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*Applications of Magnetic Susceptibility on Paleozoic Rocks*

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## *Guide Book for Field Excursion*

Devonian-Carboniferous Carbonates around Guilin,  
South China: Stratigraphy and Sedimentology

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[Front cover photo: Elephant Nose Hill in city center, symbol of Guilin City. Note the undulatory paleokarstic surface (even sinkholes) on the white grey fenestral limestones (arrows) which was covered by transgressive black bioclastic (ostracod mainly) mudstones/wackestones deposited in deeper-water condition. This subaerial exposure surface and related karstification were supposed to have been formed at the end of Frasnian (Chen et al., 2004). Dongcun Formation.]

Simplified traffic map around Guilin and Yangshuo



## ITINERARY

South China is the most important region for the Devonian researches in China in various aspects, including paleontology, biostratigraphy, lithostratigraphy, sedimentology, and Guangxi is one of the most important areas for the study of the Devonian in South China, where many typical marine Devonian outcrop sections are located. Guilin is an area with diversified (mainly Devonian) depositional facies, including restricted carbonate platform interior, open platform-platform margin, and marginal slope-basinal facies (Fig. 1). Therefore, Guilin is one of the potential areas suitable for neritic-pelagic correlation, a major goal of SDS (International Subcommittee on Devonian Stratigraphy). During this field trip, several Devonian sections of different depositional settings are expected to visit around Guilin. It is our hope that, after this field excursion, you will not only have some basic knowledge of typical Chinese Devonian in aspects of stratigraphy and sedimentology, but also enjoy the spectacular karstic scenery around Guilin.

This field excursion mainly comprises two routes: Tangjiawan-Etoucun-Nanbiancun south of Guilin and Baisha-Fuhe near Yangshuo (Fig. 1).

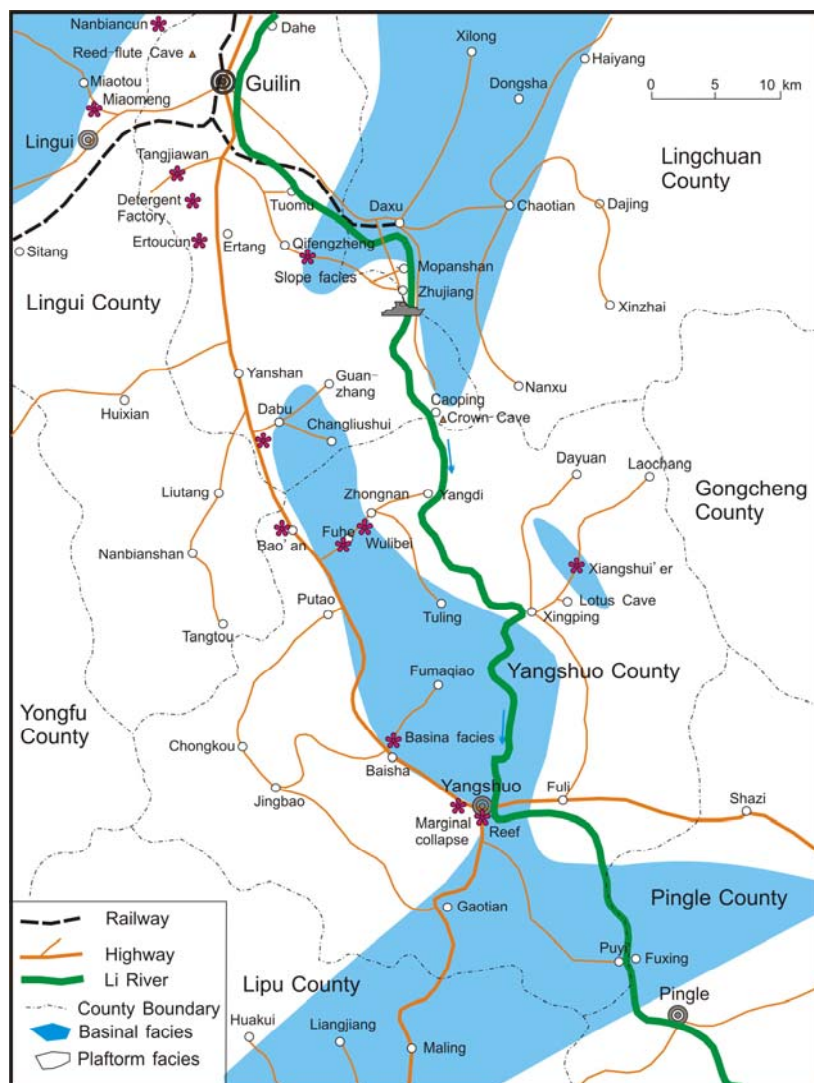


Fig. 1. Map showing outcrop locations and Late Devonian facies distribution around Guilin.

## PALEOGEOGRAPHY AND TECTONICS

From the late Early Devonian (Emsian), especially from the Middle Devonian Givetian (Middle *varcus* Zone), the South China block was initially fragmented and subsided along the antecedent coupling zone between Yangtze and Cathaysia blocks from Guangxi to Hunan in the context of a progressive transtensional tectonic activity, resulting in a transtensional (strike-slip) rift basin domain there from the Late Devonian (Chen et al., 2001; Fig. 2).

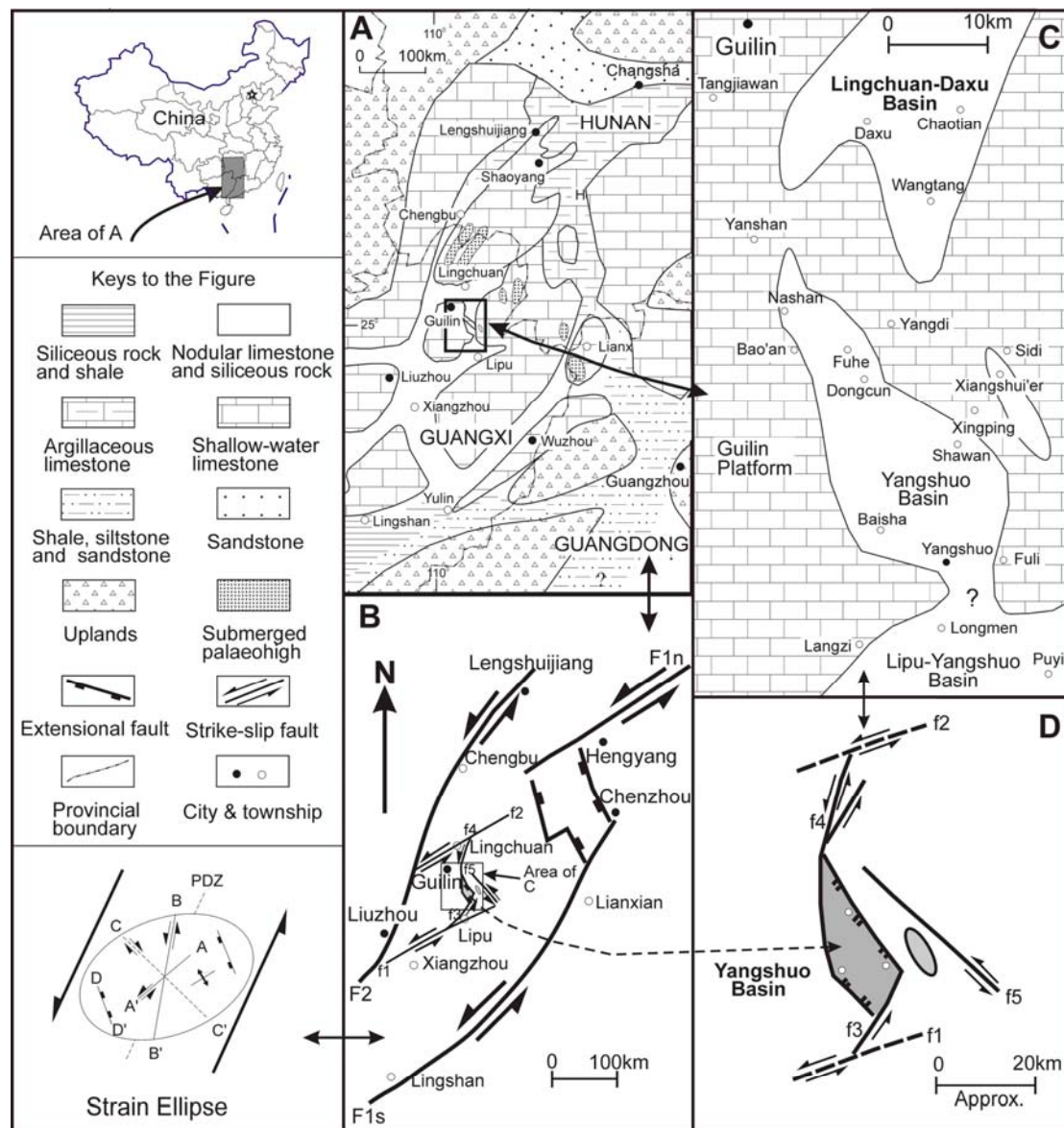


Fig. 2. Late Devonian lithofacies palaeogeography and tectonic setting in South China

Carbonate platforms (or shelf in the Early Devonian) developed on the palaeohighs were commonly bounded by curvilinearly narrow interplatform basins (or troughs) extending locally for several 100s' km long. The specific platform-basin configuration as shown in Figure 2 was interpreted

to having been resulted from the major NNE–SSW-trending, sinistral strike-slip faulting along the deep-seated basement zones, inducing a series of secondary fault zones (i.e., *en echelon*, synthetic and antithetic strike-slip fault zones, and extensional (pull-apart process) fault zones), thereby leading to an extremely complicated platform-basin configuration (Chen et al., 2001a, 2001b, 2006). The spindle- to rhomb-shaped Yangshuo (intraplatform) basin in south of Guilin was likely resulted from pull-apart process induced by secondary strike-slip faulting activity.

The Devonian marine transgression initiated from the Qingfang remnant trough in the southern Gunagxi and expanded progressively northwards in the South China (Fig. 2), in response to the basin-scale, intense basement faulting at depth (e.g., Wu Yi in Zhong et al., 1992; Chen et al., 2001a). During the Early Devonian, marine transgression only reached the central and western parts of Guangxi, including the Liujiang and Dale areas. At that time, frequent sea level changes resulted in frequent progradations/retrogradations of siliciclastic shorelines, leading to the frequent lithologic changes that were represented by different lithologic units (formations/members) in stratigraphic columns. By the very late Early Devonian and early Middle Devonian, the sea gradually covered the northeastern part of Guangxi (including Guilin) and southern Hunan Province. It was not until the Eifelian or Givetian that the marine transgression largely expanded into the central Hunan (e.g., the Xikuangshan area; Fig. 2), represented by the Tiaomajian Formation (Eifelian or Givetian age uncertain, probably early Givetian in age).

According to Wu Yi (in Zhong et al., 1992, p. 286-288), a short-term regression occurred by the late Eifelian and mid-Givetian, respectively, whereas transgression persisted from the late Givetian through Frasnian. However, during the Middle and Late Devonian transitional period, it seems that water depth changed in different ways in different depositional settings. In some areas it became deeper as that is represented by the deposition of the Liujiang Formation and the Baqi Formation (see the Stratigraphy section below; Fig. 3); the former is characterized by bedded cherts, and the latter, by thin- to medium-bedded limestones intercalated with bedded cherts. In other places, the strata are characterized by regressive deposits or even missing, i.e., in central Hunan, the lower Frasnian is mainly composed of sandstones. Tectonic controls might have played an important role, as stressed by Chen et al. (2001a, 2001b).

In the later Frasnian, there were two important deepening events: the *hassi* Zone transgression and the Lower *rhenana* Zone transgression, respectively corresponding to the Lower Rhinestreet Event, and the *semichatovae* transgression recognised world-wide, during which the ammonoid *Mesobeloceras?* fauna and *Manticoceras* fauna occurred, respectively in central Hunan Province (Ma et al., 2004).

During the Frasnian-Famennian transition, sea level dropped substantially in platform facies such as in the Leimingdong section of central Hunan (characterized by occurrence of large-scale sandstones) and the Dushan section of Guizhou and Longmenshan section of Sichuan (both characterized by occurrence of large-scale dolomite successions); whereas in deeper water settings, the picture seems complicated, both slightly shallower and deeper trends have been reported (Wang and Ziegler, 2002).

During the Famennian, the lithological succession is rather simple in a specific locality in Guangxi. Although the sea level generally dropped somewhat compared with the Frasnian, the basic paleogeographic setting was little changed.

## STRATIGRAPHY

In Guilin area, the Devonian stratigraphic successions and relationship between the platform and basin are illustrated in Figure 3.

