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New data on Hirnantian (latest Ordovician) postglacial carbonate rocks and fossils in northern Guizhou, Southwest China

Guang-Xu Wang, Ren-Bin Zhan, and Ian G. Percival

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New data on Hirnantian (latest Ordovician) postglacial carbonate rocks and fossils in northern Guizhou, Southwest China

Guang-Xu Wang, Ren-Bin Zhan, and Ian G. Percival

Abstract: The Kuanyinchiao Formation (Hirnantian, Upper Ordovician), yielding the typical *Hirnantia* fauna, has commonly been accepted as representing cool-water sediments deposited during the glacial interval in the Hirnantian GSSP region of South China. Recent investigation reveals that the uppermost carbonate-dominated part of this formation yields a warm-water rugose coral fauna with Silurian affinities at many localities of northern Guizhou Province, which substantially differs from the underlying cool-water fauna. This suggests that these carbonates were probably postglacial warm-water sediments, rather than having formed during the Hirnantian glacial interval as previously thought. Such a conclusion is consistent with the evidence from the associated brachiopod fauna, i.e., the *Dalmanella testudinaria-Dorytreta longicrura* community, which is similarly distinct from the underlying typical *Hirnantia* fauna. The sedimentological data show warm-water features at the same level (e.g., the presence of oolitic grains), also supporting this new interpretation.

Keywords: End-Ordovician, postglacial carbonates, rugose corals, brachiopods, South China
Introduction

The *Hirnantia* fauna-bearing Kuanyinchiao Formation has commonly been considered as representing the early-middle Hirnantian cool-water carbonate sediments in South China (Zhan et al. 2010; Rong et al. 2010, 2011), where the Global Boundary Stratotype Section and Point (abbreviated GSSP) for the base of the Hirnantian Stage is located (Chen et al. 2006). Furthermore, it has long been believed that there are no postglacial carbonate rocks and fossils present on the Upper Yangtze Platform, with the earliest shelly fauna following the end-Ordovician mass extinction being assigned to the Wulipo Bed (middle Rhuddanian, Llandovery, Silurian) (e.g., Rong and Zhan 2004a; Zhou et al. 2004; Rong et al. 2013). Hence there has always been a problem to make high-resolution correlation between the GSSP area and shallow-water carbonate platforms, especially those in low latitude regions (Delabroye and Vecoli 2010; Bergström et al. 2014), which consequently limits our understanding of shelly faunal turnover through the Ordovician–Silurian transition.

Our recent investigation, however, has revealed that late Hirnantian postglacial carbonates and fossils are present on the Upper Yangtze Platform of South China (Wang 2014). These occurrences have been partly documented from the Shiqian area of northeastern Guizhou (Wang G.X. et al. 2015). The present paper aims to demonstrate that the uppermost Kuanyinchiao Formation of late Hirnantian age is also represented by postglacial warm-water carbonates at many other localities in northern Guizhou (Fig. 1). Based on such new stratigraphic data, a comprehensive correlation of carbonate rocks across the Ordovician–Silurian boundary on the Yangtze Platform
The Kuanyinchiao Formation has a typical lithology of dark grey argillaceous limestone on the Upper Yangtze Platform, containing abundant brachiopods (i.e., the typical *Hirnantia* fauna), rugose corals, trilobites and a few other fossil groups (Rong 1979; Zhan et al. 2010). This rock unit is generally conformably underlain and overlain by the black shales of the Wufeng and the Lungmachi formations respectively in many near-shore areas. Graptolites from the underlying shales indicate that the base of the Kuanyinchiao Formation lies generally within the *Metabolograptus extraordinarius* Biozone, while the top is dominantly of the *M. persculptus* Biozone, but never extends to the *Akidograptus ascensus* Biozone of the basal Silurian (Rong et al. 2002, 2010; Zhan et al. 2010). The Kuanyinchiao Formation, which contains brachiopods and rugose corals indicative of cool-water environments, has been generally interpreted as representing the cool-water carbonate sedimentation associated with the major Hirnantian glaciation (Chen 1984; Rong 1984; He et al. 2007; Zhan et al. 2010; Rong et al. 2011).

