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REVIEW ARTICLE

Stratigraphic subdivision and correlation of the Carboniferous System in South China
Yang Shen* and Xun-Lian Wang
School of Earth Sciences and Resources, China University of Geosciences (Beijing), Beijing, China
(Received 14 October 2014; accepted 13 January 2015)

The Carboniferous System of South China is famous for its well-developed rock sequence, variety of depositional types, and abundant fossils. Three established Global Boundary Stratotype Section and Point (GSSP) markers have been identified in several sections in South China. Of these sections, the Pengchong section is the GSSP for the base of the Visean Stage, whereas the Dapoushang and Naqing (Nashui) sections are excellent reference sections for the bases of the Tournaisian and Bashkirian stages, respectively. Other sections have good potential for the four unestablished GSSPs and the Devonian–Carboniferous boundary in South China. The Naqing (Nashui) section is a candidate for the GSSPs of four stages: the Serpukhovian, Moscovian, Kasimovian, and Gzhelian stages. The regional stages of China include the Tangbagouan, Jiusian, Shangsian, Dewuan, Luosuan, Huashibanian, Dalaun, and Xiaodushanian. The history, definitions, reference sections, sedimentary characteristics, biostratigraphy, and correlations of these Chinese regional stages are summarized. A Carboniferous stratigraphic chart of South China is provided, showing the correlation of global chronostratigraphic and biostratigraphic units with those in South China and the lithostratigraphic units of various areas in South China. The chart is presented as a new practical framework for the stratigraphic subdivision and correlation of the Carboniferous System in South China.

Keywords: Carboniferous; Chinese regional stage; GSSP; stratigraphic chart; South China

1. Introduction

The Carboniferous period experienced critical transitions in Earth history, but it is challenging to precisely establish the timing of events. This is because Gondwana superglaciation and the consequent drastic climatic changes, sea-level fluctuations, and significant biogeographic differentiation make it difficult to establish a global timescale based on marine biostratigraphy and correlations of regional strata. Although the Carboniferous was one of the first geological periods to be defined, it is one of the most complicated and confusing in terms of stratigraphic classification and correlation (Davydov et al. 2012). To date, only three Global Boundary Stratotype Section and Points (GSSPs) – the bases of the Tournaisian, Visean, and Bashkirian stages – have been officially ratified for the Carboniferous System.

South China was located at a subequatorial–equatorial position near the eastern border of the Palaeo-Tethys Ocean during Carboniferous time (Scotese 2002; Wang et al. 2013; Figure 1). The region is well known for its complete marine Carboniferous sequence and abundant fossils. All three established GSSPs markers are identified in South China. The base of the Visean Stage is fixed with a GSSP in the Pengchong section, South China (Devuyst et al. 2003; Hou et al. 2013). In addition, South China has potential for defining the stages that are currently without GSSPs, including the Serpukhovian, Moscovian, Kasimovian, and Gzhelian. Thus, South China will play an important role in improving our understanding of the global Carboniferous System.

The main purpose of this paper is to present the stratigraphic subdivision and correlation of the Carboniferous in South China. First, the research status of the Carboniferous GSSPs and their recognition in South China are introduced. Second, the regional chronostratigraphic units and a stratigraphic chart of South China are presented. It is hoped that this paper will provide a better understanding of the Carboniferous System in South China.

2. Carboniferous GSSPs and their recognition in South China

The primary objective of the International Commission on Stratigraphy (ICS) is to define precisely the global units (systems, series, and stages) of the International Chronostratigraphic Chart. All the efforts of the Subcommission on Carboniferous Stratigraphy (SCCS) are now focused on selecting events and GSSPs for stage boundaries (Richards 2013).

The Carboniferous System has been subdivided into two subsystems, the Mississippian and the Pennsylvanian, and contains seven global stages, the Tournaisian, Visean, Serpukhovian, Bashkirian, Moscovian, Kasimovian, and Gzhelian.
Gzhelian, in ascending order (Figure 2). To date, only the GSSPs for the bases of the Tournaisian, Visean, and Bashkirian stages have been approved by the SCCS and ICS (Paproth et al. 1991; Lane et al. 1999; Devuyst et al. 2003), whereas the bases of the Serpukhovian, Moscovian, Kasimovian, and Gzhelian stages are not defined by GSSPs, and some markers for the definitions of their boundaries have not yet been selected. In addition, there are serious problems with the Devonian–Carboniferous (D–C) boundary GSSP (Ji et al. 1989; Kaiser 2009), which requires further research.