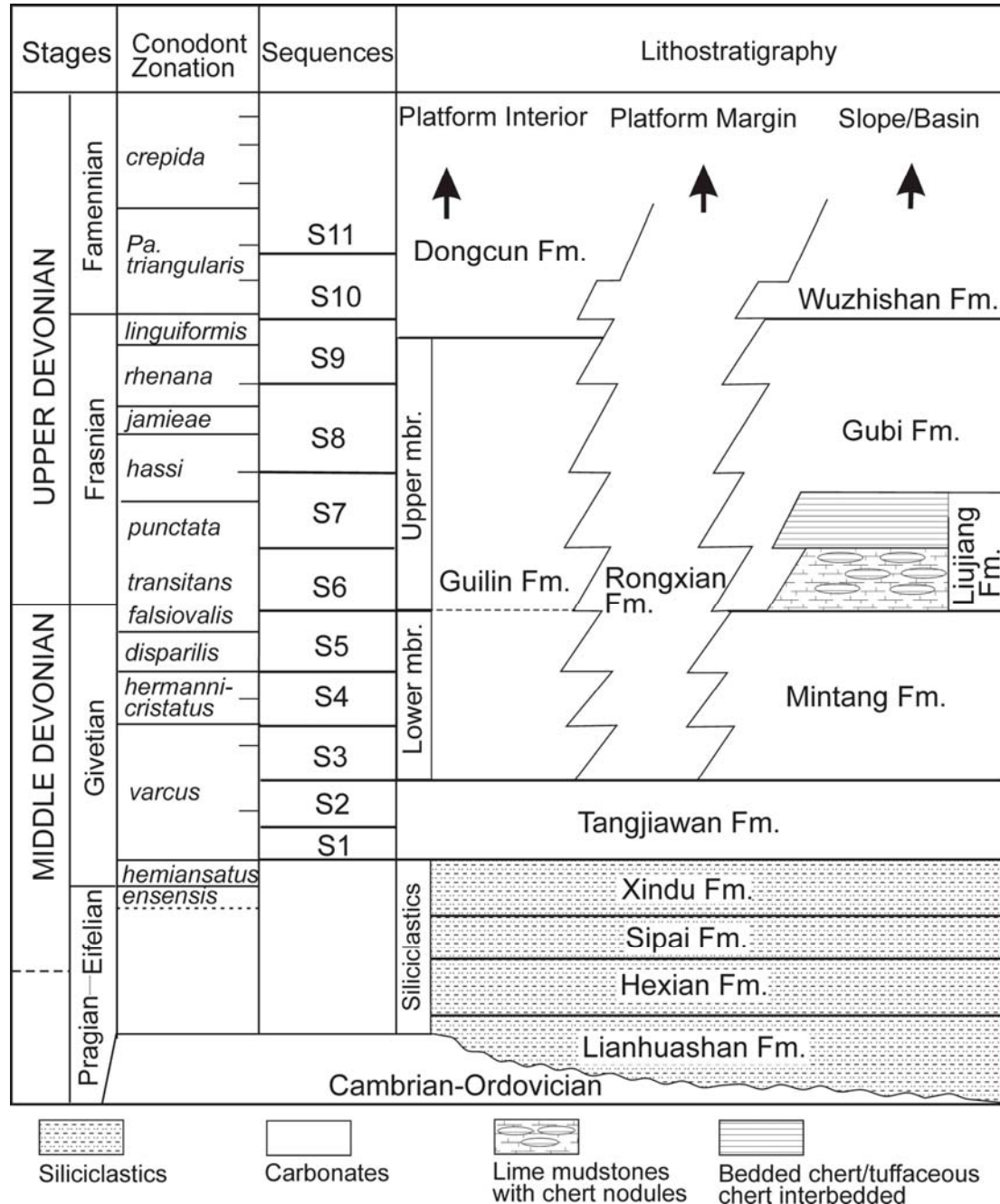


Fig. 3. Devonian stratigraphic successions and relationship between platform and basin in Guilin area.

The basal Tangjiawan Formation is the first carbonate horizon, which overlies the siliciclastic Xindu Formation; it is mainly made of stromatoporoid biostromal facies representing the initial stage of platform-basin evolution. Further upwards, the stratigraphic units vary in different depositional settings. In platform interior, the stratigraphic units, in ascending order, include Guilin, Dongcun and Ertoucun formations, spanning from Givetian to Frasnian and Famennian in age. The Guilin Formation is

characterized by cyclic stromatoporoid biostromes intertating with microbial laminites. The Dongcun Formation mainly comprises cyclic fenestral limestones. Ertoucun Formation is the uppermost horizon of Devonian and mainly composed of dark grey thin- to medium-bedded bioclastic mudstones/wackestones. In platform margin, stratigraphic unit mainly comprises Rongxian Formation ranging from the upper Givetian through Famennian, which is overlain by Ertoucun Formation as well. It is characterized by microbial buildups and shoal deposits. In marginal slope to basinal setting, the stratigraphic succession includes Mintang, Liujiang and Wuzhishan formations. The Mintang Formation is characterized by the intertating of laminated microbialites and deep-water carbonates, and ranges mainly within the upper Givetian. The Liujiang Formation is characterized by starved basinal deposits of siliceous (bedded cherts) rocks, with minor tentaculitid cherty limestones in the base. The Gubi Formation (mainly Frasnian) is chiefly composed of gravity-flow deposits at the platform margin and pelagic limestones (e.g. nodular limestone) with minor gravity-flow intercalations near the basin centre. The Wuzhishan Formation represents distal slope and basin deposits dominated by pelagic nodular limestones with minor calciturbidites, mainly of Famennian age (Fig. 3).

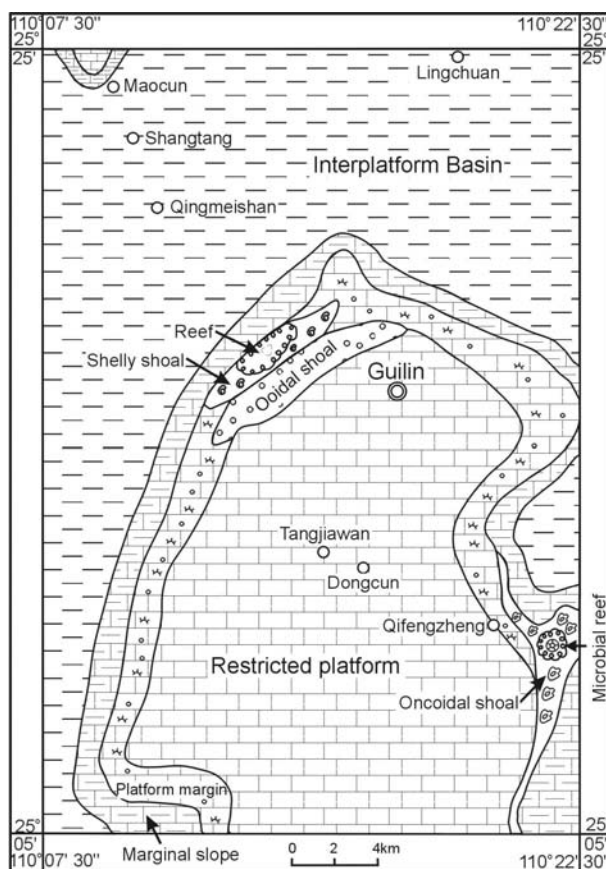
## DESCRIPTIONS OF FIELD TRIP STOPS

### DAY 1

#### Frasnian-Famennian Boundary at Tangjiawan and Devonian-Carboniferous Boundary at Ertoucun and Nanbiancun, Guilin City

In today's itinerary, we will firstly visit the platformal Frasnian-Famennian (F/F) boundary at Detergent Factory (stop 1) and then will move to the platformal Devonian-Carboniferous (D/C) boundary at Ertoucun (stop 2). Afterwards, we are going back to Tangjiawan to look platform interior succession (stop 3) and finally will have a stop at Nanbiancun to look the D/C boundary on the marginal slope setting (stop 4). After finishing these stops, an alternative choose to visit the Reed-flute Cave is tentatively planned on the way back (stop 5), if time is available (Figs. 1, 3). These localities of outcrops are located near the downtown of Guilin City and make them easily accessible by bus.

**Fig. 4.** Palaeogeographic setting of the northern portion of the Guilin Platform during the early Late Devonian (modified from GBGMR, 1988).





## Stop 1

### Frasnian-Famennian (F/F) Boundary at Detergent Factory (near Tangjiawan)

This outcrop is well cropped out at the Detergent Factory near Tangjiawan, about 6 km SW away from the downtown Guilin. Palaeogeographically, this locality was located in the platform interior of Guilin Platform (Figs. 1, 4).



**Fig. 5.** Panoramic view of Frasnian/Famennian boundary (above the Dongcun/Guilin Formation boundary) in the platform succession behind the Detergent Factory of Guilin.

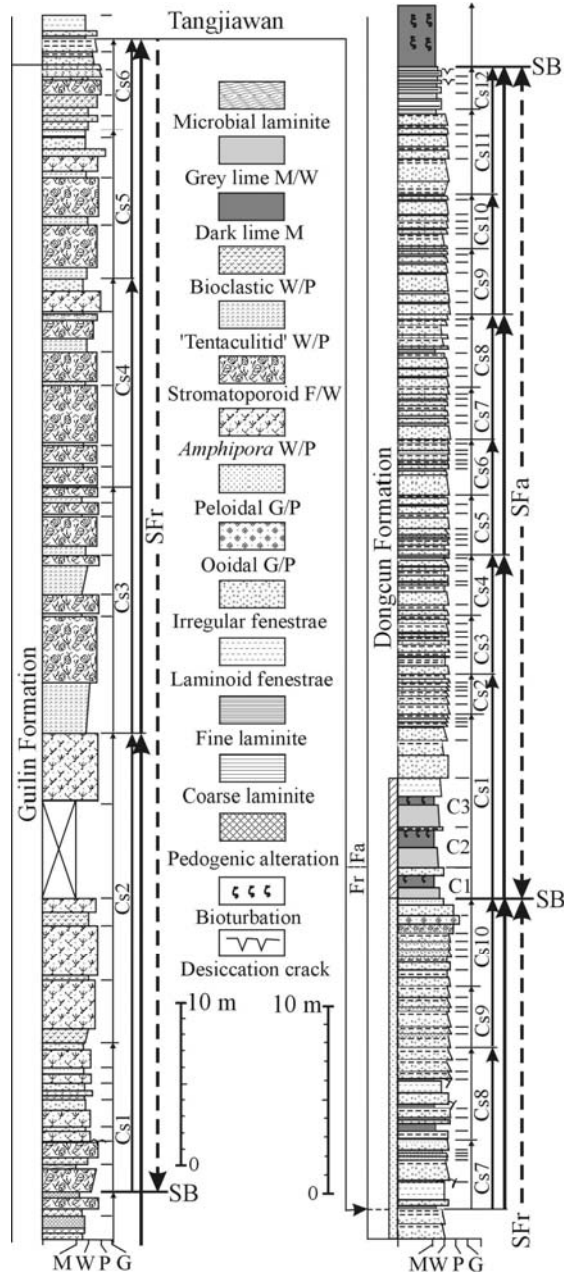
At this locality, we will examine the sharp variations in lithofacies and biofacies across the F/F boundary, across which two lithostratigraphic units are present: the Guilin and Dongcun formations (Fig. 5). The Guilin Formation is characterized by cyclic subtidal-dominant facies associations containing abundant fossils, i.e., spherical to massive stromatoporoids, and branching stromatoporoids (*Amphipora* or *Paramphipora*) (Figs. 6 and 7). The Dongcun Formation is characterized by cyclic fenestral limestone-dominant associations (Fig. 8), in which normal marine benthic fauna decline sharply with extremely rare branching *Amphipora* in the base (~10 m thick). By contrast, gastropods and ostracods occur persistently across the boundary and further upwards. These fenestral limestones mostly consist of non-radiospheric calcispheres, probably a kind of phytoplanktons in the surface water, and algal fragments (Chen & Tucker, 2003) (Figs. 7 and 9). The boundary between Guilin and Dongcun formations is very close to the F/F boundary, but not definitely determined (Ji, 1988).

Across the F/F boundary, cyclostratigraphic analysis (vertical stacking patterns) revealed two third-order depositional sequences (SFr, SFa), in which numerous generally meter-scale, upward-shallowing cycles are extensive. Apparent decrease in accommodation space (or relative sea-level) is unraveled in the base of Dongcun Formation, in parallel with the massive declining of benthic fauna (Fig. 9). Note the last occurrence of stromatoporoids in the top of this succession (Figs. 5 and 7). The subsequent three thickening cycles (with thick bioturbated lime mudstone bases) in the base of SFa (Figs. 7 and 9) represent an apparent deepening during the transgression of sequence SFa; these cycles can be correlated well with their equivalents in basinal successions each by each.

