There was no “Great Bank of Guizhou” in the Early Triassic in Guizhou Province, South China

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Abstract In the 1990s, some geologists named the Early Triassic isolated carbonate platform in the Luodian area of southern Guizhou Province in South China as the “Great Bank of Guizhou”. During the past twenty years, this term “Great Bank of Guizhou” was used in more than 300 articles in foreign countries. In the 1990s, the authors have studied the lithofacies palaeogeography of the Early and Middle Triassic in South China. In June 2014, we went to the Luodian area and studied the Early Triassic Bianyang section again. According to the geological data we acquired, in the Early Triassic of the Luodian area of southern Guizhou Province, there was only an isolated “Luodian Carbonate Platform”, while no bank existed, not to mention the “Great Bank of Guizhou”. It is worth further discussion.

Key words Early Triassic, Luolou Formation, Ziyun Formation, Great Bank of Guizhou, Luodian Carbonate Platform, Bianyang section, South China

1 Problem

In the 1990s, some geologists (Lehrmann, 1993; Lehrmann et al., 1998) named the Early Triassic isolated carbonate platform in the Luodian area of southern Guizhou Province in South China as the “Great Bank of Guizhou”. During the past twenty years, this term “Great Bank of Guizhou” was used in more than 300 articles in foreign countries, but a few articles used it in China.

The authors are both glad and puzzled about this. We are glad to know that both foreign and domestic geologists, especially the foreign geologists, proposed many new thoughtful conceptions and ideas in their articles, which made contributions to the development and innovation of Chinese geology and palaeogeography; but we are also puzzled because there was no “Great Bank of Guizhou” in the Luodian area of southern Guizhou Province; instead, there was a small-scale isolated carbonate platform.

It is worth further discussion.

In the 1990s, the authors have studied the lithofacies palaeogeography of the Early and Middle Triassic in South China (Feng et al., 1994, 1997a).

According to the geologic data of ourselves, this article will discuss whether the Early Triassic “Great Bank of Guizhou” existed or not in the Luodian area of southern Guizhou Province. The criticisms and comments from the foreign and domestic geologists are welcome.

2 Brief introduction of the stratigraphy

The Lower and Middle Triassic are widely distributed in South China and consist of various formation names in different areas (Table 1).

In the Luodian area of southern Guizhou Province, the lower part of the Lower Triassic is the Induan Stage (Feixianguan Stage) Luolou Formation, and the upper part of the Lower Triassic is the Olenekian Stage (Jialingjiang Stage) Ziyun Formation.
### Table 1  Division and correlation of the Lower and Middle Triassic in South China
(simplified from Feng et al., 1997a)

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<tr>
<th>Stratigraphy</th>
<th>Western Yunnan</th>
<th>Longmenshan Area</th>
<th>Middle Sichuan and Northern Guizhou and Southeastern Yunnan</th>
<th>Southern Guizhou and Northern Guizhou</th>
<th>Middle Hunan and Anhui</th>
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<td>Ladinian Stage</td>
<td>Tiangjingshan Stage</td>
<td>Tiangjingshan Fm.</td>
<td>Yangliujing Fm.</td>
<td>Falang Fm.</td>
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<td>Anren Fm.</td>
<td>Bianyang Fm.</td>
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<td>Beijie Fm.</td>
<td>Leikoupo Stage</td>
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<td>Volcanic Rocks</td>
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<td>Anisian Stage</td>
<td>Leikoupo Stage</td>
<td>Beijie Fm.</td>
<td>Leikoupo Fm.</td>
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<td>Olenekian Stage</td>
<td>Jialingjiang Stage</td>
<td>Lamei Fm.</td>
<td>Jialingjiang Fm.</td>
<td>Jialingjiang Fm.</td>
<td>Maocao Fm.</td>
<td>Anshun Fm.</td>
<td>Yongningzhen Fm.</td>
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<td>Induan Stage</td>
<td>Feixiangguan Stage</td>
<td>Feixiangguan Fm.</td>
<td>Feixiangguan Fm.</td>
<td>Yelang Fm.</td>
<td>Feixiangguan Fm.</td>
<td>Feixiangguan Fm.</td>
<td>Yelang Fm.</td>
<td>Luolou Fm.</td>
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<td>Luguhu Fm.</td>
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<td>Permian</td>
<td>Heinishao Fm.</td>
<td>Leping Fm.</td>
<td>Changxing Fm.</td>
<td>Dalong Fm.</td>
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<td>Zhejiang Fm.</td>
<td>Heshan Fm.</td>
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Fm. = Formation
In the Bianyang section of the Luodian area, the basal rock of the Induan Luolou Formation is the yellowish green mudstone, 3–5 cm thick (the “event layer”), which is in conformable contact with the Upper Permian Dalong Formation. The lower part of the Luolou Formation mainly consists of grey thin-bedded to medium-bedded limestone, marlrite, calcareous mudstone, and siliceous mudstone. Near the bottom of the lower part of the Luolou Formation, the mudstone is interbedded with thin-bedded siliceous rock (2–5 cm thick), and contains Claraia wangi, Ophiceras sp. The upper part of the Luolou Formation consists of gravel-sized intraclast limestone, sand-sized intraclast limestone and limestone, interbedded with thin-bedded mudstone. The thickness of the Luolou Formation is 60.8 m. In Guizhou and Guangxi area, the thickness of the Luolou Formation varies greatly (20–1021 m).