2.1. Tournaisian Stage

2.1.1. GSSP for the base of the Tournaisian Stage

The GSSP for the base of the Tournaisian Stage, Mississippian Subsystem, and Carboniferous System has been defined at the base of bed 89 in the La Serre section, Montagne Noire, southern France (Paproth et al. 1991). The boundary is defined by the first appearance datum (FAD) of the conodont Siphonodella sulcata, within the Siphonodella praesulcata–S. sulcata evolutionary lineage (Paproth et al. 1991). At present, the boundary definition needs restudy.
Studies by Ji et al. (1989) and further work (Kaiser 2009) indicate there are problems with the D–C Boundary GSSP (Paproth et al. 1991) at La Serre, France, and with the conodont lineage used for boundary definition. The GSSP level at the base of bed 89 in the La Serre section seems to fall in the upper part of the Siphonodella sulcata Zone or even in the overlying Siphonodella duplicata Zone (Kaiser 2009). There is no record of the phylogenetic transition from Siphonodella praesulcata to S. sulcata at La Serre (Kaiser 2009). Some studies show that the determination of S. sulcata is subjective and the species is not a suitable marker for the base of the Carboniferous (Kaiser and Corradini 2011). The Devonian and Carboniferous subcommissions of the ICS have formed a task group to work on the D–C boundary problem (Richards 2009). At present, the primary tasks for the D–C boundary task group are to locate an appropriate event marker to define the boundary and to find a suitable section for the GSSP (Aretz 2014).

There is still no general agreement for the criteria of the D–C boundary definition, but there are some guidelines for further activities and discussions (Aretz 2014). A multidisciplinary approach should be used for boundary definition. The new boundary definition does not need to be a conodont. The major late Famennian extinction (Hangenberg Event) is a good potential candidate for a new definition of the boundary (Aretz 2014).

### 2.1.2. Reference section for the base of the Tournaisian Stage in South China

The D–C boundary has been identified in several sections of pelagic or outer shelf facies in South China, including the Nanbiancun section in Guangxi (Yu 1988), which is the auxiliary stratotype section for the D–C boundary, and the Muhua and Dapoushang sections in Guizhou (Hou et al. 1985; Ji et al. 1988, 1989). A biostratigraphically well-constrained tuff near the D–C boundary in the Dapoushang section provides an excellent opportunity to date this important boundary (Liu et al. 2012). Herein, the Dapoushang section is introduced as a reference section in South China.

1. Location. The Dapoushang section is located in Muhua village, 25 km south of Changshun County in Guizhou Province, South China (Figure 1).

2. Geological background. The strata of the Dapoushang section across the D–C boundary are continuous and well exposed. The section contains the Upper Devonian Daihua Formation (beds 029–0) and the uppermost Devonian to lower Carboniferous Wangyou Formation (beds 1–29), which are mainly composed of bioclastic limestone of pelagic facies (Ji et al. 1989; Liu et al. 2012).

3. Biostratigraphy. In the D–C boundary section, five conodont zones have been identified: the Middle Siphonodella praesulcata, Upper S. praesulcata, S. sulcata, Lower S. duplicata, and Upper S. duplicata zones (Ji et al. 1989; Figure 3). In addition, the section contains an abundance of other micro- and macrofossils (ammonoids, trilobites, ostracodes, brachiopods, corals, and vertebrate microfossils). Two vertebrate microfossil zones (the Phoebodus politus–Petalodus daitinhaensis and Acanthodes guizhouensis zones) and two ammonoid zones (the Parawocklumeria and Gattendorfia zones) have been identified across the D–C boundary interval (Ji et al. 1989).

4. U–Pb zircon age. Approximately 5–10 cm of brownish-yellow bentonite (tuff) directly underlies bed 0, which is in the Upper praesulcata conodont Zone and located nearly 30 cm below the D–C boundary (base of bed 1) in the Dapoushang section (Liu et al. 2012; Figure 4). U–Pb SHRIMP analyses of zircons from the tuff yielded a \(^{207}\text{Pb}/^{238}\text{U}\) concordia age of 359.6 ± 1.9 Ma (Liu et al. 2012). Based on this new single-zircon SHRIMP age and previously published work on the biostratigraphy and sequence stratigraphy of the D–C transition interval, the age of the D–C boundary at Dapoushang, Guizhou, China, is estimated to be 359.58 Ma (Liu et al. 2012).