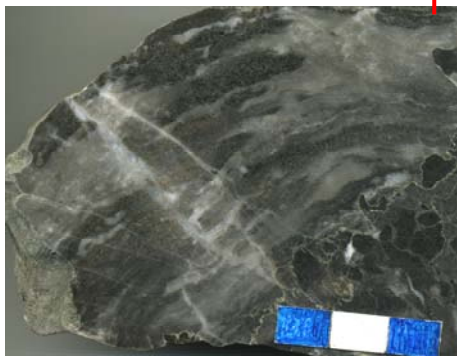
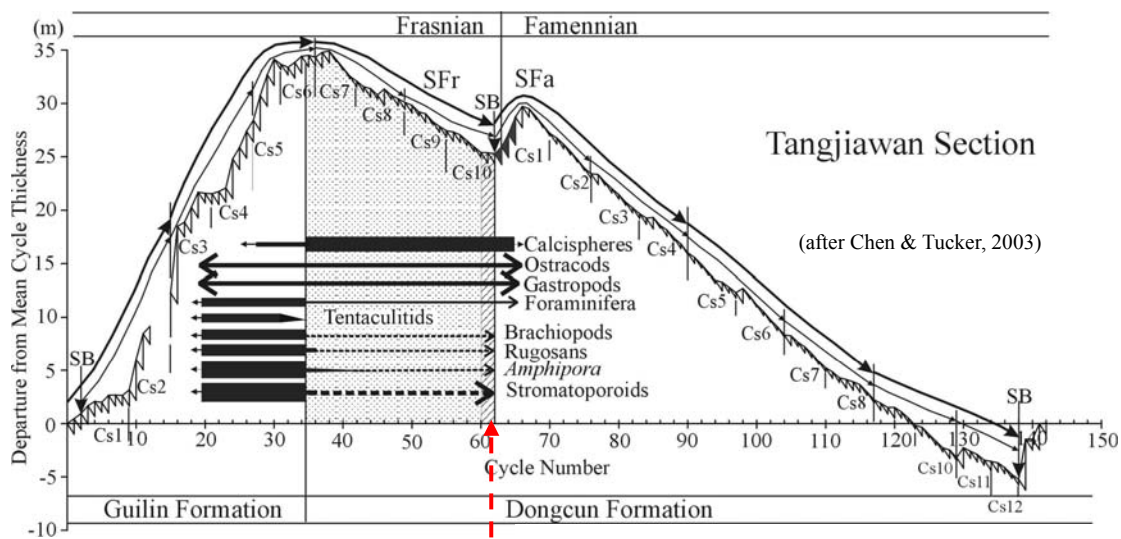


**Fig. 6.** Spaghetti-like *Amphipora* bafflestones/wackestones of the Upper Devonian (Frasnian) Guilin Formation in the Tangjiawan-Dongcun section.

**Fig. 7.** High-resolution cyclostratigraphy in the platform succession across the F/F boundary. Note the internal facies variations within cycles and cycle stacking patterns. Short horizontal lines on the right of the logs mark bounding surfaces of dm- to m-scale shallowing-upward cycles. Vertical thin, medium and thick line arrows define cycle sets (Cs), mesocycle sets and megacycle sets, respectively. The F/F boundary is tentatively placed at the base of the second thickening (or deepening) cycle in the lower part of Dongcun Formation in view of the similar cycle patterns in basinal successions. Note the sharp changes in lithology and fauna near the F/F boundary (after Chen & Tucker, 2003).



**Fig. 8.** Cyclic fenestral limestones starting with irregular fenestral limestones grading upward into laminoid fenestral limestones, typical deposits after the F-F event in platform interior. Dongcun Fm., Dongcun.



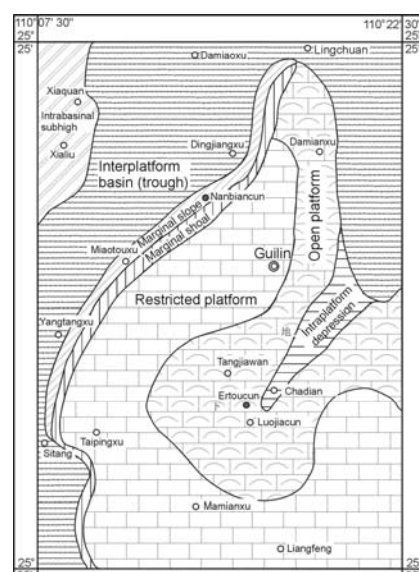
**Fig. 9.** Fischer-plots showing cycle stacking patterns, long-term changes in accommodation space (or sea-level changes) and biotic declining patterns patterns across the F/F boundary at Tangjiawan. Thin line arrows and thick arrows define the ranges of mesocycle sets and megacycle sets, respectively. Dotted interval represents the horizon of massive decline of normal marine fauna coincident with a significant decrease in accommodation space; slashed bar represents the highest occurrence of marine benthos at this locality. Black triangles below the curve represent three thick deepening cycles.

## Stop 2

### Devonian-Carboniferous (D/C) Boundary at Ertoucun

This outcrop is located at Ertoucun-Luojiaocun, southern Guilin, about 1 km south of the F/F boundary at the Detergent Factory. Similarly, this locality was also located in the platform interior (Figs. 1 and 10).

At this locality (Fig. 11), we will examine the lithofacies and faunal changes across the Devonian-Carboniferous (D/C) boundary in platform successions (Fig. 12). The topmost Devonian horizon (Ertoucun Formation, or No. 1 Member of Yanguan Fm.) mainly comprise medium- to thin bedded bioclastic wackestones/mudstones with a thin layer of shale on the top. The basal Carboniferous succession (Yingoudong Fm.) consists of thin-bedded bioclastic wackestones, grading into nodular limestones.



**Fig. 10.** Palaeogeographic setting of the northern portion of Guilin Platform during the Early Carboniferous (modified from GBGM, 1988).

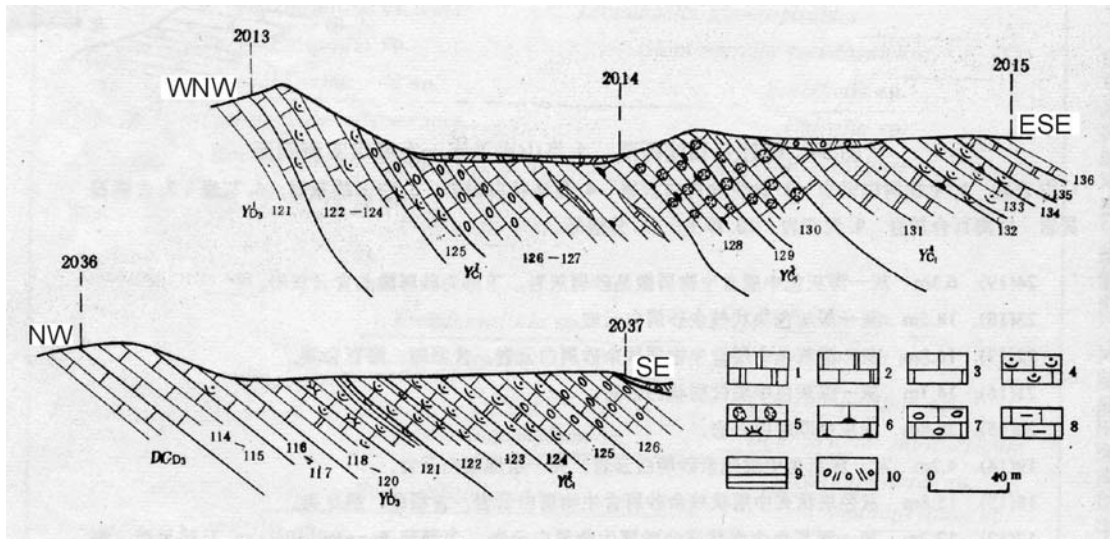


Fig. 11. Outcrop cross-section showing general features across D/C boundary at Ertoucun-Luojiaocun villages. 1-dolomite, 2-dolomitic limestone, 3-limestone, 4-bioclastic limestone, 5-crinoidal limestone, 6-algal limestone, 7-nodular limestone, 8-argillaceous limestone, 9-shale, 10-regolith (after GBGMR, 1988).

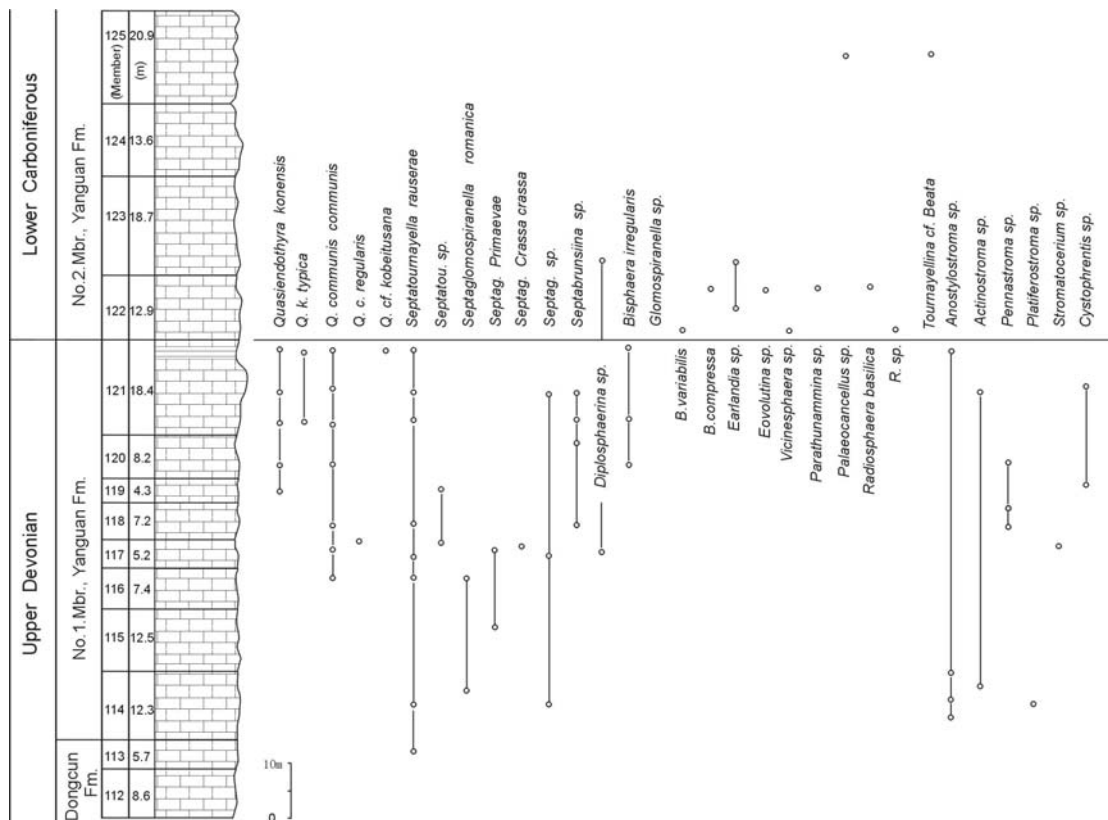


Fig. 12. Main faunal (foraminera) variations across the D/C boundary in the platform succession at Ertoucun (after GBGMR, 1988).

Herewith the brief description of the profile of D/C boundary as follows (after GBGMR, 1988):  
 No. 2 Member of Yanguan Formation (149 m) or Yinggoudong Formation

**Bed 127:** 54.0 m thick (covered, but cropped out along the strike), dark grey medium- to thick-bedded micritic limestones with minor chert and dolomite nodules. Containing corals *Pseudoouralinia* sp., and ostracods.

**Bed 126:** 28.4 m thick, dark grey medium-bedded bioturbated nodular micritic limestone. Including corals *Syringopora* sp; brachiopods *Compsita* sp., *Eomarginifera* sp.; gastropods and foraminiferas *Palaeocancellus* sp., *Evolutina* sp.

**Bed 125:** 20.9 m thick, dark grey medium-bedded, burrowed nodular micritic limestones. Bearing foraminera *Tourmayellina* cf. *beata*, *Palaeocancellus* sp., *Bisphaera* sp., and corals.

Bed 124: 13.6 m thick, grey to dark grey medium-bedded dolomitic bioclastic micritic limestone. Bearing brachiopods, corals and gastropods.

**Bed 123:** 18.7 m thick, grey to black medium-bedded dolomitic micritic limestones. Containing foraminiferas *Earlandia* sp., *Diplosphaerina* sp., ostracods *Shivaella nichesi*, *Primita* sp., *Bairdia* sp., *Acratia* sp., corals *Siphonophyllum* sp., and brachiopods.

