from the Niutitang Formation in the Longshancun section near Weng' an County, Guizhou; (d) cranidium, WDe-6; (e) pygidium, WDe-5. (f), (g), (h) *Tsunyidiscus armatus* (Zhang et Zhu, 1980), from the Niutitang Formation in the Longshancun section near Weng' an County, Guizhou; (f) cranidium WDe-13; (g) pygidium WDe-15; (h) exoskeleton, WDe-16, $\times 15$. (i) *Tsunyidiscus aclis* Zhou, 1975, from the "black shale unit" of Yu' anshan Formation, pygidium (by Steiner et al., 2001).

1.2 Southern Anhui Province

Pangwangcun section: This section is located in southeastern Jianxin, Dongzhi County, where it is exposed along the road from Pangwang Village to Dongzhi County Town (Fig. 1(7)). The section starts in the Piyuncun Formation. Succeeding strata consist of the Huangboling Formation and the lower part of the Yangliugang Formation. The upper member of the Piyuncun Formation is composed of about 23 m of siliceous sandstone with intercalations of carbonaceous shale. In addition, lenticular limestone beds occur in the basal part of this member. The Huangboling Formation consists of three members. The lower member is composed of about 32 m of "algal stone coal" and black carbonaceous shale containing sponge spicules. The middle member, about 40 m thick, contains limestones with *Hupeidiscus orientalis*. The lower part of the upper member is composed of about 130 m of black carbonaceous mudstone containing complete sponges; the upper part of this member consists of about 377 m of gray silty mudstone yielding the trilobites *Cheiruroides primigenius* Chang and *Redlichia (Pteroredlichia) chinensis* Walcott (Fig. 2(7)).

Lantian section: This section is located in north-eastern Xiuning County (Fig. 1(8)). The Piyuncun Formation is similar lithologically to rocks in the Pangwangcun section. The Hetang Formation conformably overlies the upper member of the Piyuncun Formation, the lower part of which consists of about 20 m of "algal stone coals" containing complete sponges (Fig. 2(8)).

2 Taxonomic revision and stratigraphic distribution of Early Cambrian eodiscoids

To date, 12 genera and 51 species of eodiscoids have been reported and described from the Early Cambrian of the Yangtze Platform. Again, however, the taxonomy of these fossils is controversial^[8~11]. The most recent investigation, based on published type specimens and new material, revealed that only seven eodiscoid genera are valid (for detailed discussions see Master thesis of Yang Aihua¹⁾). Moreover, only four of the 32 published species of *Tsunyidiscus* are valid. These four species are *T. niutitangensis* Chang, 1966, *T. aclis* Zhou, 1975, *T. armatus* (Zhang et Zhu), 1980 and *T. tingi* (Lu), 1974. *Hupeidiscus orientalis* Chang, 1974 is the sole

1) Yang A. H. Eodiscoids and stratigraphy of Early Cambrian black shales in eastern Guizhou and southern Anhui. Unpublished Master's thesis, Nanjing Institute of Geology and Palaeontology, 2002-1~91.

species of its genus; the other seven described species are junior synonyms of the type species. Because of page limitation, here we only give diagnosis of these five species and their stratigraphic distribution.

2.1 *Tsuniyidiscus aclis* Zhou, 1975

Emended diagnosis: Cephalon semi-elliptical in outline; glabella convex and narrow, divided into three lobes by very faint, broad, shallow transglabellar furrows; occipital ring extending posteriorly into a stout spine; anterior border broad, with about ten small bosses arranged in a regular pattern; posterolateral limb extending posterolaterally into a long and stout genal spine; eye lines long and narrow. Pygidium semicircular in outline, with five to six pairs of pleural furrows; axial posterior tip reaching the border furrow; stout axial spine present on the posterior axial tip^[12] (Fig. 3(i)).

Stratigraphic distribution: *T. aclis* occurs only in the basal part of the *Wutingaspis-Eoredlichia* Interval Zone (Fig. 4).

2.2 *Tsuniyidiscus armatus* (Zhang et Zhu, 1980)

Emended diagnosis: Dorsal exoskeleton elliptical in outline. Glabella convex, narrow, divided by two very shallow transglabellar furrows; occipital ring extending backward into a small spine; border furrow broad and deep; border broad, slightly convex, with bosses; eye lines clear. Thorax with three segments. Pygidium semi-elliptical in outline; pygidial axis elevated; pleural fields smooth (Fig. 3(f), (g), (h)).