In Muhua area, there are several D–C boundary sections. Of these sections, the Muhua II and Dapoushang sections are suitable as the candidate section for the D–C boundary GSSP (Hou et al. 1985; Ji et al. 1989). First, they have continuous limestone development across the D–C boundary. Second, they have continuous conodont zones and other significant fossil groups near the D–C boundary. Third, they have more than one bed of volcanic ash near the D–C boundary. The studies around the
D–C boundary are now under way, including geochemical profiles and volcanic ash beds, which have the potential for defining the boundary. The first volcanic ash bed yielding radiometric age around the Hangenberg equivalent beds in Muhua area may be a good marker for the D–C boundary.

2.2. Visean Stage

2.2.1. GSSP for the base of the Visean Stage

The GSSP for the base of the Visean Stage has been defined at the base of bed 83 in the Pengchong section, Guangxi, South China (Devuyst et al. 2003; Hou et al. 2013; Figure 1). The boundary is defined by the FAD of the benthic foraminifer *Eoparastaffella simplex* within the *Eoparastaffella ovalis–E. simplex* evolutionary lineage (Devuyst et al. 2003; Hou et al. 2013; Figure 5).

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**Figure 3.** Distribution of conodonts in the Dapoushang section (after Ji et al. 1989). 1–2, *Siphonodella praesulfata*; 3–6, *Siphonodella sulcata*; 7–8, *Siphonodella duplicata*.

**Figure 4.** Devonian (D)–Carboniferous (C) boundary interval in the Dapoushang section. The star indicates the location of the bentonite dated at 359.6 Ma.
2.2.2. Pengchong GSSP in South China

(1) Location. The Pengchong section is located near the village of Pengchong, 15 km NNE of Liuzhou City, and about 130 km SW of Guilin City, South China (Figure 1).

(2) Geological background. Palaeogeographically, the Pengchong area was located in an intraplatform basin or on a basin slope during Mississippian time (Devuyst et al. 2003). In this area, the Carboniferous lithostratigraphic sequence is divided into, in ascending order, the Luzhai, Bei’an, and Simen formations (Shen and Tan 2009). The Luzhai Formation contains three members: the lower and upper members are composed of thin-bedded dark siliceous mudstone interbedded with thin-bedded chert, and the middle member (the Pengchong Member) consists of dark grey limestone beds of various thicknesses with subordinate thin- to medium-bedded dark calcareous shales (Devuyst et al. 2003). The GSSP boundary horizon is located within the Pengchong Member.

Figure 5. Tournaisian (T)–Visean (V) boundary interval in the Pengchong section (modified from Hou and Zhou 2008).
(3) Biostratigraphy. The Pengchong Member in the Pengchong section contains abundant and diversified foraminifers and some important index conodonts (Figures 5 and 6; Devuyst et al. 2003; Tian 2005; Hou et al. 2008, 2013). Three foraminiferal zones can be recognized: the Upper *Eoparastaffella rotunda* Zone (from the base of the Pengchong Member to bed 82), the *Eoparastaffella simplex* Zone (from the base of bed 83 to bed 181), and the *Pojarkovella nibelis* Zone (from the base of bed 182). The Tournaisian–Visean (T–V) boundary is placed at the first appearance of *E. simplex*, at the base of bed 83. In addition, conodonts can be used as an auxiliary marker. The FAD of the conodont *Gnathodus homopunctatus* is 5 m above the T–V boundary, and the last appearance datum (LAD) of *Scaliognathus anchoralis europensis* is 30 m below the T–V boundary (Hou and Zhou 2008; Hou et al. 2013).
2.3. Serpukhovian Stage

The Visean–Serpukhovian boundary is not yet defined by a GSSP. An index for boundary definition has been selected but has not been voted on by the task group and SCCS for final approval (Richards 2014).

For boundary definition, the task group uses the FAD of the conodont Lochria ziegleri in the evolutionary lineage Lochria nodosa–Lochria ziegleri (Richards 2014). This lineage, along with the associated faunas and strata, is being studied in several areas. The Naqing (Nashui) section in South China and the Verkhnyaya Kardailovka section in the southeastern Urals of Russia have the best potential as GSSP candidates (Richards 2010; Qi et al. 2013b).