**Bed 122:** 129.9 m thick, grey to dark grey thin-bedded micritic limestones. Containing foraminiferas *Bisphaera variabilis*, *B. compressa*, *Earlandia* sp., *Evolutina* sp., *Vicinesphaera* sp., *Parathurammina* sp., *Radiosphaera basilica*, *R. sp.*, corals *Siphonophyllum* sp., and brachiopods and gastropods.

*NO. 1 Member of Yanguan Formation (76 m) or Ertoucun Formation*

**Bed 121:** 18.4 m thick, grey medium- to thick-bedded peloidal-bioclastic wackestones, with minor fenestral algalites. A thin shale layer (5 cm thick) occurs 2 m below the top surface. Abundant fossils and locally concentrated (i.e., stromatoporoids) in layers. Containing stromatoporoids *Anostylostroma* sp., corals *Cystophrentis* sp., foraminiferas *Quasiendothyra konensis typica*, *Q. kobeitusana*, *Bisphaera irregularis*, *Septaournayella rauserae*, *Septabrunsiina* sp., and minor brachiopods and gastropods.

**Bed 120:** 8.2 m thick, grey medium- to thick-bedded bioclastic wackestones with well developed stylolites. Containing stromatoporoids *Pennastroma* sp., foraminiferas *Quasiendothyra c. communis*, *Q. konensis*, *Septaournayella rauserae*, *Septaglomospiranella* sp., *Septabrushiiina* sp., *Bisphaera irregularis*, and brachiopods and gastropods.

### Stop 3

#### Platform interior deposits from Givetian to Frasnian at Tangjiawan

The outcrop starts from Tangjiawan village and extends eastwards along the hill (see Fig. 1 for location). The first carbonate horizon that overlies the siliciclastic succession is Tangjiawan Formation; it is mainly composed of thick stromatoporoid biostromal facies (Fig. 13A), grading upwards into microbial laminites, thus constituting very thick shallowing-upward cycles (up to 20 m thick). This stratal unit was locally strongly dolomitized, in which some of biotic skeletons were dissolved as mouldic vugs and plugged by saddle dolomite cements (Fig. 13B) (Chen et al., 2004), however, the dolomitization was generally inhomogeneous, more intensive along fracture zones, so it was likely induced by structurally-controlled hydrothermal activity.

The overlying Guilin Formation is characterized by more extensive cyclicity and less dolomitization. Extensive meter-scale shallowing-upward cycles commonly start with stromatoporoid bafflestones or wackestones, grading upwards into branching stromatoporoid-dominated facies capped by microbial laminites (Fig. 13C). Further upward, paleosoils can be found on the top of cycles near the

Givetian/Frasnian boundary.

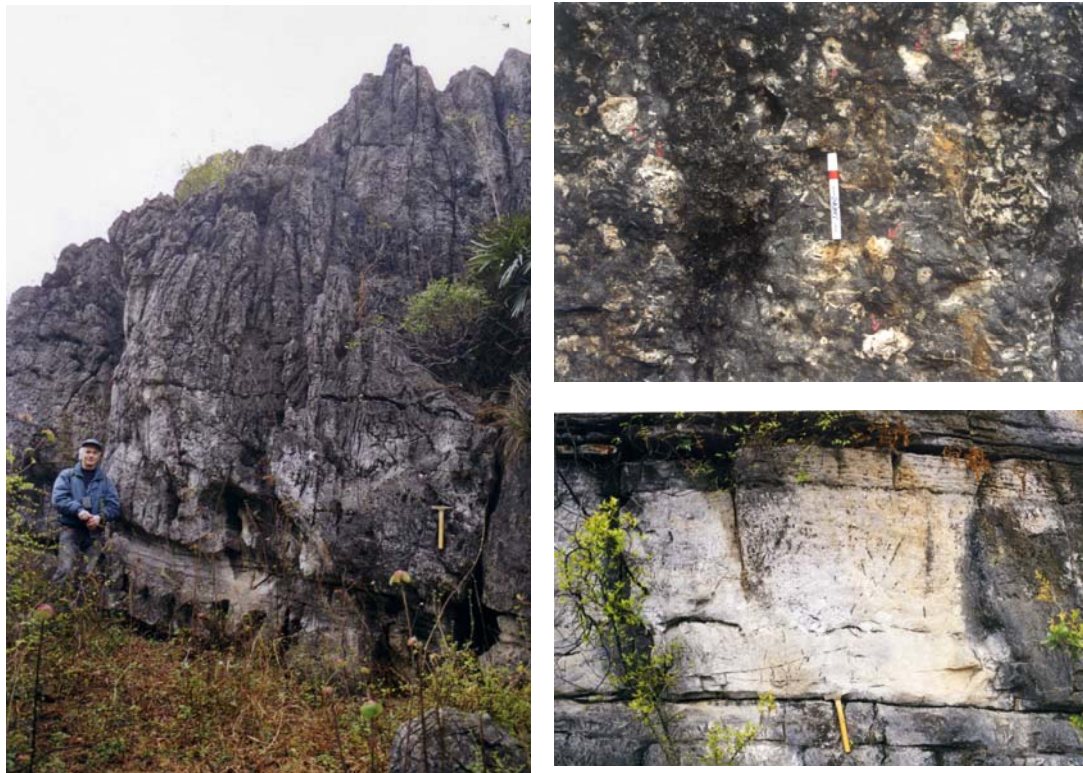


Fig. 13. (A-Left) Very thick to massive biostromal facies being composed of stromatoporoid boundstone, overlying the microbial laminate (the standee is ME Tucker). (B-Upper right) Strongly dolomitized stromatoporoid wackestone/bafflestone, mouldic skeletal vugs plugged by saddle dolomite and later megacalcite crystals (arrows). (C-Lower right) Shallowing-upward cycle commencing with bulbous to hemispheric stromatoporoid bafflestone/wackestone, passing upwards into branching *Amphipora* bafflestone/wackestone capped by the microbial laminite.

## Stop 4

### Devonian-Carboniferous Boundary at Nanbiancun

This outcrop is located at Nanbiancun, about 4 km northwest of Guilin city. Palaeogeographically, it was located at the marginal slope of the Guilin Platform during the D/C transition (Fig. 10). Integrated studies of lithostratigraphy, biostratigraphy, chronostratigraphy, lithofacies, geochemistry and magnetostratigraphy have been conducted on the D/C boundary (Yu et al., 1988), which was approved as the para-stratotype section candidate of the D/C boundary.

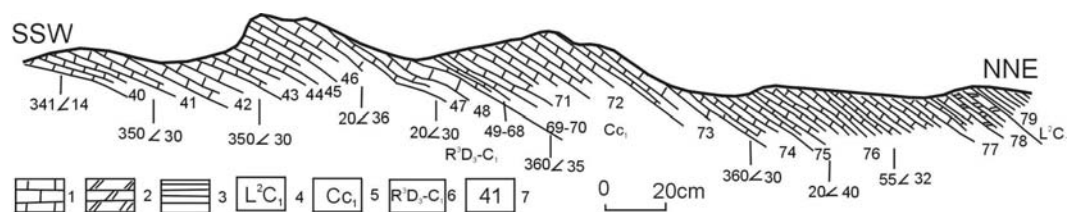
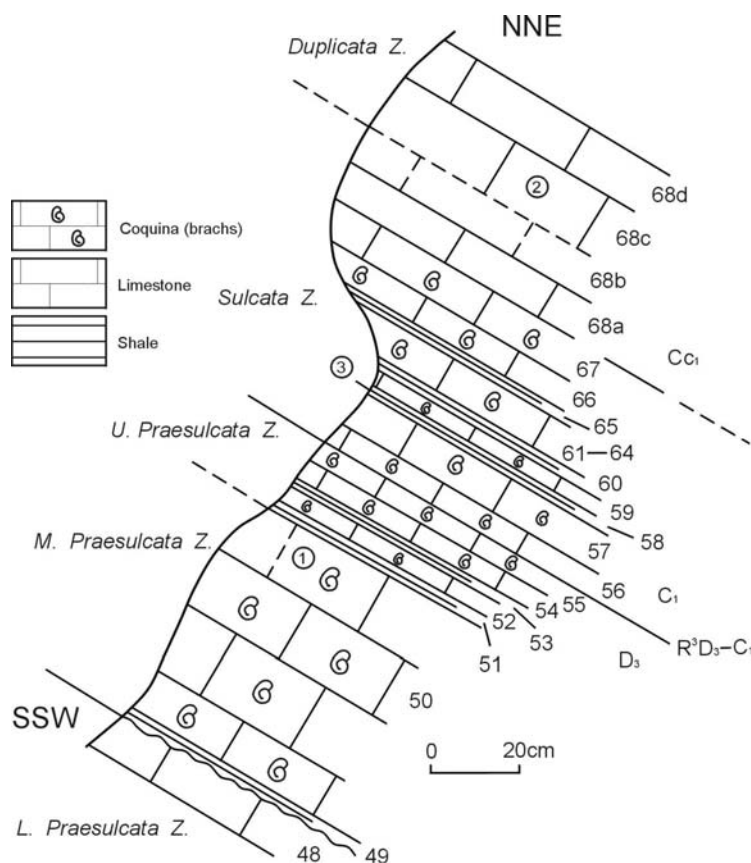


Fig. 14. Outcrop cross-section of D/C boundary at Nanbiancun. 1-limestone, 2-siliceous rock, 3-shale, 4-No. 2 Member of Luzhai Formation, 5-Chuanbutou Formation, 6-No. 3 Member of Rongxian Formation, 7-Bed number (after GBGMR, 1988).



**Fig. 15.** Close-up look of the outcrop showing the D/C boundary at Nanbiancun (after GBGMR, 1988).

At this locality, we will examine the litho- and biostratigraphic variations across the D/C boundary, which is placed along the boundary between beds 55 and 56 in the top of Rongxian Formation (Figs. 14 and 15), based on the evolution of conodont *Siphonodella praesulcata*—*S. sulcata* community (Fig. 16). An apparent event could have occurred between beds 48 and 50, expressed by a serrated surface on the top of Bed 48 overlain by a thin layer (Bed 49) of black shale (0.4 cm) or directly by the coquina limestone, above which coquina limestones are intercalated with several thin layers of black (or dark grey) shales (Fig. 15). This coquina limestone-dominant succession

(beds 49—67) was named as the Nanbiancun Formation by some researchers (i.e., Yu et al., 1988).

Herewith the description of lithological and biotic variations across the D/C boundary at Nanbiancun as follows (GBGMR, 1988):

#### *Upper Member of Rongxian Formation*

**Bed 67:** 9 cm thick, light grey-grey coquina limestones (brachiopods mostly). Yields **conodonts** *Siphonodella praesulcata*, *S. sulcata*, *S. praesulcata* M.2, *S. praesulcata* M.4, *S. sulcata*, *S. semichatovae*, *Polyghathus c. communis*, *Bispathodus* sp.; **trilobite** *Proetus* (*Pudoproetus*) *guangxiensis*; **brachiopods** *Ambocoelia* sp., *Brachythris guilinensis* sp. nov., *B. suborbicularis*, *B.* sp., *Camarotoechia kinlingensis*, *Celsifornix* sp., *Cleiothyridina* cf. *humerosa*, *Crurithysis parvus* sp. nov., *Dielasma corculum* sp. nov., *D. kingi*, *D. cf. pentagonum*, *D.* sp., “*Pustula*” sp., *Guilinospirifer obscure* gen et sp. nov., *G. peregrinus* gen et sp. nov., *Leptagonia analoga*, *Martiniella mazor*, *Martinothyris convex* sp. nov., *M. delicatula* sp. nov., *Mucrospirifer guilinensis* sp. nov., *M. karaukensis*, *Neospirifer?* sp., *Parallelora obesa* sp. nov., *Schuchertella* sp., *Schizophoria resupinata* var. *lyelliana*, *Syringothyris? guilinensis* sp. nov., *S. hannibalensis?* *Rhipidomella michelini*, *Unispirifer* aff. *Clachratus*, *U. tornacensis*, *Yanguania dushanensis*, *Y. pingtagensis*; **corals** *Circella guangxiensis*, *Caninophyllum* sp. nov., *Pseudozaphrentoides* sp., *Dibunophyllum* sp.; **bivalves** *Aviculopecten* sp.; **algae** *Solenopora* sp., *Renalcis granosus*, *Parachaetetes* sp.