At the Bianyang section of the Luodian area, the Olekian Ziyun Formation mainly consists of medium-bedded to thick-bedded gravel-sized intraclast limestone, gravel-sized intraclast-bearing limestone, sand-sized intraclast limestone and bioclastic limestone, interbedded with dark grey, thin-bedded marlrite and mudstone. The graded bedding often occurred in gravel-sized intraclast limestone and sand-sized intraclast limestone. The Ziyun Formation, 148.6 m thick, is in conformably contact with the underlying Luolou Formation.

3 Rock types

At the Bianyang section, there are various carbonate rocks, siltstone, mudstone, and thin-bedded siliceous rock. The content (%) of these rock types in the Luolou Formation and Ziyun Formation are listed in Table 2.

Grain limestone is the limestone in which the grain content is \( \geq 50\% \). There are two kinds of grain limestone, i.e., the sparry grain limestone and limemud grain limestone.

The grain limestone in which the intergranular pores are filled with sparry calcite cement is the sparry grain limestone. It is equivalent to the “sparry allochemical limestone”, mainly the “intramicrite”, “oomicrite”, and “biomicrite” which Folk (1962) proposed. It may be also equivalent to the “grainstone” or “packstone” of Dunham’s classification system (Dunham, 1962). This limemud grain limestone is the main grain limestone of Bianyang section. The grains are mainly algal sand-sized intraclasts and fossil fragments. The oolites are secondary and the typically sand-sized intraclasts are rare.

The granular limestone is limestone in which the grain content is 50%–25%. It may be equivalent to the “packstone” of Dunham’s classification system (Dunham, 1962).

The grain-bearing limestone is limestone in which the grain content is 25%–10%. It may be equivalent to the “wackestone” of Dunham’s classification system (Dunham, 1962).

The limemud limestone is mud-sized crystalline limestone. It is equivalent to the “micrite” of Folk (1962) and the “mudstone” of Dunham’s classification system (Dunham, 1962); but the “mudstone” of Dunham’s classification system (Dunham, 1962) is not perfect, because it is duplicate with the “mudstone” consisting of clay minerals.

The dolostone is mainly penecontemporaneous mud-sized crystalline dolostone.

The gravity flow limestone is mainly clastic flow limestone.

In general, in the Luolou Formation and Ziyun Formation of Bianyang section, the content of various carbonate rocks is >50%, but the content of grain limestone (mainly the limemud grain limestone) is <10% (Table 2).

4 Palaeogeographic maps

4.1 The lithofacies palaeogeographic map of the Early Triassic Induan (Feixianguan) Age in South China

Based on various quantitative data of 45 first order sections, 33 second order sections, and 200 third order sections, and according to the isoline map of thickness (m), the isoline map of content (%) of shallow water carbonate rocks, the isoline map of content (%) of grains with sparry calcite cement, the isoline map of content (%) of penecontemporaneous dolomite, the isoline map of content (%) of deep water sedimentary rocks, and the isoline map of content (%) of strata with marine fossils, then integrating with other regional geological data and via comprehensive analyses, the quantitative lithofacies palaeogeographic map of the Early Triassic Induan Age in South China was composed (Figure 1).
The quantitative data of all sections and the isoline maps are omitted. The first order sections were studied and measured by us, and all kinds of quantitative data from these sections are reliable. The second order sections were measured by previous researchers and were verified by us, the quantitative data of these sections are basically reliable. The third order sections were measured by previous researchers, the data of these sections were collected by us, and the lithologic and thickness data are roughly reliable and can be used as mapping references.