2.4. Bashkirian Stage

2.4.1. GSSP for the base of the Bashkirian Stage

The GSSP for the base of the Pennsylvanian and of the Bashkirian Stage has been fixed in the lower Bird Spring Formation at Arrow Canyon, in the Great Basin, Nevada, USA, and is defined by the FAD of the conodont Declinognathodus noduliferus sensu lato within the evolutionary lineage Gnathodus girty simplex–Declinognathodus noduliferus s.l. (Lane et al. 1999).

2.4.2. Reference section for the base of the Bashkirian Stage in South China

The FAD of the conodont Declinognathodus noduliferus has been identified in many sections in South China, including the Baping section in Guangxi (Xu et al. 1987) and the Dianzishang and Naqing (formerly called the Nashui or Luosu section) sections in Guizhou (Rui et al. 1987; Wang et al. 2004; Qi et al. 2014). The latter is a reference section in South China.

(1) Location. The Naqing section is exposed on the side of the Wangmo–Luodian highway (S312), 45 km SW of Luodian county, 7 km SW of Luosu township and 2 km SW of the village of Naqing. The section is easily accessible by car from Guiyang, the capital of Guizhou Province (Figure 1).

(2) Geological background. The Naqing section is a relatively deeper-water carbonate-slope facies section that contains thin- to medium-bedded grey wackestone and packstone beds intercalated with chert beds (Qi et al. 2013b).

(3) Biostatigraphy. The FADs of the conodont Declinognathodus noduliferus and the fusulinacean Millerella marblensis are at the base of bed 6(B), which is the Mississippian–Pennsylvanian boundary (Rui et al. 1987; Wang et al. 2004; Figure 7). The Gnathodus bilineatus bollandensis and Eostaffella mosqensis zones are below the boundary, and the Declinognathodus noduliferus and Millerella marblensis–Eostaffella postmosqensis zones are above the boundary (Rui et al. 1987; Wang et al. 2004).

The Naqing section is also the stratotype section of Chinese Luosuan Stage. This section has several advantages compared with other sections (Rui et al. 1987). First, it is well exposed, and composed of continuous sequences of marine carbonates containing abundant and highly diverse conodont and foraminiferal faunas. Second, it has a transitional conodont fauna characterized by shallow and deeper water types of conodonts, with a complete conodont sequence. Third, the conodont Declinognathodus noduliferus made its first occurrence at the base of Luosuan in association with the fusulinacean Millerella marblensis.

2.5. Moscovian Stage

The base of the Moscovian Stage is not defined by a GSSP, and an index for the boundary definition has not been selected (Richards 2013; Alekseev 2014).

Several conodonts and fusulinids have been proposed as potential indices for the GSSP. Currently only two conodont species, Declinognathodus donetzianus and Diplognathodus ellesmerensis, are considered to have substantial potential for definition of a boundary position close to the original base of the type Moscovian (Alekseev 2014). If a morphologic chronocline could be demonstrated from the ancestral species to Dip. ellesmerensis at Naqing, this would provide an almost ideal level for the GSSP (Qi et al. 2010; Groves 2011; Wang et al. 2011; Alekseev 2014).

Several candidate sections for the GSSP are being studied, but the Naqing section in southern Guizhou Province, South China, appears to have the greatest potential (Qi et al. 2010; Wang et al. 2011; Richards 2013; Alekseev 2014).

2.6. Kasimovian Stage

The base of the Kasimovian Stage is not defined by a GSSP, but the SCCS task group studying this boundary has concluded that the FADs of the conodonts Idiognathodus sagittalis and Idiognathodus turbatus have good potential as markers for the base of the Kasimovian (Ueno et al. 2011; Richards 2013). Recently, the FAD of Idiognathodus heckeli, the
precursor species to *I. turbatus*, has been considered as another potential boundary marker (Ueno and Task Group 2014).

If the FAD of *I. turbatus* or *I. heckeli* is to be used for boundary definition, the Naqing (Nashui) section in southern Guizhou Province, South China, would be an excellent candidate for the GSSP (Barrick et al. 2010; Qi et al. 2013a; Ueno and Task Group 2014).

2.7. Gzhelian Stage

The base of the Gzhelian Stage is not yet defined by a GSSP, but is defined by the FAD of the conodont *Idiognathodus simulator* sensu stricto in the potential evolutionary lineage *Idiognathodus eudoraensis–I. simulator* (Heckel et al. 2008; Villa et al. 2009).