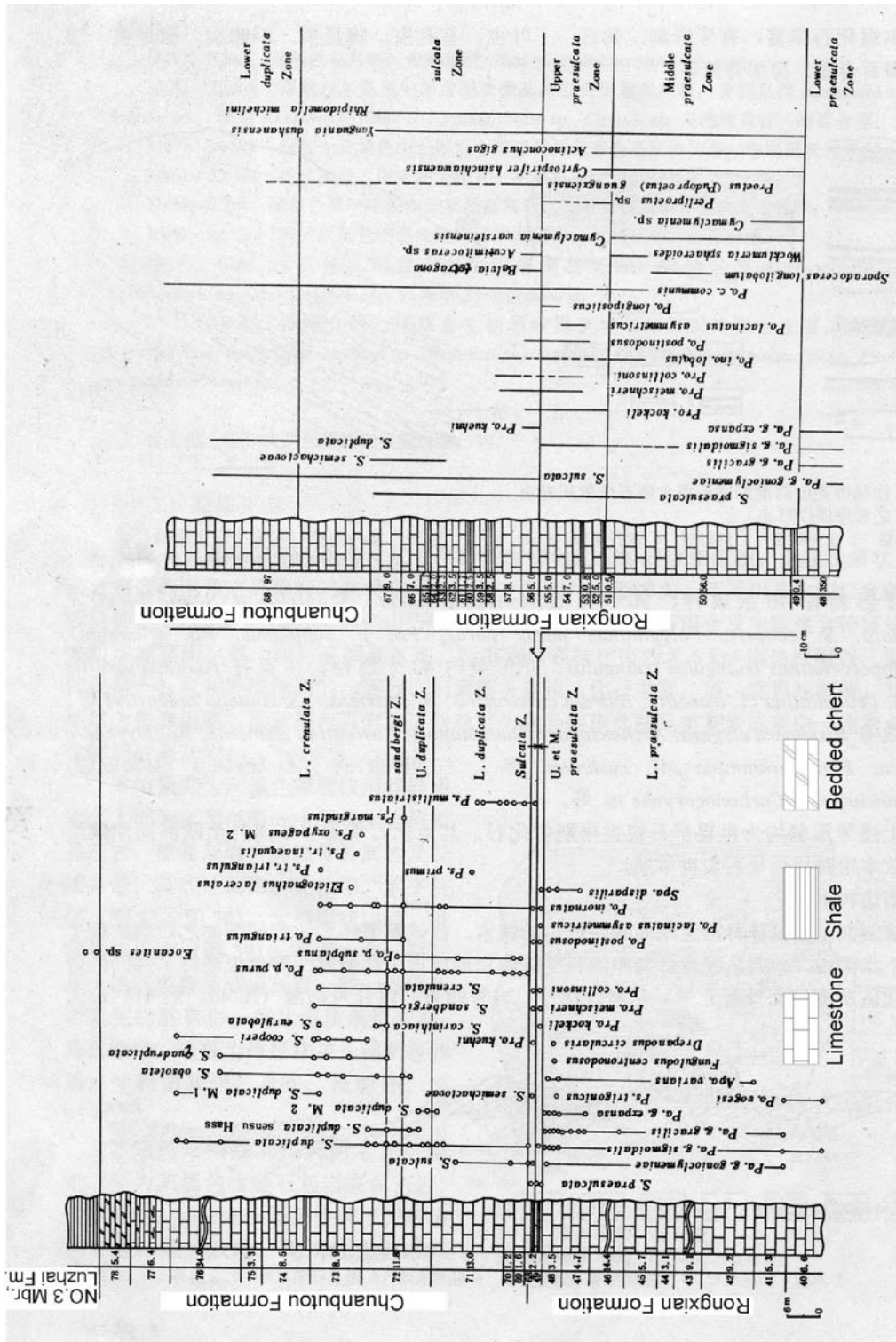


Fig. 16. Conodont biostratigraphy across the D/C boundary at Nanbiancun (Yu, 1988; GBGMIR, 1988).



**Bed 66:** 7 cm thick, grey peloidal-shelly grainstones/packstones. Yields **conodonts** *Siphonodella praesulcata* M. 1, *S. sulcata*, *Polygnathus c. communis*, *Po. inornatus*, *Bispathodus aculeatus aculeatus*; **algae** *Girvanella kasakiensis*, *Sphaeroporella conchatiformis*; **corals** *Guilinophyllum convlutum*; **brachiopods** *Actinoconchus orbicularis*, “*Camarotoechia*” *kinglingensis*, *Syringothyris hannibalensis*, *Schizophoria resupinata* var. *lyelliana*, *Cleiothyridina* cf. *huerosa*, *Unispirifer* aff. *clathratus*, *Yanguania dushanensis*.

**Bed 65:** 1.1 cm thick, grey bioclastic limestones. Yields **conodont** *Siphonodella* sp.

**Bed 64:** 2 cm thick, grey coquina limestones. Containing **conodonts** *Siphonodella* sp., *Polygnathus c. communis*; **brachiopods** *Schizophoria resupinata* var. *lyelliana*, *S. resupinata*, *Unispirifer tornacensis*, *Yanguania dushanensis*.

**Bed 63:** 2.3 cm thick, grey shelly wackestones with minor argillaceous matter. Yields **conodonts** *Siphonodella semichactovae*, *Polygnathus c. communis*; brachiopods *Rhipidomella michelini*, *Schizophoria resupinata* var. *lyelliana*.

**Bed 62:** 3.5 cm thick, grey shelly wackestones with minor argillaceous matter. yields *Polygnathus c. communis*.

**Bed 61:** 1.7 m thick, grey to dark grey shelly wackestones. Yields **conodonts** *Siphonodella sulcata*, *S. praesulcata*, *Polygnathus c. communis*; brachiopods *Schizophoria resupinata* var. *lyelliana*, *Syringothyris* sp.

**Bed 60:** 2.5 cm thick, grey bioclastic shale.

**Bed 59:** 3.5 cm thick, grey-dark grey coquina limestones. Yields **conodonts** *Siphonodella sulcata*, *S. praesulcata*; and bivalves.

**Bed 58:** 2.5 cm thick, grey shale interbedded with bioclastic limestones. Yields **conodonts** *Siphonodella praesulcata* M. 2, *S. sulcata*; **ostracods** *Bairdia curvirostris*, *B. cestriensis*, *Praepilantina* cf. *truncata*, *Shishaella porrecta*; and **brachiopods**.

**Bed 57:** 8 cm thick, grey to light grey shelly grainstones. Yields **conodonts** *Siphonodella praesulcata* M. 1→*S. praesulcata* M. 2, *S. sulcata*, *Protognathus meischneri*, *Pro. collinsoni*, *Polygnathus c. communis*, *Po. inornatus lobotus*, *Bispathodus stabilis*, *B. a. aculeatus*; **brachiopods** *Actinoconchus orbicularis*, *Brachythyris guilinensis*, “*Camarotoechia*” *kinlingensis*, *Cleiothyridina* cf. *humerosa*, *Cyrtina acutirostris*, *Dielasma kingi*, *Guilinospirifer obscure*, *martinothyris convex*, *M. delicata*, *Martiella mazor*, *Schizophoria resupinata*, *S. r.* var. *lyelliana*, *Syringothyris?* *guilinensis*, *S. cf. texta*, *Unispirifer tornacensis*, *Yanguania dushanensis*.

**Bed 56:** 5 cm thick, grey to light grey coquina limestone, with inverse grading. Yields **conodonts** *Siphonodella praesulcata* M. 1→*S. praesulcata* M. 2, *S. praesulcata* M. 4, *S. sulcata*, *Pro. kocki*, *Pro. kuehni*, *Polygnathus c. communis*, *Po. postinodosus*, *Po. cf. inornatus*, *Pseudopolygnathus dentilineatus*, *Bispathodus. a. aculeatus*; **ammonites** *Acutimitoceras* sp., *Balvia tetragona*; **trilobites** *Proetus (Pudoproetus) guangxiensis*; **ostracods** *Shishaella porrecta*, *Bairdia moreyi*; gastropods *Porecellia* sp., *Platyceras* cf. *vetusta*, *P. (Orthonythia) acutirostris*; brachiopods “*Camarotoechia*” *kinlingensis*, *Cleiothyridina* cf. *humerosa*, *Crurithyris* sp., *Dielasma kingi*, *Guilinospirifer obscure*, *G. peregrinus*, *martinothyris convex*, *M. delicata*, *Martiella mazor*, *Mucrospirifer guilinensis*, *M. cf. mundulus*, *Rhipidomella michelini*, *Schizophoria resupinata* var. *lyelliana*, *Semiproductus irregularicostatus*, *S. sp.*, *Syringothyris?* *guilinensis* sp. nov., *Torynifer* sp., *Unispirifer tornacensis*, *Yanguania dushanensis*; **algae** *Solenopora* sp; **bivalves** *Posidonia* sp., *Pernopecten* sp., *Palaeolima* sp. A, *Pterinopecten* sp.

**Bed 55:** 5 cm thick, grey to light grey coquina limestones. Yields conodonts *Siphonodella praesulcata* M. 1→*S. praesulcata* M. 2, *Protognathus kocki*, *Pro. mischneri*, *Palmatolepis gracilis sigmoidalis*, *Polygnathus c. communis*, *Po. postinodosus*, *Po. longiposticus*, *Po. magnidentatus*, *Po. inornatus lobotus*, *Rhodalepis inornatus*; trilobites *Perliproetus?* sp.; **brachiopods** *Actinoconchus orbicularis*, *A. cf. paradoxus*, *Brachythyris guilinensis*, *Cleiothyridina cf. humerosa*, *C. submabrancea*, *Crurithysis aff. lunievensis*, *Cyrtospirifer?* sp., *Dielasma corcula*, *D. kingi*, *Guilinospirifer obscure*, *Martinothyris convex*, *M. delicata*, *Martiella mazor*, *Mucrospirifer depressa*, *M. guilinensis*, *M. karaukensis*, *Rhipidophyris? obesus*, *Schizophoria resupinata*, *S. r. var. lyelliana*, *Semiproductus irregularicostatus*, *Spirifer nanbiancunensis*, *Unispirifer tornacensis*, *Yanguania dushanensis*; **algae** *Parachaetes* sp. B, *Pseudochaetetes elliotti*; **bivalves** *Palaeolima* sp. A, *Pterinopecten* sp.

**Bed 54:** 7 cm thick, grey-light grey coquina limestones. Yields conodonts *Siphonodella praesulcata* M. 1, *S. praesulcata* M. 1→*S. praesulcata* M. 2, *Protognathus kocki*, *Pro. mischneri*, *Pro. collinsoni*, *Palmatolepis gracilis sigmoidalis*, *Polygnathus c. communis*, *Po. postinodosus*, *Pseudopolygnathus detilineatus*; **ostracods** *Bairdia moreyi*, *Shishaella porrectea*; **gastropods** *Phymatopleura* sp.; **brachiopods** *Actinoconchus orbicularis*, *A. cf. paradoxus*, “*Camarotoechia*” *kinlingensis*, *Cleiothyridina cf. humerosa*, *C. submabrancea*, *Crurithysis aff. lunievensis*, *Dielasma corculum*, *D. kingi*, *Guilinospirifer obscurus*, *Leptagonia analoga*, *Martinothyris convex*, *M. delicata*, *Martiniella mazor*, *M. pentagonia*, *Mucrospirifer depressa*, *M. guilinensis*, *M. karaukensis*, *Schizophoria resupinata*, *S. r. var. lyelliana*, *Syringothyris? guilinensis*, *S. hannibalensis?*, *Unispirifer tornacensis*, *Yanguania dushanensis*; **bivalves** *Posidonia* sp., *Rhipidothyris? obesus*; **fishes** *Phoebodus* sp.; algae *Parachaetes cf. garwoodi*.

**Bed 53:** 0.8 cm thick, grey shale intercalated with bioclastic limestones. Yields **conodonts** *Siphonodella praesulcata*, *Polygnathus inornatus*, *Bispathodus spinulicostatus*.

**Bed 52:** 5 cm thick, light grey coquina limestone. Yields conodonts *Siphonodella praesulcata* M. 1, *Protognathus kocki*, *Polygnathus c. communis*, *Polygnathus inornatus*; **trilobites** *Perliproetus?* sp.; **brachiopods** *Actinoconchus elongatus*, *A. orbicularis*, *A. cf. paradoxus*, *A. gigas*, *Brachythyris guilinensis*, *Cyrtospirifer hsinchiawensis*, *Martinothyris convex*, *Mucrospirifer depressa*, *M. cf. mundulus*, *Parallelora obesa*, *Schizophoria resupinata var. lyelliana*, *Semiproductus irregularicostatus*, *Spirifer nanbiancunensis*.