However, lithological and faunal variations through the Kuanyinchiao Formation have been reported at different localities. He (1978) first noted that the uppermost part of the formation yields the distinctive rugosan *Paramplexoides* at some localities of Bijie, northwestern Guizhou. Rong and Li (1999) recognized a new low-diversity brachiopod community from the same level, termed the *Dalmanella*...
*testudinaria-Dorytreta longicrura* community. Although it includes a few brachiopods found in the lower beds of the Kuanyinchiao Formation, this community lacks characteristic elements of the typical *Hirnantia* fauna (e.g., *Hirnantia*, *Kinnella*, *Cliftonia* and *Paromalomena*) (Table 1), and was considered to be a variant (in response to temperature, water depth and substrate fluctuations) of the *Hirnantia* fauna (Rong and Li 1999). Subsequently, the presence of oolitic grains in this formation, which suggests a warm-water environment, has been confirmed at Dongkala of Fenggang (Li et al. 2005, 2008) and at Zhongshu of Renhuai (Wang Y.C. et al. 2015). The puzzling presence of such warm-water carbonates during the Hirnantian glaciation has been attributed by Li et al. (2005, 2008) to the diversion of cold-water currents by the paleolandmass of South China.

**Distribution of warm-water coral fauna**

The Late Ordovician warm-water coral fauna occurs at many localities of northern Guizhou, which are grouped into two distinct areas labeled as A and B (Fig. 1).

In area A, the Kuanyinchiao Formation has conformable contacts with the underlying and overlying rocks, and ranges in thickness from 1.3 to 2 m at different localities (Fig. 2a, b). It consists of dark grey calcareous mudstone and argillaceous limestone bearing the *Hirnantia* fauna in the lower part, and bioclastic limestone in its upper part containing a warm-water coral fauna and a distinctive *Dalmanella testudinaria-Dorytreta longicrura* brachiopod community in the uppermost beds.
(Rong and Li 1999). Ooids were documented from the same level at Zhongshu of Renhuai in the area (Wang Y.C. et al. 2015).

At Guanyintang of Fenggang County in area B the Kuanyinchiao Formation shows disconformable contacts with overlying and underlying rocks, and has a reduced thickness of 0.5 m (Fig. 2c) (Rong et al. 2011). The formation is composed of bioclastic limestone, with a warm-water coral fauna similar to that of area A (Fig. 2d). Its brachiopod fauna is still poorly understood. In addition, oolitic grains were reported from the equivalent limestone at Dongkala, about 5 km southwest of Guanyintang (Li et al. 2005).

The lithological and faunal data presented above indicates that the Kuanyinchiao Formation in area B is most likely comparable with the uppermost part of the same formation in area A (Fig. 3).

**Warm-water coral faunal analysis**

As shown in Figure 3 and Table 1, this warm-water coral fauna is dominantly composed of the distinctive solitary rugosans *Paramplexoides* and *Lambeophyllum*?, in contrast to the underlying cool-water forms, which are typified by distinctive solitary streptelasmatids commonly with much thicker septa and walls (He et al. 2007). This older coral fauna, which is more widespread and restricted to the lower-middle Hirnantian in South China, shows some similarity to the coeval Borenshult coral fauna from central and south-central Sweden (Neuman, 1969). Available occurrence data of *Paramplexoides* confirm its warm-water nature and
Silurian affinities. This genus has been documented from the uppermost Ordovician Keel Formation, an oolitic limestone from mid-western Laurentia (McAuley and Elias 1990), which was situated in the tropic region (Jin et al. 2013). Other records are exclusively from considerably younger Silurian rocks of similarly low latitude regions, including the Shihniulan Formation of northern Guizhou (Kong and Huang 1978) and the Lalong Formation of southern Gansu (South China paleoplate) (He and Chen 1999); the Zhaohuajing Formation of central Ningxia, North China (Gao 1987); the Bridge Creek Formation of central New South Wales, Australia (Mclean 1974) and the Gun River and Jupiter formations of Anticosti Island, Canada (Mclean and Copper 2013).