Stratigraphic distribution: This species first occurs in the basal part of the *Wutingaspis-Eoredlichia* Interval Zone and extends into the middle of the *Wutingaspis-Eoredlichia* Interval Zone (Fig. 4).

2.3 *Tsuniyidiscus niutitangensis* (Chang, 1966)^[13]

Emended diagnosis: Glabella extremely narrow, extending anteriorly to the border furrow; occipital ring extending posteriorly into a small spine; posterior margin of the cranium with prominent or faint geniculation. Thorax composed of three segments. Mature pygidium bears four pairs of pleural furrows; axial lobe faintly segmented; axial posterior tip does not reach the border furrow (Fig. 3(d), (e)).

Stratigraphic distribution: This species occurs mainly in strata of middle and late Qiongzhusian age.

2.4 *Tsuniyidiscus tingi* (Lu, 1942)

This species was first described and illustrated by Lu^[14]. It differs from the other three species in having five pairs of pleural furrows on the mature pygidium. *T. tingi* generally occurs in the upper Qiongzhusian but may extend into the lower Canglangpuian in Jingdingshan, Guizhou Province^[14] (Fig. 4).

2.5 *Hupeidiscus orientalis* (Chang, 1953)^[15]

Emended diagnosis: Dorsal exoskeleton elongate elliptical in outline. Glabella convex, narrow, conical, with two faint transglabellar or discontinuous glabellar furrows; anterior border narrow and without bosses; palpebral lobes narrow; eye lines long and narrow; genal spines present or absent. Thorax composed of three segments. Pygidium semi-elliptical in outline; axial lobe convex, narrow or stout, with 3 segments and three axial tubercles on the axial lobe; pleural region without pleural furrows, finely granulated (Fig. 3(a), (b), (c)).

Stratigraphic distribution: This species generally occurs in the upper part of the *Yunnancephalus* Assemblage Subzone of the Qiongzhusian Stage, and is abundant in the *Drepanuroides* zone of the Canglangpuian Stage (Fig. 4).

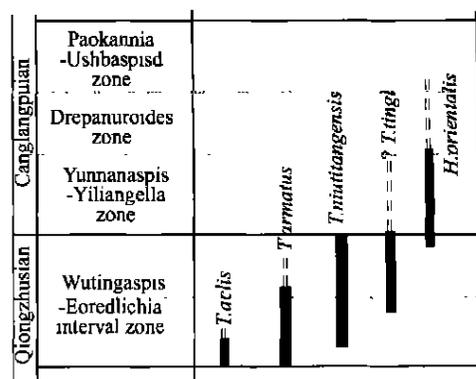


Fig. 4. Stratigraphic distribution of *Tsuniyidiscus* and *Hupeidiscus*.

3 Stratigraphic implications

The relatively short stratigraphic ranges of *Tsuniyidiscus* and *Hupeidiscus* (Fig. 4) make these eodiscoids potentially useful for stratigraphic correlation of the Lower Cambrian black shales of the Yangtze Platform. In eastern Yunnan Province, *T. aclis* and *T. niutitangensis* first appear at the lower

part of *Wutingaspis-Eoredlichia* Interval Zone of the Qiongzhusian Stage^[16~18] (Fig. 2). *T. niutitangesis* occurs about 10m above the base of the Niutitang Formation in the Gezhongwu section, indicating that the lower part of the Niutitang Formation belongs the middle-upper Qiongzhusian Stage. In addition, small shelly fossils from the upper member of the Gezhongwu Formation in this section belong in the *Siphogonuchites-Halkieria* Assemblage-Zone, suggesting that most of the Meishucunian Stage is missing and thus that the boundary between the Niutitang and Gezhongwu formations is a major unconformity^[19~21]. Although small shelly fossils have not been found in the basal part of the Niutitang Formation in the Songling section, the Fe-Ni-Mo-rich layer, which occurs at the base of the Qiongzhusian in eastern Yunnan (Meishucun section in Jinning^[16] and sections in Dezhe, Qujing) and at the base of the Niutitang Formation in the Gezhongwu^[22] and Songlin sections of Guizhou^[3], can be used as a marker bed for regional correlation. The correlations above suggest that only the basal part of the Niutitang Formation in Guizhou represents the upper part of the Meishucunian Stage. The middle and upper parts of the Niutitang Formation can be assigned at least to the Qiongzhusian Stage on the basis of the occurrence of *T. niutitangesis* (5 m above the Fe-Ni-Mo ore layer in the Songlin section, see Fig. 2). Therefore, the age of the Zunyi biota is Qiongzhusian, equivalent to that of the Chengjiang biota in other facies.