**Bed 51:** 0.5 cm thick, grey shale.

**Bed 50:** 56 cm thick, light grey to dark grey coquina limestones. Concave shells dominant with geopetal fabrics common. Dolomite-calcite cemented veins (1-2 cm wide) common with bitumen inside locally. Abundant **brachiopods** *Actinoconchus elongatus*, *A. gigas*, *A. orbicularis*, *A. cf. paradoxus*, “*Camarotoechia*” *kinlingensis*, *Cleiothyridina submabrancea*, *Composita cf. salve*, *Crurithysis aff. lunievensis*, *Cyrtospirifer hsinchiawensis*, *Dielasma corculum*, *D. kingi*, *Heteralosis abnomalis*, *Leptagonia analoga*, *Martiniella mazor*, *M. pentagonia*, *Mucrospirifer depressa*, *M. karaukensis*, *M. guilinensis*, *Parallelora obesa*, *punctospirifer sp.*, *Romingerina paradoxiformis*, *R. simplex*, *Schizophoria? imbricate*, *Schizophoria resupinata*, *S. r. var. connivens*, *Schuchertella sp.*, *Syringothyris hannibalensis*, *Spirifer nanbiancunensis*, *S. cf. platynotus*, *Straparollus sp.*, *Yanguania dushanensis*, *Y. pintangensis*; **conodonts** *Siphonodella praesulcata*, *Palmatolepis gracilis sigmoidalis*, *Po. inornatus*, *Po. in. lobotus*, *Polygnathus c. communis*, *Bispathodus. Aculeatus*, *Spathognathus disparilis*; **ammonites** *Wocklumeria sphaeroides*, *Cymaclymenia warsteinensis*, *C. sp.*, *Sporadoceras longilobatum*; **ostracods** *Bairdia moreyi*, *Bouckaertites cf. komiensis*, *Shishaella porrectea*; **gastropods** *Platyceras cf. vetusta*, *P. nanbiancunensis*, *P. incerta*, *P. (Orthonychia) acutirostris*,

*Straparollus aequalis*, *Natiria eleganta*; **Algae** *Palaeomicrocodium devonicum*; corals *Canadiphyllum? nabiancunensis*, *Pseudoroemeripora* sp.; **bivalves** *Romingeria paradoxiformis*, *Rhipidophyris? obesus*, *leptodesma (Leiopteria)* cf. *lunulata*, *Mytilarca chemungensis*, *Cypricardina* sp., *Sanguinolites* cf. *unioniformis*; **echinoids** *Mesoblastus* sp.; **bryozoans** *Rhombopora* sp.

**Bed 49:** 0.4 cm thick, black shale.

**Bed 48:** 3.5 cm thick, light grey peloidal limestones intercalated with algal limestones. Yields **conodonts** *Palmatolepis gracilis sigmoidalis*, *Palmatolepis g. expansa*, *Pa. g. gonioclymeniae*, *Pseudopolygnathus trigonicus*, *Apatognathus varians*, *Drepanodina circularis*, *Spathognathus disparilis*, *centronodosus*; **algae** *Renalcis granosus*, *Solenopora.*, *Girvanella* sp., *Nostocites vesiculosa*, *Palaeomicrocodium devonicum*.

## Stop 5 (alternatively):

On the way back from the Stop 4, we will visit the Reed-flute Cave, a typical karstic cave system, also a very popular scenic interest in Guilin area, where we can see the spectacular stalagmites and stalactites whose diversified shapes that inspired numerous legendary stories (Fig. 17). To make your own stories using your wonderful imaginations from what you have seen!



**Fig. 17.** Photo showing the splendid stalactites and stalagmites in the karstic cave (Reed-flute Cave).

## DAY 2

### Boat excursion on the Li River, basinal successions and stratal patterns from platform to basin

First of all, we will have a boat trip on the Li River to see the spectacular karstic landscapes. On the way back from Yangshuo, we will have a short stop at a petrol station, ~1 km away from the Yangshuo, to look the platform collapse near the F/F transition, and have another short stop at Baisha to look the basinal facies succession across the F/F boundary, then will go ahead to the Zhongnan village to see the

strata pattern and geometry in the platform-basin transitional zone, afterwards will be back to Fuhe to look the basinal deposits and cyclicity from Tangjiawan, to Mintang, to Liujiang, to Gubi and Wuzhishan formations along the highway, including the F/F boundary (Fig. 1).

### **Stop 1: Boat excursion on the Li River (optional)**

We will take the bus from the lodging place to the Zhujiang (or Mopanshan) pier, then taken on the two-storey sightseeing boat to start the excursion on the Li River down to Yangshuo (Fig. 1). A boat trip on the peaceful *Li River* is the absolutely high point of any visit to the Guilin. A cruise from Guilin to Yangshuo, visitors will experience the winding and twisting Li River, pass many bizarre tower hills whose shapes have inspired and fired numerous imaginations and legendary stories (Fig. 18). If you are luck, you can experience the peaceful and harmonic life of local people along the river: cormorant fishermen in narrow bamboo boats (rafts), bathing children, water buffaloes, small tranquil villages and women doing their washing on banks of the river along the way.



**Fig. 18.** Photo showing the well-known scenery of painted (or nine-horse) hill along the Li River near Xingping.

Except for the sightseeing interests, the geology related to the spectacular karstic landscapes could be definitely a dessert for this trip. The most breathtaking karstic landscapes occur in the Devonian Rongxian Formation (Upper Devonian) along the river between Caoping and Xingping towns, along which a narrow shallow-water “bridge” or saddle (platform) occurred, linking the Guilin Platform to a larger platform to the east in the Devonian (Figs. 1 and 2). The Rongxian Formation is generally composed of chemically pure and physically brittle microbial limestones, readily resulting in fracturing in the course of later folding and uplift at the onset of the Mesozoic. Progressive fracturing, leaching and dissolution by meteoric waters in the course of exhumation of the specific limestones finally evolved into the spectacular karstic tower hills as that we would see. By contrast, no typical karstic towers but generally mild hills commonly occur in the more muddy and bedded basinal deposits as we see along the river from the Xingping down to the Yangshuo. This trip will end at Yangshuo.

## Stop 2

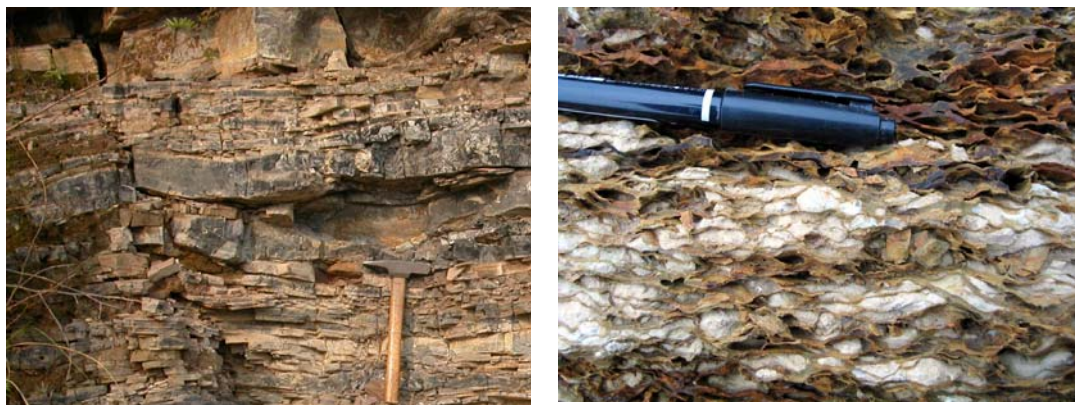
On the way back from Yangshuo, we will have a short stop at a petrol station ~1 km away from Yangshuo (Fig. 1), to have a quick look on the platform collapse occurring in the F/F transitional interval. A magnificent undulatory slide to fault escarpment is overlain by thick megabreccias (~50 m thick) and translational blocks (Fig. 19). These gravity-flow deposits are considered as the equivalents to the calciturbidites in deeper basinal successions (i.e., at Fuhe, Stop 3) (Chen et al., 2001; Chen and Tucker, 2003).



**Fig. 19.** Photo showing the large-scale undulatory slide and fault escarpment, overlain by megabreccia and translational blocks at the petrol station near Yangshuo.

## Stop 3

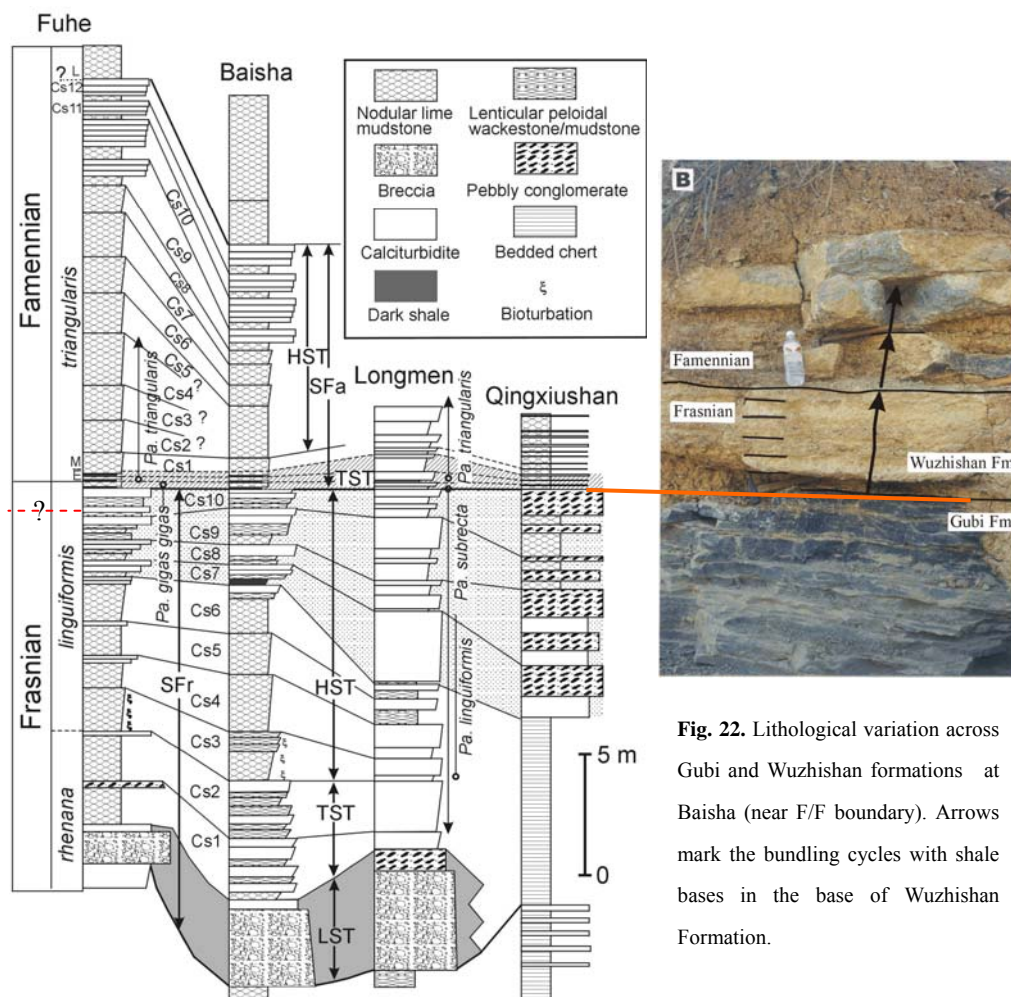
This locality is about 10 km north of Yangshuo, on the eastern roadside of Baisha along the Guilin-Yangshuo highway (Fig. 1). At this locality, we will have short stop to examine the lithological variation in the basinal succession, from the Liujiang, Gubi to Wuzhishan formations, near the F/F boundary.



**Fig. 20.** (A) Bedded chert intercalated with brownish tuffaceous layers in Liujiang Formation at Baisha. (B) Nodular limestones in Wuzhishan Formation at Baisha.

The Liujiang Formation consists of thin-bedded chert interbedded with brownish and grey tuffaceous layers (Fig. 20A), which is overlain by Gubi Formation comprising calcareous gravity flow deposits (debrites and turbidites) and nodular (or lenticular) limestones. It is overlain by the Wuzhishan Formation composed overwhelmingly of nodular limestones (Fig. 20B) with minor calciturbidites (Fig.