In South China, the *I. simulator* fauna is moderately abundant and diverse across the Kasimovian–Gzhelian.
boundary in the Naqing (Nashui) section (Barrick et al. 2010; Ueno and Task Group 2014). The Naqing section has promise as a potential GSSP candidate.

3. Regional chronostratigraphic units of China

The Carboniferous of China is well known for its well-developed strata, variety of depositional types, and abundant fossils. More than a century has passed since the first paper was published on the Chinese Carboniferous (Richthofen 1882). Since that time, extensive research has been carried out, and the regional chronostratigraphic framework of China has been established and improved (e.g. Yang et al. 1962; Hou et al. 1982; Zhang 1987; Wang 1990b; Jin et al. 2000; Wang and Jin 2003).

The Carboniferous System in China was divided into two subsystems, four series, and eight stages in the Carboniferous volume of the Stratigraphic Lexicon of China (Jin et al. 2000: Figure 8); this scheme has been widely accepted (e.g. Wang and Jin 2000, 2003, 2005; Heckel and Clayton 2006; Menning et al. 2006; Davydov et al. 2012; Wang et al. 2013). The eight regional stages are, in ascending order, the Tangbagouan, Jiusian, Shangsian, Dewuan, Luosuan, Huashibanian, Dalaun, and Xiaodushanian. The traditional Carboniferous regional stages of China used the unit stratotype concept, which strengthens the importance of rock units and of fauna assemblages, but have no clear definition for its basal boundaries, such as the Jiusi and Shangsi stages. At present, most Chinese stages, especially of the Upper Carboniferous, have clear boundary definitions using the FAD of the species of foraminifers or conodonts. The type sections of the regional stages in China are located in shallow-water facies, except for the Luosuan Stage, which is in a relatively deeper-water facies. All the stratotypes of these regional stages are located in South China, and are described below.

3.1. Tangbagouan Stage

(1) History. The stage was suggested by Jin et al. (2000) as a chronostratigraphic extension of the Tangbagou Formation, which was named by Ting (1931).

(2) Definition. The boundary definition for the base of the Tangbagouan Stage is the same as that of the Tournaisian. The stage corresponds roughly to the coral Pseudouralinia Zone.

(3) Reference section. The Qilinzhai section is the stratotype, and is located 4 km W of Dushan County, Guizhou Province, South China (Figure 1).

(4) Sedimentary characteristics. In type area, the stage includes the Tangbagou Formation, which is composed of limestone, sandstone, and mudstone of inner shelf facies (Jin et al. 2000).

(5) Biostratigraphy. In shallow-water facies, the fossil content of the Tangbagouan beds is dominated by the rugose coral Pseudouralinia Zone, which can be subdivided into three subzones: the Ps. tangpakouensis, Koninckophyllum sp.–Ps. tangpakouensis, and Ps. gigantea subzones (Jin et al. 2000). In addition, the stage contains three brachiopod zones (the Unispirifer–Yanguania, Martiniella–Eochoristites, and Finospirifer shaoyangensis zones) and six foraminiferal zones (the Bisphaera, Chernyschinella, Palaoaspiroplectamina, Tuberdendothyra, Spinendothyra, and Dainella zones). The conodont succession of this stage consists of six zones, which are found in pelagic facies. These are the Siphonodella sulcata, S. duplicata, S. sandbergi, S. crenulata, S. isosticha, and Ganthodus typicus zones. The goniatites Gattendorfia spp., Initoceras folliformis, and I. simile are found in the S. duplicata Zone (Hou et al. 1985; Ji 1987; Ji et al. 1988).

(6) Correlation. This stage can be correlated to the lower and middle parts of the Touraisian Stage. In type area, the uppermost part of the Tangbagou Formation, near the beds below the Xiangbai Sandstone, contains foraminifers Dainella, Spinobrunsiina, Septabrunsiina, Planendothyra, Paraendothyra, and others, and represent a beginning of the Dainella Zone (Hou et al. 2011). The Dainella Zone is in the upper Touraisian (Hance et al. 2011).

![Figure 8. Chinese subdivisions of the Carboniferous System (after Jin et al. 2000).](image)
3.2. **Jiusian Stage**

(1) History. The name of this stage is taken from the Jiusi Sandstone, which was established by Ting (1931).

(2) Definition. The stage is a chronostratigraphic extension of the Xiangbai and Jiusi formations. It has no clear lower boundary definition, which may be within the foraminifer *Dainella* Zone.