The coral Lambeophyllum? has been reported from the upper Sandbian (Upper Ordovician) of North America, co-occurring with rugosans Streptelasma, Favistina and Palaeophyllum (Okulitch 1938; Webby et al. 2004; Baars et al. 2013) in the equatorial American-Siberian realm (Webby 1992). Additional possible records come from the upper Katian Sanqushan Formation in southeast China (He and Chen 2004), occupying a warm-water oxygenated environment (Rong and Chen 1987; Rong and Zhan 2004b).

Postglacial interpretation for the uppermost Kuanyinchiao Formation

The end Ordovician extinction has been generally accepted as consisting of two pulses based on the fossil records, corresponding to the start and end of the Hirnantian
glaciation (Harper et al. 2014). However, new sedimentological data suggest that this glaciation may have experienced many episodes of various magnitudes (e.g., Ghienne et al. 2014). Even if this is the case, it is reasonable to assume that the magnitudes of glacial cycles during and after the major Hirnantian glaciation are too small to produce a substantial faunal turnover. In view of this, the glacial interval used in the present paper corresponds to the major Hirnantian glaciation, which possibly include small-scale interglacial intervals. Similarly, the postglacial interval after the major Hirnantian glaciation commonly corresponds to the survival interval following the second pulse of the extinction event, though this interval may also contain small-scale glacial episodes.

Corals display a high sensitivity to temperature fluctuation that enables them to be useful for paleoenvironmental analysis, particularly around the Hirnantian glaciation. The warm-water rugose coral fauna from the uppermost Kuanyinchiao Formation occurs immediately above the typical cool-water *Hirnantia* fauna associated with the major Hirnantian glaciation, and shows latest Ordovician transitional to Silurian affinities. These observations argue against the possibility that this rugose coral fauna flourished during short-lived interglacial periods of the major glaciation, because if that was the case, the coral fauna should occur between (rather than above) horizons yielding the *Hirnantia* fauna and would solely display Ordovician affinities. We therefore suggest that the carbonate rocks from this level probably represent postglacial sedimentation, rather than having been deposited during the glacial interval (or possible small-scale interglacial periods within this
interval) as was commonly believed (Rong and Li 1999; Li et al. 2005, 2008; Wang Y.C. et al. 2015). This interpretation is consistent with the associated brachiopod fauna from this interval (Rong and Li 1999). Considering its low diversity and differences from the typical Hirnantia fauna in the underlying beds (Table 1), we suggest that this fauna probably indicates a postglacial survival interval following the major Hirnantian glaciation. The warm-water sedimentological features of these carbonates mentioned above also support this new interpretation (Li et al. 2005, 2008; Wang Y.C. et al. 2015). Such a conclusion also explains why the lower and middle parts of the Kuanyinchiao Formation in area A are completely absent in area B, which is probably due to the regression related to the major Hirnantian glaciation. This regression likely resulted in the deposition of argillaceous limestone containing Hirnantia fauna in the relatively deeper area A contemporaneous with the stratigraphic gap forming in near-shore area B as the sea level dropped.

**Correlation of carbonates across the Ordovician and Silurian boundary in South China**

To date, the postglacial carbonates of late Hirnantian (Ordovician) and early-middle Rhuddanian (Silurian) age on the Yangtze Platform include: 1) the uppermost Kuanyinchiao Formation (upper Hirnantian) in northern Guizhou; 2) the Shiqian Formation (upper Hirnantian, possibly straddling the Ordovician–Silurian boundary) in Shiqian of northeastern Guizhou (Wang G.X. et al. 2015); and 3) the
Wulipo Bed (middle Rhuddanian) in Meitan of northern Guizhou (Rong and Zhan 2004a; Wang G.X. et al. 2015). A refined correlation of these rocks is presented here (Fig. 4). It should be noted that, because it contains a fauna distinct from that of the Shiqian Formation, the uppermost Kuanyinchiao Formation is suggested to be slightly older than the Shiqian Formation, although their correlation cannot be completely ruled out.