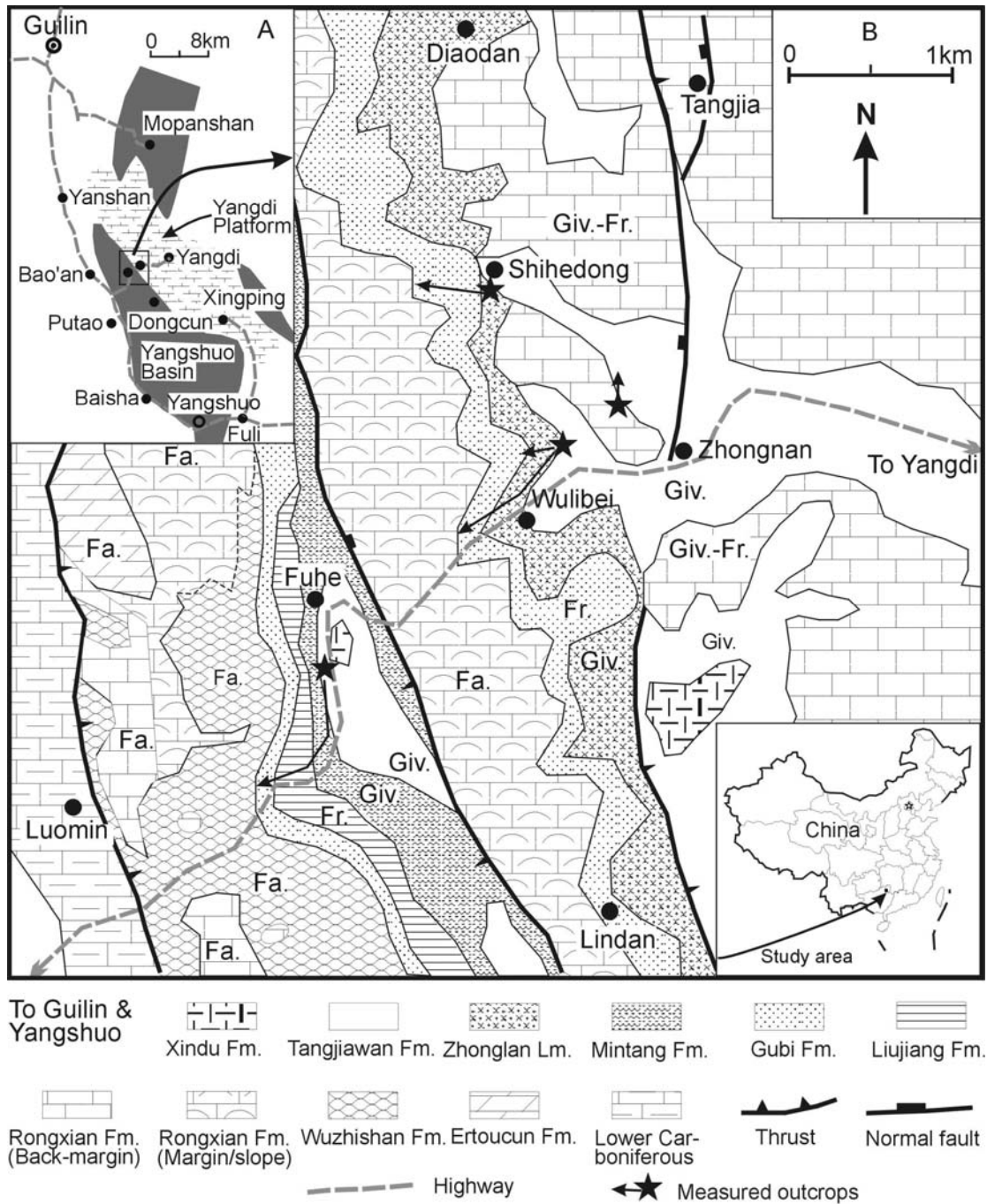
21). The boundary between Gubi and Wuzhishan formations is characterized by the thin-bedded calciturbidites (Gubi Formation) overlain by three shale-based nodular limestone cycles (Figs. 21 and 22), grading upwards into overall nodular limestones, identical with the F/F succession at Fuhe as we will see at Stop 5. Two third-order depositional sequences are identified across the F/F boundary: the lower sequence Fra and the upper sequence Fa (Chen & Tucker, 2003), in which smaller-scale cycle sets (Sc) consisting of (generally 6-8) bundling cycles are well illustrated (Fig. 20). Therefore, a sea-level fall followed by a rapid sea-level rise occurred during the F/F transition (Chen et al., 2002; Chen & Tucker, 2003). An overall positive carbon isotope excursion was revealed across the F/F boundary (Chen et al., 2002, 2005).



**Fig. 21.** Depositional (third-order) sequences in deep-water successions across the F/F boundary in Guangxi area. Sequences: SFr, top Frasnian sequence; SFa, lowermost Famennian sequence. Cs1—Cs12, cycle sets (parasequence sets) within sequences. LST, TST and HST: lowstand, transgressive and highstand deposits, respectively. Dotted horizon is the calciturbidites of late HST deposits in SFr; slashed horizon is the transgressive deposits of SFa (modified from Chen & Tucker, 2003, with additional data).

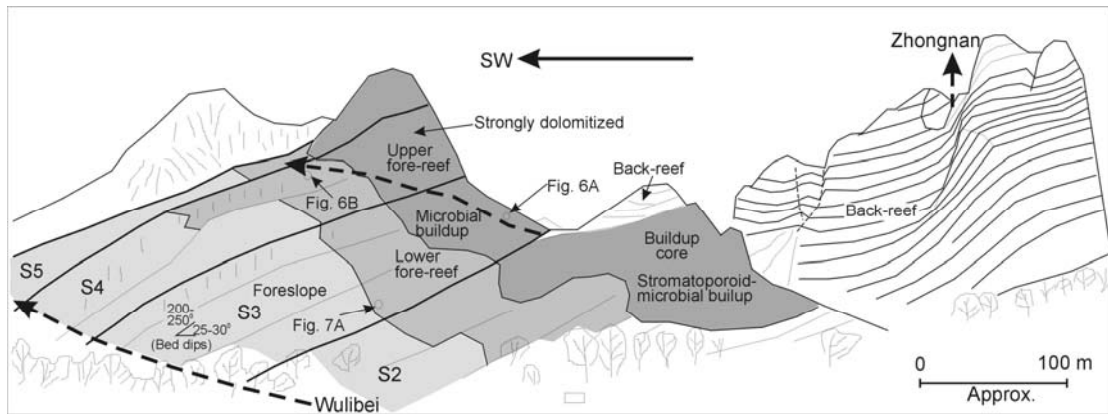
## Stop 4

The outcrop is located near Zhongnan village, on the way between the main highway (to Guilin) and Yangdi. Geologically, it was located at the transitional zone from the platform margin to marginal slope (Figs. 1 and 23).



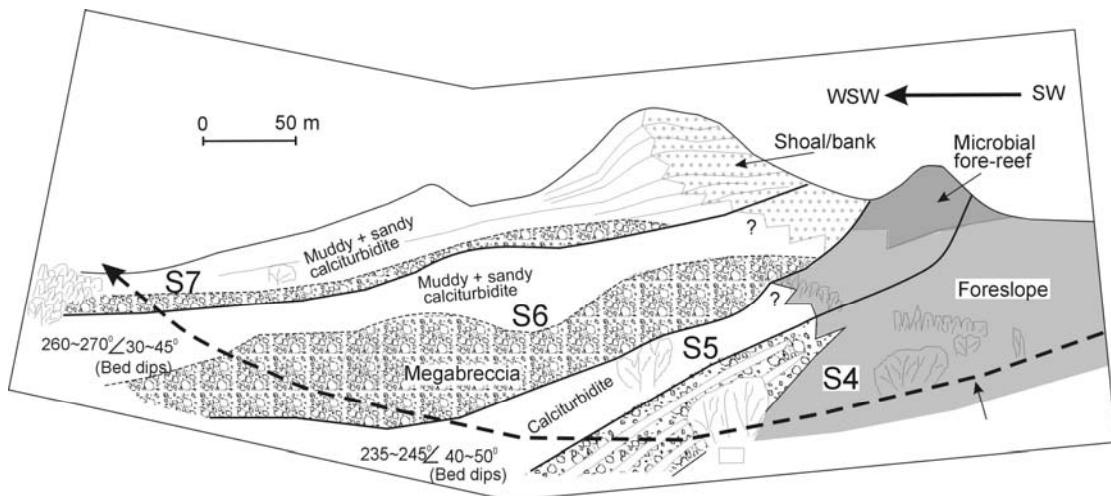
**Fig. 23.** (A) Sketch map showing the configuration of Yangshuo Basin and surrounding platforms around Guilin area. (B) Geological map of area from Fuhe to Zhongnan near Yangdi where deposits of platform margin (nearly horizontally stratified) to slope and basin crop out along the highway. Giv.-Givetian, Fr.-Frasnian, Fa.-Famennian.

The original stratal pattern and geometry from platform margin to marginal slope (horizontal to declined strata) are likely preserved from Zhongnan to Wulibei. During the Givetian, the platform margin was rimmed with microbial buildups (dominated by cyanobacterial *Renalcis-Epiphyton* assemblage), which was transferred to a sandy shoal-rimmed carbonate platform system in the early Frasnian (Fig. 24) (Chen et al., 2002).



**Fig. 24.** A panoramic sketch drawing of photo mosaics showing the stratal pattern transition from the horizontal platform strata (the hill right back in distance) to the inclined foreslope strata of Givetian. Note the aggradational architecture of microbial buildup on the slope. Sequences (S2-S5) are separated by the thick lines. Box at the bottom of hill is 3.5 m high.

This situation occurred in accompanying with a large-scale platform collapse, likely resulted from block-tilting at the platform margin in response to a jerky faulting, such that massive megabreccias and slump blocks being scraped from the mid-upper slope and foreslope moved downdip to the lower slope (Fig. 25). In the latest Frasnian, small-scale microbial buildups colonized once again on the slope, which further thrived on the platform margin during the F/F transitional interval and later on (Chen et al., 2002).



**Fig. 25.** Sketch drawing of photo mosaics showing the general depositional succession and geometry changes from microbially-rimmed platform to sand-shoal platform system from the uppermost Givetian to the Frasnian. The two lower megabreccia/breccia units are composed of microbialites derived from the updip microbial buildups. The upper breccia unit at the base of S7 is mainly composed of stromatoporoid buildup clasts. This diagram is the westward-extending part of Fig. 13 approximately in the dipping direction of slope. Bush-like patterns mean heavy vegetation. Box at the bottom is 3.5 m high.

## Stop 5

The outcrop is located at Fuhe (along the bank of a reservoir), about 1.5 km away from the main highway to Guilin (Figs. 1 and 23). Geologically, this locality was located in the basinal area of the Yangshuo basin. At this stop, we can see the complete stratigraphic succession from Tangjiawan to



Mintang, Liujiang, Gubi and Wuzhishan formations, spanning from Givetian to Famennian in age (Figs. 3 and 23). Firstly, we will see the basal carbonate unit of Tangjiawan Formation, which was totally dolomitized, with extensive mouldic vugs of skeletons and zebra fractures cemented by saddle dolomite and calcite crystals as seen at Tangjiawan (Fig. 26) (Chen et al., 2004). The Mintang Formation is mainly composed of bioclastic mudstones/wackestone intercalated with deep-water microbialites, in which tentaculitids are contained. Liujiang Formation comprises basal chert limestones and bedded cherts upwards in the lower Frasnian. The siliceous succession, 20-25 m thick, consists of black thin-bedded chert interbedded with brownish tuffaceous layers (Fig. 27). REE geochemistry suggests these chert deposits were mainly precipitated from hydrothermal venting fluids channelled through the basement faults at depths, as indicated by convex-shaped REE patterns and positive Eu anomalies (Chen et al., 2006).



Fig. 26. Strongly dolomitized limestones of Tangjiawan Formation. Note the saddle dolomite-filling mouldic vugs of stromatoporoids and brecciation.