(3) Reference section. The Jiusi section is the stratotype, and is located 4 km SW of what was previously known as Datang County (now part of Luodian County), Guizhou Province, South China (Figure 1).

(4) Sedimentary characteristics. In the type area, the stage includes stratigraphic sequences composed of the Xiangbai and the Jiusi formations. The Xiangbai Formation contains sandstone and shale of littoral facies. The Jiusi Formation consists mainly of limestone, sandstone, and mudstone of open-platform deposits.

(5) Biostratigraphy. In shallow-water facies, the coral and brachiopod faunas of this stage are grouped into the *Thysanophylloides* Zone and the *Levitisia humerusa–Delepinae subcarinata* and *Vitiliproductus groeberi–Fugilis* *humanensis* assemblages (Zhang 2000). In pelagic facies, the Jiusian Stage contains three conodont zones, the *Scaliognathus anchoralis, Gnathodus texanus–G. homopunctatus*, and *Lochria commutata* zones (Xiong and Zhai 1985; Wang 1990a).

(6) Correlation. This stage can be correlated to the upper part of the Visean Stage and the lower part of the Tongtai Island Stage. The base of the Jiusian Stage is placed at the base of the Xiangbai Sandstone without any palaeontological marker. Based on foraminifer from Tangbagou Formation, the lower boundary may be within the foraminifer *Dainella* Zone in the upper Tournaisian Stage.

3.3. **Shangsian Stage**

(1) History. The stage was first proposed by Zhang (1988) as the time equivalent of the Shangsi Formation or the Shangsi Limestone (Ting 1931).

(2) Definition. The stage has no clear lower boundary definition, but corresponds roughly to the coral *Yuanophyllum* Range Zone.

(3) Reference section. The Liuzhai section is the stratotype, and is located in the town of Baijin, Huishui County, Guizhou Province, South China (Figure 1).

(4) Sedimentary characteristics. In the type area, the stage includes most of the Shangsi Formation, which is mainly composed of open-platform limestone deposits.

(5) Biostratigraphy. In shallow-water facies, the corals of this stage are recognized as being of the *Yuanophyllum* Range Zone, characterized by *Palaeosmilia* and *Kueichophyllum heishihkuanense* in the lower part, *Aulinia carinata* in the middle part, and *Palastraee* in the upper part (Wang 1990b; Wang and Jin 2003). The foraminiferal succession consists of the *Koskinotextularia, Neoarchaediscus*, and *Eostaffella tenebrosa* zones. In pelagic facies, the Jiusian Stage contains three conodont zones (the *Gnathodus bilineatus bilineatus, Lochria nodosa*, and *L. ziegleri* zones).

(6) Correlation. This stage can be correlated to the upper part of the Visean Stage. The upper boundary of the Shangsian Stage is slightly above the top of the Visean Stage, and it is correlated to the base of the conodont *Lochria cruciformis* Zone.

3.4. **Dewuan Stage**

(1) History. The stage was defined by Yang et al. (1980) as the time span of the Dewu Formation.

(2) Definition. The lower boundary of the stage is defined by the FAD of the foraminifer ‘*Millerella*’ *pressula* (Wu 2008a).

(3) Reference section. The Yashui section is the stratotype, and is located in the town of Yashui, Huishui County, Guizhou Province, South China (Figure 1).

(4) Sedimentary characteristics. The Dewuan Stage includes the uppermost Shangsi Formation to the lower Baizuo Formation in the Yashui section, which is dominated by carbonate rocks of shallow-water facies.

(5) Biostratigraphy. The Dewuan beds contain the foraminiferal ‘*Millerella*’ *pressula* and *Eostaffellina paraprortvae* zones in the type Yashui section (Wu 2008a, 2008b). The stage also contains the brachiopod *Striatifera striata–Gigantoproductus edelburgensis* Assemblage Zone and the coral *Koninclophyllum–Dibunophyllum bipartitum* Zone. In pelagic facies, two conodont zones can be discerned: the *Lochria cruciformis* and *Gnathodus bilineatus bollundensis* zones (Qi and Wang 2005).

(6) Correlation. This stage can be correlated approximately to the Serpukhovian Stage. The lower
boundary of the Dewuan Stage is correlated to the base of the conodont Lochriea cruciformis Zone, which is the second conodont zone above the base of the Serpukhovian Stage.