Conclusions

In northern Guizhou Province, the uppermost Kuanyinchiao Formation differs significantly both in sedimentological characteristics (being composed of bioclastic limestone with oolitic intervals) and faunal components (containing a warm-water rugose coral fauna of latest Ordovician age with early Silurian affinities) from underlying beds in the same stratigraphic unit that are grey argillaceous limestones bearing the typical Hirnantia fauna dominated by cool-water brachiopods. We contend that the carbonates of the uppermost Kuanyinchiao Formation probably represent warm-water sedimentation rather than glacial deposits as was previously thought, and that they most likely postdate the major Hirnantian glaciation phases. Recognition of these postglacial carbonates and fossils adds to a growing list of near-contemporaneous strata of latest Ordovician age in South China that, due to their thinness and limited extent, have previously been overlooked or misinterpreted. Increased awareness of these strata should result in further discoveries that will underpin a better and more accurate understanding of the end-Ordovician mass
extinction.

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References


Figure and Table Captions

**Fig. 1.** Locality map showing study areas (A and B) and localities in the text, indicated by hollow triangles. Note that the thick dashed line represents the inferred shore-line during the late Hirnantian interval, based on Rong et al. (2011) and Wang G.X. et al. (2015).

**Table 1.** Taxonomic list of brachiopods and corals from the Kuanyinchiao Formation in the study area. Brachiopod identification is from Rong and Li (1999), and coral faunal list is based on He et al (2007) and our unpublished data.

**Fig. 2.** Outcrops showing some key Ordovician and Silurian boundary successions in study areas. (a)-(c) showing Hirnantian sequence at Zhonggou of Bijie, Shichang of Renhuai and Guanyintang of Fenggang in northern Guizhou respectively; (d) close-up view of the Kuanyinchiao Formation at Guanyintang of Fenggang, showing the abundant warm-water rugose corals; coin for scale is 20.5 mm in diameter.

**Fig. 3.** Stratigraphic correlation of the Ordovician–Silurian boundary successions between the study areas A (Zhougou of Bijie) and B (Guanyintang of Fenggang). Representative rugose corals from the Kuanyinchiao Formation are illustrated with their stratigraphic levels indicated.

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102x64mm (600 x 600 DPI)
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179x92mm (300 x 300 DPI)
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68x39mm (600 x 600 DPI)
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<th>Brachiopods</th>
<th>Corals</th>
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<td><strong>Typical Hirnantia fauna</strong></td>
<td><em>Hirnantia sagittifera</em>, <em>Hirnantia</em> sp., <em>Triplesia</em> sp., <em>Cliftonia</em> sp., <em>Eostropheodonta parvicostellata</em>, <em>Plectothyrella crassicosta</em>, <em>Hindella crassa incipiens</em></td>
<td>Amplexobrachyelasma, Brachyelasma, Bodophyllum, Dalmanophyllum, <em>Densigrewingkia</em>, <em>Eurogrewingkia</em>, <em>Helicelasma</em>, <em>Kenophyllum?</em>, <em>Leolasma</em>, <em>Pyconoides</em>, <em>Salvadorea</em>, <em>Sinkiangolasma</em>, <em>Siphonolasma</em>, <em>Streptelasma</em>, <em>Ullernelasma</em> and some other genera</td>
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<td><strong>Lower-middle part</strong></td>
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<td>dominated elements: <em>Plectothyrella crassicosta</em>, <em>Hindella crassa incipiens</em>, <em>Fardenia modica</em>, <em>Eostropheodonta</em> sp., <em>Amplexobrachyelasma</em>, <em>Brachyelasma</em>, <em>Bodophyllum</em>, <em>Dalmanophyllum</em>, <em>Densigrewingkia</em>, <em>Eurogrewingkia</em>, <em>Helicelasma</em>, <em>Kenophyllum?</em>, <em>Leolasma</em>, <em>Pyconoides</em>, <em>Salvadorea</em>, <em>Sinkiangolasma</em>, <em>Siphonolasma</em>, <em>Streptelasma</em>, <em>Ullernelasma</em> and some other genera</td>
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