In Figure 1, the eroded region in land is the area in which the thickness is zero. The alluvial and fluvial area in land is the area between the zero isoline of thickness and the zero isoline of the strata with marine fossils. The carbonate platform is the area in which the content of shallow water carbonate rocks is $\geq 50\%$. The clastic platform is the area in which the content of shallow water carbonate rocks is $< 50\%$. The deep water basin is the area in which the content of deep water sedimentary rocks is $\geq 50\%$. The carbonate bank, penebank, and embryonic bank are the areas in which the content of grains with sparry calcite cement are $\geq 30\%$, 29$\%$–20$\%$, and 19$\%$–10$\%$ respectively.

From Figure 1, it can be seen:

In the southern Guizhou Province, there was a Luodian Carbonate Platform. Since this Luodian Carbonate Platform was located in a broad basin of Guizhou–Guangxi–Hunan Basin, it can be named as isolated Luodian Carbonate Platform.

In the southern Guizhou Province, in the Early Triassic Induan (Feixianguan) Age, there was only one isolated Luodian Carbonate Platform; there were no carbonate bank, penebank or embryonic bank.

4.2 The lithofacies palaeogeographic map of the Early Triassic Olenekian (Jialingjiang) Age in South China

Based on various quantitative data of 41 first order sections, 26 second order sections, and 194 third order sections, and according to the isoline map of thickness (m), the isoline map of content (%) of shallow water carbonate rocks, the isoline map of content (%) of penecontemporaneous dolostone, the isoline map of content (%) of grains with sparry calcite cement, the isoline map of content (%) of gypsum, the isoline map of content (%) of deep water sedimentary rocks, and the isoline map of content (%) of the strata with marine fossils, and using the same mapping method as Figure 1, the quantitative lithofacies palaeogeographic map of the Early Triassic Olenekian (Jialingjiang) Age in South China was composed (Figure 2).

From Figure 2, it can be seen:

In the southern Guizhou Province, in the Early Triassic Olenekian (Jialingjiang) Age, there were two isolated carbonate platforms, i.e., the Luodian Carbonate Platform and Duyun Carbonate platform, and there were no carbonate bank, penebank, or embryonic bank.

4.3 The palaeogeographic maps of other monographs

According to the Regional Geology of Guizhou Province by the Bureau of Geology and Mineral Resources of Guizhou Province (1987), in the palaeogeographic maps of the Early Triassic of Induan Age and Olenekian Age (the maps are omitted), in the Luodian area of southern

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### Table 2 Content (%) of rock types of the Lower Triassic Luolou Formation and Ziyun Formation of Bianyang section in Luodian area, southern Guizhou Province, South China

<table>
<thead>
<tr>
<th>Rock types</th>
<th>Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Luolou Formation</td>
</tr>
<tr>
<td>Carbonate rock</td>
<td></td>
</tr>
<tr>
<td>Grain limestone</td>
<td>6.2</td>
</tr>
<tr>
<td>Granular limestone, grain-bearing limestone</td>
<td>24.5</td>
</tr>
<tr>
<td>Limestone mud limestone</td>
<td>44.6</td>
</tr>
<tr>
<td>Gravity flow limestone</td>
<td>12.0</td>
</tr>
<tr>
<td>Dolostone</td>
<td>——</td>
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<tr>
<td>Siltstone</td>
<td>4.1</td>
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<tr>
<td>Mudstone</td>
<td>7.8</td>
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<tr>
<td>Thin-bedded siliceous rock</td>
<td>0.8</td>
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</tbody>
</table>
There was no “Great Bank of Guizhou” in the Early Triassic in Guizhou Province, South China.
Figure 2  Lithofacies palaeogeographic map of the Early Triassic Olenekian (Jialingjiang) Age in South China (Simplified from Feng et al., 1997a).
Guizhou Province, there was only one isolated carbonate platform which was surrounded by a broad open sea (shelf) and there was no bank.

In the Atlas of Lithofacies Palaeogeography of South China (Liu and Xu, 1994), in the lithofacies palaeogeographic maps of the Early Triassic Induan Age and Olenekian Age (the maps are omitted), in the Luodian area of southern Guizhou Province, there was only one isolated carbonate platform which was surrounded by a broad semi-deep sea, and there was no bank.

In another book Triassic Lithofacies Palaeogeography and Mineralization in South China (Wu et al., 1994), in the lithofacies palaeogeographic maps of the Early Triassic Induan Age and Olenekian Age (the maps are omitted), in the Luodian area of southern Guizhou Province, there was only one isolated carbonate platform which was surrounded by a broad basin. In this book, the carbonate bank was not mentioned in the descriptions of the Early Triassic palaeogeography of the southern Guizhou Province.

In general, in these three monographs, in their palaeogeographic maps of the Early Triassic Induan Age and Olenekian Age, and in the Luodian area of southern Guizhou Province, there was only one isolated carbonate platform which was surrounded by deep water sedimentary area. All of the three books did not mention a carbonate bank.