3.5. Luosuan Stage
(1) History. The Luosuan Stage was named by Rui et al. (1987) and its type section is at Luosu township.
(2) Definition. The lower boundary of this stage is marked by the FAD of the conodont Declinognathodus noduliferus or the fusulinacean Millerella marblensis (Rui et al. 1987).
(3) Reference section. The Luosu section is the stratotype, and is located about 7 km SW of Luosu, Luodian County, Guizhou Province, South China (Figure 1). The Luosu section is also called the Nashui section or the Naiqing section in the literature.
(4) Sedimentary characteristics. The rock sequence of the Luosuan Stage in the type section is composed mainly of planar-laminated wackestone interbedded with packstones, grainstones, and cherty beds, representing slope deposits (Rui et al. 1987).
(5) Biostratigraphy. Five conodont zones have been identified. In ascending order, they are the Declinognathodus noduliferus, Idiognathoides sulcatus, I. sinuatus, I. corrugatus, I. pacificus, and Neognathodus symmetricus zones in the type section (Wang and Qi 2002; Wang et al. 2004). The Luosuan beds also contain the fusulinacean Millerella marblensis–Eostaffella postmosquensis Zone (Rui et al. 1987) and the ammonoid Homoceras Zone (Ruan 1981).
(6) Correlation. This stage can be correlated to the lower part of the Bashkirian Stage. The lower boundaries of the Luosuan and Bashkirian stages are coincident and defined by the FAD of the conodont Declinognathodus noduliferus (Rui et al. 1987; Lane et al. 1999). And the upper boundary of the Luosuan Stage is coincident with the base of the fusulinacean Pseudostaffella antiqua Zone, which is in the lower part of Bashkirian Stage (Zhang et al. 2004; Davydov et al. 2012).

3.6. Huashibanian Stage
(1) History. This stage was first named by Yang et al. (1980) after the Huashiban Formation.
(2) Definition. The lower boundary of the Huashiban Stage is defined by the FAD of the fusulinacean Pseudostaffella antiqua, within the Eostaffella protvae–Pseudostaffella antiqua evolutionary lineage (Zhang et al. 2004, 2008a).
(3) Reference section. The stratotype is situated at Huashiban village, about 30 km E of Panxian County, Guizhou Province, South China (Figure 1).
(4) Sedimentary characteristics. In the type section, the stage is represented by the Huashiban Formation, which is mainly composed of open-platform limestone deposits.
(5) Biostratigraphy. In the type section, two fusulinacean zones are present, the Pseudostaffella antiqua–P. antiqua posterior and the Pseudostaffella composita–P. paracompressa zones. The stage contains two ammonoid zones: the Reticulochina guizhouense and Branneroceras branneri–Gastrioceras cf. cumbriensis zones (Zhang et al. 2008a). The associated corals and brachiopods are assigned to the Lithostrotionella stylaxis–Carinthiaphyllum exquisitum–Acrosathyus Assemblage Zone and the Choristites mansuyi–Plicatifera choai Assemblage Zone, respectively (Jin et al. 2000).
(6) Correlation. This stage can be correlated to the middle part of the Bashkirian Stage, because the fusulinacean Pseudostaffella antiqua–P. antiqua posterior Zone of the lower part of the Huashibanian is correlated to the Pseudostaffella antiqua Zone of the middle part of the Bashkirian Stage (Zhang et al. 2004; Davydov et al. 2012).

3.7. Dalaun Stage
(1) History. The stage name was derived from the Dala Formation, which was established by Jin et al. (1962).
(2) Definition. The lower boundary of the Dalaun Stage is marked by the first appearance of the fusulinacean Profusulinella (e.g. P. priscoidea or P. parva; Zhang et al. 2008b).
(3) Reference section. The stratotype is situated at Dala village, about 30 km E of Panxian County, Guizhou Province, South China (Figure 1).
(4) Sedimentary characteristics. In the type section, the stage is represented by the Dala Formation, which mainly consists of limestone deposited in an open-platform environment.
(5) Biostratigraphy. There are six fusulinacean zones in the type section: the Profusulinella priscoidea–P. parva, Profusulinella aljutovica–Taitzehoella
3.8. Xiaodushanian Stage

(1) History. The name Xiaodushan Stage was given by Zhou et al. (1987), with the type section situated at Xiaodushan village.

(2) Definition. The lower boundary of this stage is defined by the first appearance of the fusulinacean Protriticites (Zhou et al. 1987).