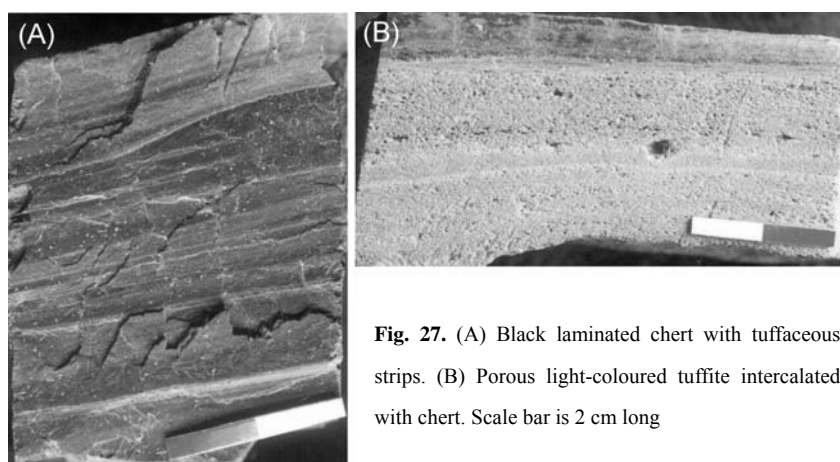
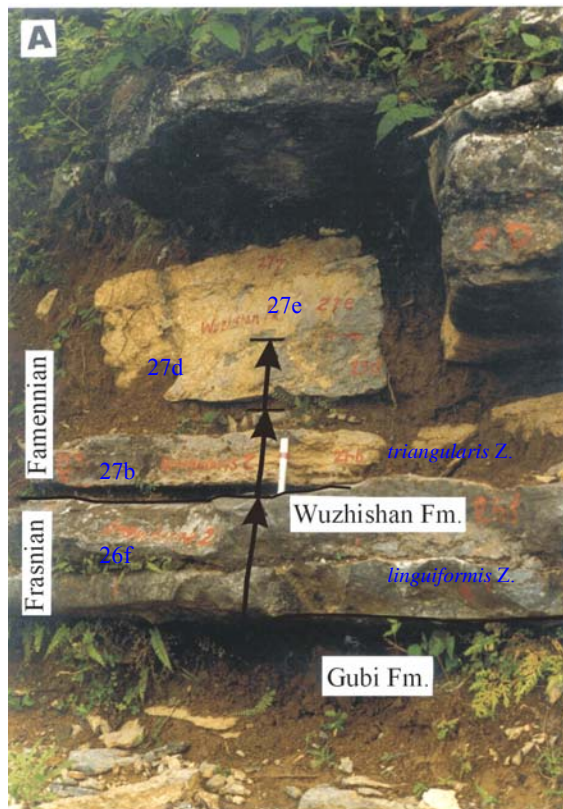


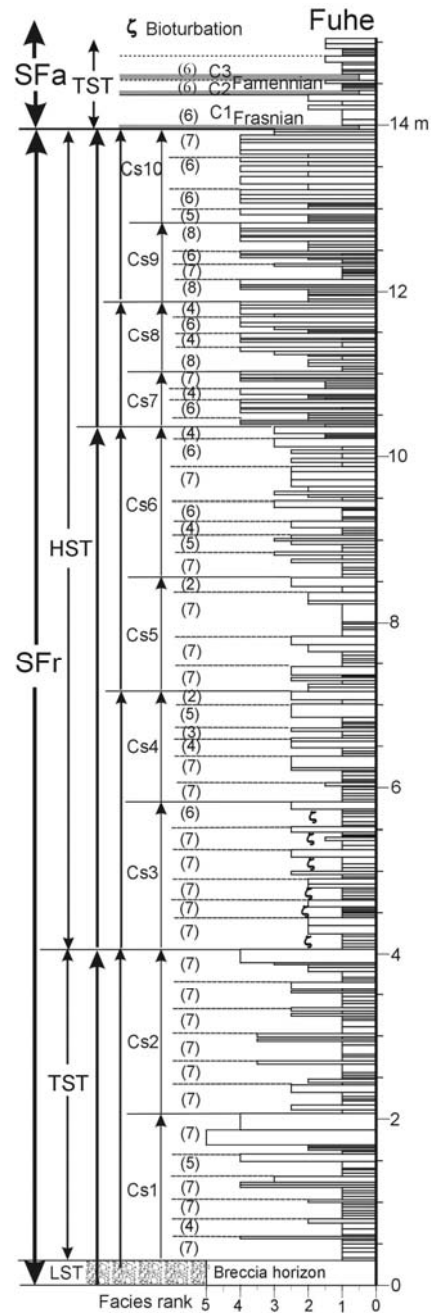
Fig. 27. (A) Black laminated chert with tuffaceous strips. (B) Porous light-coloured tuffite intercalated with chert. Scale bar is 2 cm long

Going upwards, nodular limestones, with minor gravity-flow deposits, predominate over the basinal succession (Gubi and Wuzhishan formations), in which different hierarchies of depositional cyclicity are extensive (Chen & Tucker, 2003). Two third-order depositional sequences (SFr, SFa) are identified across the F/F boundary (Fig. 21), in which higher-order cycles are further recognized (Fig. 28 and 29). The boundary between this two sequences is very close to, but a little below the biostratigraphic boundary between the Frasnian-Famennian boundary constrained by the conodont zonation (Ji, 1989; GBGMR, 1994) (Fig. 21). Therefore, a relative sea-level fall and a subsequent sea-level rise are revealed across the F/F boundary.



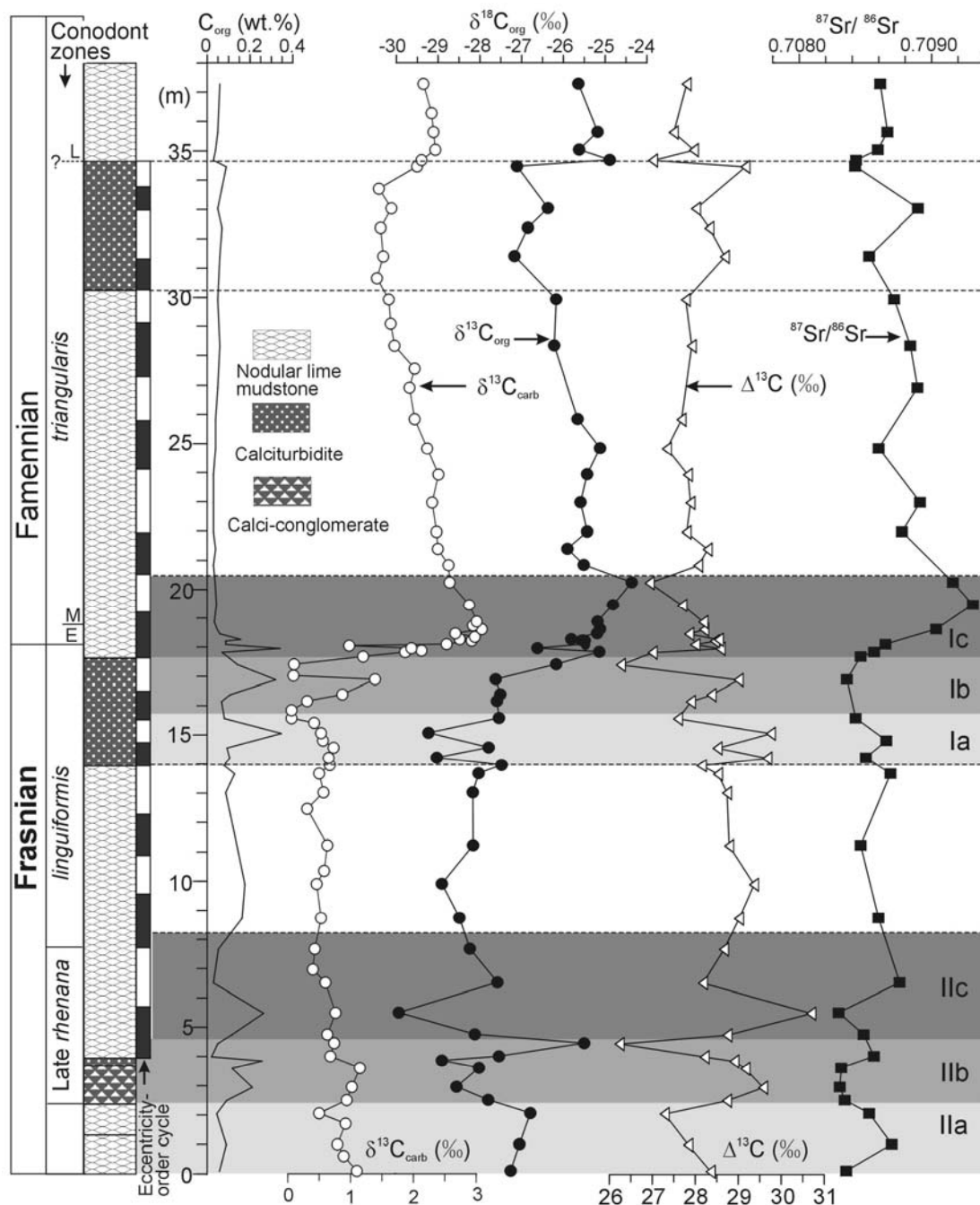
**Fig. 28.** Lithological variation across the F/F boundary at Fuhe. Arrows define the bundling cycles. Note: Bed 26f was assigned to the Gubi Formation by Ji (1989) and GBGMR (1994).

The smallest-scale cycle is the stratification bed; 6-8 stratification beds commonly bundle into a cycle (bundling cycle), which further group into cycle sets (with 6-8 cycles), mesocycle sets (with two cycle sets) and megacycle sets (with four cycle sets), respectively (Fig. 29). Such a cycle stacking pattern suggests a Milankovitch orbital forcing on the cycle stacking



**Fig. 29.** Details of stacking patterns of higher-order cycles in SFr at Fuhe. Bundling cycles (C) (numbers within brackets: numbers of stratification beds of each cycle) are grouped into cycle sets (Cs1—Cs10), mesocycle sets (marked by the second line of arrows from the right), and megacycle sets (marked by the third line of arrows from the right). Facies ranks: 0.5—shale, 1—nodular lime mudstone, 2—lenticular/boundinage peloidal wackestone/mudstone, 3—cm-bedded distal calciturbidite, 4—calciturbidite, 5—breccia (modified from Chen & Tucker, 2003).

patterns and cyclicity. In this case, the bundling cycles, cycle sets, mesocycle sets and megacycle sets were formed in response to the perturbations of precession, eccentricity, intermediate eccentricity and long eccentricity, respectively (see Chen & Tucker, 2003), thereby each spanning 16-18, 100, 200 and 400 kyrs. Cyclostratigraphic analysis revealed four cycle sets in the uppermost horizon of SFr related to sea-level fall (~400 kyr), and three bundling cycles in the lowermost of SFa in response to a rapid sea-level rise (~50 kyr).



**Fig. 30.**  $\delta^{13}C_{carb}$ - $\delta^{13}C_{org}$ - $^{87}Sr/^{86}Sr$  isotopic systematics from micrites across the F/F boundary at Fuhe, Guilin.  $\Delta^{13}C = \delta^{13}C_{carb} - \delta^{13}C_{org}$ . Carbon isotopic compositions are reported in per mil with respect to VPDB standard. Shaded horizons (I, II) roughly correspond to the upper and lower Kellwasser horizons, within which shorter-term (~200 ka) isotopic perturbations (Ia—Ic, IIa—IIc) are identified (modified from Chen et al., 2005).

High-resolution  $\delta^{13}\text{C}_{\text{carb}}-\delta^{13}\text{C}_{\text{org}}-^{87}\text{Sr}/^{86}\text{Sr}$  isotopic studies from identical sample sets were carried out within the high-resolution sequence-cycle stratigraphic frameworks across the F/F boundary (Fig. 30). An overall positive excursion of  $\delta^{13}\text{C}_{\text{carb}}-\delta^{13}\text{C}_{\text{org}}-^{87}\text{Sr}/^{86}\text{Sr}$  isotopic systematics (Chen et al., 2005), which is independent on the abundance of organic matter, starts from the base of calciturbidite horizons (upper *linguiformis* zone) (four eccentricity-forcing cycles), and ends in the base of nodular limestone successions (two eccentricity-forcing cycles), thereby spanning ~600 ka in duration (Fig. 30).

Moreover, the magnitude of the maximum  $\delta^{13}\text{C}_{\text{org}}$  excursion is larger (~ 4.5‰ VPDB) than that of  $\delta^{13}\text{C}_{\text{carb}}$  excursion (~ 2.5‰ VPDB), but the timing of the  $\delta^{13}\text{C}_{\text{org}}$  excursion is later (~ 100 ka). Within this overall positive excursion, three shorter-term isotopic perturbations (Ia—Ic), each spanning ~ 200 ka, can be further identified, which are better expressed by the variations in  $\Delta^{13}\text{C}$  values (=  $\delta^{13}\text{C}_{\text{carb}}-\delta^{13}\text{C}_{\text{org}}$ ) (Fig. 30). The latest perturbation (Ic), temporally equivalent to the UKW *in stricto*<sup>[3]</sup>, is characterized by concurrent positive shifts of  $\delta^{13}\text{C}_{\text{carb}}-\delta^{13}\text{C}_{\text{org}}-^{87}\text{Sr}/^{86}\text{Sr}$  isotopic systematics, but by different timing to the maximum shifts. The earlier two perturbations (Ia and Ib), which are localized within the calciturbidite horizon with a negative  $^{87}\text{Sr}/^{86}\text{Sr}$  excursion, are characterized by slightly earlier shifts of  $\delta^{13}\text{C}_{\text{org}}$  values, both negatively and positively, than  $\delta^{13}\text{C}_{\text{carb}}$  values (Fig. 30).

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