5 About the Chinese articles of “Great Bank of Guizhou”

As mentioned above, in China, there were a few articles that discussed the “Great Bank of Guizhou”. We only found 5 articles altogether, i.e., the Yu et al. (1998), Lehrmann (1999) which was translated from English to Chinese and published in the year 2000, Lehrmann et al. (2009), Xiao et al. (2009), and Li et al. (2011). The authors of these articles are all the partners of Lehrmann who coined the term “Great Bank of Guizhou”.

However, their explanations of the “Great Bank of Guizhou” are rather hard to understand.

In Yu et al. (1998), the first sentence of the abstract is that “the Great Bank of Guizhou is an isolated Triassic carbonate platform located in the Youjiang Basin”.

In Lehrmann (1999) which was translated from Geology (in English) and published in the year 2000 at Guangxi Geology (in Chinese), the first sentence of “Geological Environment” is that “Calcimicrobial mounds and biostromes were found in Lower Triassic strata in the interior of an isolated platform called the Great Bank of Guizhou in the Nanpanjiang basin of southern China”.

In the abstract of Lehrmann et al. (2009), there was the term of “isolated platform (Great Bank of Guizhou)”. In Xiao et al. (2009), the first sentence is that “the Great Bank of Guizhou is a well developed isolated Triassic carbonate platform located in the most northern side of the Nanpanjiang Basin”.

In Li et al. (2011), the first sentence of the abstract is that “the Great Bank of Guizhou located in the Nanpanjiang Basin was an isolated carbonate platform, the initial development of which started at the end period of Late Permian and the last development of which ended in the early Late Triassic”.

In the above 5 articles, there are at least 4 points that are worth discussing.

1) All authors of these articles think that the “Great Bank of Guizhou” and the “isolated carbonate platform” are identical. It is not right. The “carbonate bank” and the “carbonate platform” are two different geological terms that cannot be equalized.

2) Most authors of these articles identified the geological age of “Great Bank of Guizhou” as the entire Triassic. It is not accurate. In our books (Feng et al., 1994, 1997a), the isolated “Luodian Carbonate Platform” only existed in the Early Triassic Induan Age and Olenekian Age. If this isolated carbonate platform was formed at the end period of the Late Permian and ended in the early Late Triassic, it is in need of evidence of sections and palaeogeographic maps.

3) The authors of these articles determined the “Great Bank of Guizhou” was located in the “Youjiang Basin” (Nanpanjiang Basin); but in Figure 1 and Figure 2 herein, in the Early Triassic Induan Age and Olenekian Age, the isolated “Luodian Carbonate Platform” was located in the “Guizhou–Guangxi–Hunan Basin”, not in the “Youjiang Basin” (Nanpanjiang Basin). The Youjiang area (Nanpanjiang area) in the Early Triassic was not a deep water basin, but a shallow water carbonate platform. Certainly, these two figures of ours were composed in the 1990s, and there could be problems and mistakes. Any criticisms are welcome.

4) “The calcimicrobial mounds and biostromes were found in the interior of the isolated platform called the Great Bank of Guizhou”. It was an important development. However, generally speaking, the microbial mound and biostrome are formed in the water body of low hydrodynamic energy, and they do not coexist with the bank which is formed in the water body of high hydrodynamic energy.
6 What is a carbonate platform?

The general definition is that within a stratigraphic unit (such as series, stage, formation), the area in which the shallow water carbonate rocks are predominant, can be defined as a carbonate platform.

Our definition is that within a stratigraphic unit (such as series, stage, formation), the area with the content of shallow water carbonate rocks is \( \geq 50\% \), can be defined as a carbonate platform.

Both definitions are correct. The former is qualitative, and the latter is quantitative.

According to these two definitions of carbonate platform and the content of carbonate rocks of the Lower Triassic Luolou Formation and Ziyun Formation of Bianyang section in Luodian area is \( >50\% \) (Table 2), in the Early Triassic Induan Age and Olenekian Age, and in the Luodian area of southern Guizhou Province, there was a Luodian Carbonate Platform. Because this carbonate platform was located in a broad deep water basin, it can be named as the isolated Luodian Carbonate Platform.

7 What is a carbonate bank?

“Carbonate bank” or “Bank” is a term of the carbonate sedimentary environment and palaeogeography. It was first used in the “Great Bahama Bank” and the “Little Bahama Bank” in the Bahama region (Blatt et al., 1972).

In our books (Feng et al., 1994, 1997a, 1997b, 1998, 2005) and paper (Feng et al., 2014), there are two kinds of carbonate bank, i.e., the sparry bank and the limemud bank.