(3) Reference section. The Xiaodushan section is the stratotype, and is located in Xiaodushan village, Guangnan County, Yunnan Province, South China (Figure 1).

(4) Sedimentary characteristics. The Xiaodushanian beds in the type section are mainly composed of open-platform limestone deposits.

(5) Biostratigraphy. Five fusulinacean zones have been identified in the type section (in ascending order): the Protriticites subschwagerinoides, Tritylites montiparus, T. schwageriniformis, T. dictyophorus, and T. shikhaniensis compactus zones (Zhou et al. 1987). In most areas of South China, the fusulinaceans of this stage are usually grouped into two genozones, the Montiparus and Protriticites zones (Wang and Jin 2003). The coral and brachiopod faunas of this stage are grouped into the Nephelophyllum–Pseudotimania–Pseudocarniaphyllium Zone and the Choristites jigulensis–Protranidanthus Assemblage Zone, respectively (Zhang 2000).

(6) Correlation. This stage can be roughly correlated to the Kasimovian and Gzhelian stages, because the fusulinacean Protriticites subschwagerinoides Zone of the lower part of the Xiaodushanian Stage is correlated to the Protriticites ovoides–Praeobolobites burkemensis Zone of the uppermost part of the Moscovian Stage or the Protriticites pseudomontiparbus Zone of the lower part of the Kasimovian Stage (Zhou et al. 1987; Davydov et al. 2012).

4. Carboniferous stratigraphic chart of South China

Figures 9 and 10 and the Supplemental Figure at http://dx.doi.org/10.1080/00206814.2015.1008591 show a comprehensive Carboniferous stratigraphic correlation chart for South China. Some of the major features of the chart are explained below.

The international Carboniferous time scale and biostratigraphic zonation (ammonoids, foraminifers, and conodonts) were taken from The Geologic Time Scale 2012 (Davydov et al. 2012), with minor modifications, including moving the conodont Scalognathus anchoralis Zone from the lower Visean to the uppermost Tournaisian, which is widely supported (Lane et al. 1980; Belka 1985; Webster and Groessens 1991; Perret and Delvolvé 1994; Perri and Spalletta 1998; Tian 2005), and is consistent with the Pengchong GSSP.

The numerical ages for the stage boundaries in the Carboniferous are taken from The Geologic Time Scale 2012 (Davydov et al. 2012) and the 2014 version of the ICS International Stratigraphic Chart (Cohen et al. 2013). The Carboniferous chronostratigraphic framework of China is from the Carboniferous volume of the Stratigraphic Lexicon of China (Jin et al. 2000). The regional stages in China are based on successions in South China.


Based on tectonic setting, lithofacies associations, and biotic assemblages, South China can be divided into two depositional provinces: the Yangtze Province and the

Figure 9. Carboniferous stratigraphic chart of South China (part A).
Southeast Province (Wang et al. 2013). Twenty-three typical lithostratigraphic successions of South China are shown in the chart (Figures 9 and 10), and the locations of these successions are marked by numbers in Figure 11. The thicknesses of Carboniferous units in different areas of South China are variable and the typical ones are summarized in Figure 12.

5. Conclusions

(1) GSSPs for the bases of the Tournaisian, Visean, and Bashkirian stages have been officially ratified for the Carboniferous System. All three established GSSPs markers have been identified in several sections in South China. The base of the Visean Stage is fixed with a GSSP in the Pengchong section, South China. The Dapoushang and Naqing sections are excellent reference sections for the bases of the Tournaisian and Bashkirian stages, respectively.

(2) The Carboniferous of South China has good potential to study the four unestablished GSSPs and the D–C boundary. Moreover, the Naqing (Nashui) section is a candidate for GSSPs for the Serpukhovian, Moscovian, Kasimovian, and Gzhelian stages. In the future, South China will play a significant role in improving the global definition of the Carboniferous System.

(3) Regional Carboniferous stages in China are the Tangbagouan, Jiusian, Shangsian, Dewuan, Luosuan, Huashibanian, Dalaun, and Xiaodushanian stages. All the type sections of the Chinese stages are located in South China, and most of the stratotypes of those stages are well studied in terms of biostratigraphy and sedimentary characteristics.

(4) The Carboniferous stratigraphic chart of South China provides a comprehensive summary of the current status of the Carboniferous in South China. It represents a new practical framework for Carboniferous subdivision and correlation in South China.
Figure 12. Thickness of Carboniferous units at the typical areas of South China.
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