The occurrence of *T. niutitangesis* about 10m above the base of the Niutitang Formation in the Longshancun section indicates that the lower part of the Niutitang Formation can also be placed in the middle-upper Qiongzhusian Stage. The lower part of the Mingxinsi Formation, with *Hupeidiscus* and *Metaredlichia*, may belong in the lower Canglangpuian Stage, as *Metaredlichia* first occurs in the lower Canglangpuian Stage^[2]. These correlations suggest that the major part of the Niutitang Formation in NW and SW Guizhou is equivalent in age to the Yu'anshan Formation in Yunnan.

Because of their similar trilobite records, the limestone at the top of the Jiumenchong Formation in the Huanglian and Wuhe sections can be correlated with the lower part of the Mingxinsi Formation in the Longshancun section, suggesting that these limestones are Canglangpuian in age. The lower part of the Jiumenchong Formation is very similar lithologically to the Niutitang Formation in the Longshancun

section. Additionally, the lower parts of these units contain so-called "rhabdopleurids" or colonial monopodial "hydrozoans." Thus, the lower part of the Jiumenchong Formation may be equivalent to the Niutitang Formation, although we do not have biostratigraphic evidence to confirm this correlation. Nevertheless, a distinct and widely distributed phosphatic concretion horizon, generally present at the base of the Jiumenchong and Niutitang formations, can potentially be used as a marker bed for regional correlation (Fig. 2). This is because the phosphatic nodules at the base of Early Cambrian black shale occur in nearly all facies of the Yangtze Platform, indicating that this horizon represents the beginning of a transgressive event which generally occurred no later than the early Qiongzhusian, and may have started during the late Meishucunian (from the base of the Shiyan-tou Formation to the base of the Yu'anshan Formation in eastern Yunnan).

Because of the common occurrence of *H. orientalis*, the upper part of the middle member of the Huangboling Formation in the Pangwangcun section in S Anhui may correlate with the upper part of the Early Canglangpuian Jiumenchong Formation in the Wuhe section in Guizhou. In addition, the upper member of the Huangboling Formation contains *Cheiruroides primigenius* Chang and *Redlichia (Pteroredlichia) chinensis* Walcott, both of which are common in the Mantou Formation (Longwangmiaoian) of the North China Plate^[9]. This fact further supports the conclusion that the upper part of the middle member of the Huangboling Formation belongs in the Canglangpuian Stage. Accordingly, the lower member of the Huangboling Formation may belong in the Qiongzhusian Stage. A "Stone Coal" horizon at the base of the Huangboling and Hetang formations in S Anhui can be used as a marker bed for the boundary between the Qiongzhusian and Meishucunian stages. This is because the "Stone Coal" horizon at the base of the Qiongzhusian occurs throughout the Yangtze Platform (Fig. 2). However, the sequences in the Hetang Formation in Zhejiang Province are complex; they are well developed in certain sections such as the Diben section in Kaihua County, while in other sections (e.g., the Wujialing Section in Jiangshan County^[23, 24]) the Hetang Formation unconformably overlies the Denying Formation (Fig. 2). Therefore, the sections of the Hetang Formation in S Anhui and Zhejiang provinces are chronostratigraphically different, and integrated approaches to

their detailed correlation are required (Fig. 2).

4 Conclusions

Bio- and lithostratigraphic correlations indicate that the limestone bed in the lower part of the Mingxinsi Formation, the Upper Member of the Jiumenchong Formation, and the upper part of the Middle Member of the Huangboling Formation are mutually equivalent and also early Canglangpuian in age. The lower part of the Niutitang and Jiumenchong formations in E Guizhou, which mainly represent Qiongzhusian strata, may be correlated with the Lower Member of the Huangboling Formation. The basal part of the Niutitang Formation, which may be equivalent to the Upper Meishucunian Shiyantou Formation in eastern Yunnan, is very condensed. Extraordinarily well preserved sponge faunas and non-mineralized fossils in the lower part of the Niutitang and Hetang formations generally are not older than the Qiongzhusian (Fig. 2).

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