7.1 Sparry bank

In a carbonate-dominated stratigraphic unit (such as series, stage, formation), the area with the content of sparry grain limestone \( \geq 50\% \), 49\%–30\% and 29\%–10\% can be defined respectively as sparry bank, sparry penebank and sparry embryonic bank.

Also, in a carbonate-dominated stratigraphic unit (such as series, stage, formation), the area with the content of grains with sparry calcite cement \( \geq 30\% \), 29\%–20\% and 19\%–10\%, can be defined respectively as sparry bank, sparry penebank and sparry embryonic bank.

They are two kinds of method to define the sparry banks.

In the sparry grain limestone, the grains are sand-sized intraclasts, ooids (ooliths) and eroded fossil fragments. Because these grains are formed and sedimented in the water body of high hydrodynamic energy, and their intergranular pores are unfilled, therefore the sparry calcite cement can be filled into these pores during the diagenetic stage, and thus the sparry grain limestone is formed.

These sparry bank, penebank and embryonic bank, especially the sparry bank, are the typical banks which were formed in the water body of high hydrodynamic energy.

7.2 Limemud bank

In a carbonate dominated stratigraphic unit (such as series, stage, formation), the area with the content of lime mud grain limestone \( \geq 50\% \), 49\%–30\%, and 29\%–10\%, or the content of grains with limemud \( \geq 30\% \), 29\%–20\%, and 19\%–10\%, can be defined respectively as limemud bank, limemud penebank and limemud embryonic bank (Feng et al., 1998, 2005).

In the limemud grain limestone, the grains are sand-sized intraclasts, ooids and eroded fossil fragments. These grains are formed in the water body of high hydrodynamic energy, but are sedimented in the water body of low hydrodynamic energy, and thus their intergranular pores are filled with limemud.

Therefore, the hydrodynamic conditions of water body of limemud bank, penebank and embryonic bank are obviously different from those of sparry bank, penebank and embryonic bank. They are two different kinds of bank. In conducting of the sedimentary environment analysis and the palaeogeographic study, geologists should treat them differently and not confuse them together.

Here, another issue should be noticed. If the grains in limemud grain limestone are non-eroded fossil fragments (mainly naturally decomposed, \textit{in situ} accumulated, and \textit{in situ} buried), even though these non-eroded fossil fragments with high content (%), they should not be defined as a bank. These non-eroded fossil fragments accumulation can be named as a biostrome, biocrowd (Feng et al., 1997b, 2014), or biomound.

According to the definitions of sparry banks and limemud banks, and the content of grain limestones (mainly limemud grain limestone) of the Lower Triassic Luolou Formation and Ziyun Formation of Bianyang section in Luodian area which is \(<10\% \) (Table 2), therefore in the Early Triassic Induan Age and Olenekian Age, and in the Luodian area of southern Guizhou Province, there were no bank, penebank or embryonic bank, not to mention the “Great Bank of Guizhou”.

However, in some beds of the Luolou Formation and
Ziyun Formation, there were limemud grain limestones, and there existed some small-scale limemud bank, penebank and embryonic bank; but these small limemud banks in some beds did not represent the Early Triassic Induan Age or Olenekian Age, and should not be named as the “Great Bank of Guizhou”.

8 Conclusions

Summarizing the discussions above, the following conclusions are proposed:

1) In the Luodian area of southern Guizhou Province in South China, the content of carbonate rocks of the Lower Triassic Luolou Formation and Ziyun Formation is >50%, there was a Luodian Carbonate Platform in the Early Triassic Induan Age and Olenekian Age. Because this carbonate platform was located in a broad deep water basin, it should be named as the isolated Luodian Carbonate Platform.

2) In the Luodian area, the content of the grain limestone (mainly limemud grain limestone) of the Lower Triassic Luolou Formation and Ziyun Formation is <10%, therefore, in the Early Triassic Induan Age and Olenekian Age, there were no bank, penebank or embryonic bank, not to mention the “Great Bank of Guizhou”.

3) The isolated “Luodian Carbonate Platform” whose name matches the reality, can be used continuously. But the “Great Bank of Guizhou” whose name does not match the reality, cannot be used continuously. The “Great Bank of Guizhou” is not identical to the isolated “Luodian Carbonate Platform”.

4) Proposing the “Great Bank of Guizhou” and the wide citation of this term have made a contribution to the development of Chinese palaeogeography and geology. In this paper, we present a different opinion and try to catch people’s attention. “A hundred flowers blossom and a hundred schools of thought contend” is better than “one flower and one thought”. Under the guideline of the “Two hundred”, let us work together to continually develop both Chinese and international palaeogeography and geology.

References


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