PROPOSED GLOBAL STANDARD STRATOTYPE-SECTION AND POINT FOR THE PAIBIAN STAGE AND FURONGIAN SERIES (UPPER CAMBRIAN)

Prepared on behalf of the International Subcommission on Cambrian Stratigraphy for the International Commission on Stratigraphy by:

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Introduction

Regional stage- and series-level schemes are available and in widespread use for all major Cambrian continents, but the Cambrian System currently has no formally accepted subdivisions applicable on a global scale. The base of the Cambrian System, and the Palaeozoic Eonothem, at the base of the *Trichophycus* (or *Treptichnus*, *Phycodes*) *pedum* Zone in Newfoundland has been ratified (Brasier et al., 1994; Landing, 1994; Gehling et al., 2001), and the base of the overlying Ordovician System at the base of the *Iapetognathus fluctivagus* Zone (Cooper & Nowlan, 1999) has been chosen, but internal divisions within the Cambrian System have not been determined (Geyer & Shergold, 2000). For much of the Nineteenth and Twentieth Centuries, the Cambrian was subdivided into three parts, but recognition of a thick pre-trilobitic lower Cambrian (Landing, 1994, 1998; Landing et al., 1998), equivalent to roughly half of Cambrian time (Landing et al., 1998) provides a strong incentive to adopt a four-fold division of the Cambrian (Landing, 1998; Palmer, 1998; Geyer & Shergold, 2000), with two series in the lower half, and two series in the upper half, of the system. Geyer & Shergold (2000), in reviewing the current state of knowledge about internal Cambrian divisions, emphasized the need to subdivide the system according to practical, intercontinentally recognizable horizons instead of according to a tripartition carried over from traditional usage. With the addition of a large pre-trilobitic interval to the lower part of the Cambrian, subequal division of the system into three parts could lead to considerable confusion over newer and older Lower, Middle, and Upper Cambrian series, and would likely lack adequate horizons for recognition of stage and series boundaries globally.

At least 11 candidate horizons for global chronostratigraphic correlation are present in the upper half of the Cambrian System (Geyer & Shergold, 2000), although not all are equally useful for stage and series boundaries. If a four-fold division of the Cambrian (Palmer, 1998) is ultimately adopted, internal boundaries can be expected to roughly correspond to the first appearance datum (FAD) of trilobites, the FAD of an intercontinentally distributed fossil (perhaps the trilobite *Oryctocephalus indicus*), and the FAD of the agnostoid trilobite *Glyptagnostus reticulatus* (e.g., Palmer, 1998; Geyer & Shergold, 2000; Peng & Babcock, 2001; Peng et al., 2001c). Division of the Cambrian into a greater number of series, however, is possible (Geyer & Shergold, 2000). Of the suggested and recommended positions of series boundaries (Shergold & Geyer, 2001), the FAD of *G. reticulatus* corresponds to palaeo-oceanographic and biotic events of considerable global importance (e.g., Geyer & Shergold, 2000; Saltzman et. al., 2000; Peng et al., 2001c). This position is one of the most clearly recognizable datum points in the Cambrian; a position closely corresponding to the first appearance of *G. reticulatus* is recognizable in strata of eastern and western Gondwana, Baltica, Kazakhstan, Siberia, Laurentia, and Avalonia (e.g., Palmer, 1962; Geyer & Shergold, 2000; Peng & Robison, 2000; Peng et al., 2001c; Fig. 1), and can be identified with precision using multiple lines of evidence. Despite ongoing discussions concerning the total number and placement of series boundaries in the Cambrian System, a decision on the interval comprising the uppermost series is unaffected, and it is appropriate to move forward with ratification of a boundary position for the base of the uppermost Cambrian series and its corresponding lower stage.

The purpose of this proposal is to seek formal recognition for the base of a global stage and series boundary that represents the base of the uppermost Cambrian series. The proposed global standard stratotype-section and point (GSSP) for the base of the Paibian Stage (new name) and the Furongian Series (new name) is at the FAD of *G. reticulatus* in the section near Paibi, Hunan Province, China (Peng & Robison, 2000; Peng et al., 2001c, 2001e; Figs. 2-7). The proposed GSSP position in the Paibi section fulfills all of the geological and biostratigraphic requirements for a GSSP (Remane et al., 1996). Among other methods that should be given due weight in the selection of a GSSP (Remane et al., 1996), chemostratigraphic, palaeogeographic, facies-relationship, and sequence-stratigraphic information is available. The section is accessible, and of unrestricted access for research. Upon ratification of this proposal, it is expected that a permanent monument marking the GSSP position will be erected, and that the site will be permanently protected in a national geological reserve. This will ensure continued free access to the site for research purposes.

The Furongian Series differs in content from the upper Cambrian of the most recent versions of the preliminary Cambrian time scale (Geyer et al., 2000) and the global standard scale (Cowie and Bassett, 1989; Remane et al., 2000). Following internationally accepted practice for defining global chronostratigraphic units (Hedberg, 1976; Salvador, 1994), the choice of a boundary-stratotype at the base of the *Glyptagnostus reticulatus* Zone is the best available for defining the lower boundary of an upper Cambrian series (see review in Geyer & Shergold, 2000). Although this position differs from most traditional, and regionally applicable, positions of the base of the upper Cambrian (Fig. 1), this position has the important advantage of being identifiable on a global scale, thus overcoming the problem of conflicting regional stratigraphic standards.

The relative suitability of available horizons for the base of the uppermost Cambrian series has been discussed by members of the Cambrian Stage Subdivision Working Group of the International Subcommission on Cambrian Stratigraphy (ISCS), and the base of the *G. reticulatus* Zone has been selected as the base of the upper Cambrian series by an 85% majority of the Voting Members of the ISCS (Shergold & Geyer, 2001). Choices for sections containing the base of the *G. reticulatus* Zone are available in South China, Kazakhstan, Siberia, Australia, and Laurentia (Shergold & Geyer, 2001). In 2001, the Cambrian Stage Subdivision Working Group visited sites in South China containing the proposed boundary position. After examining the Paibi section, the Working Group met in Zhijin, Guizhou Province, China, and discussed the merits of the available candidate sections. The consensus of opinion was that only two viable candidates exist for the GSSP for the base of the upper Cambrian series: the Paibi section, China (Dong, 1990; Peng & Robison, 2000; Peng et al., 2001c, 2001e), and the Kyrshabakty River section, Malyi Karatau, Kazakhstan (Ergaliev, 1980, 1990).

In early 2002, Voting Members of the ISCS were asked to vote on whether to forward to the International Commission on Stratigraphy (ICS) the proposal to establish the FAD of *Glyptagnostus reticulatus* in the Paibi section, Hunan, China, as the base of the Paibian Stage and Furongian Series. By 1 April 2002, 17 votes had been received; 14 votes (82%) were in favour of the proposal. Two Voting members voted against the proposal, one Voting Member abstained, and two Voting Members did not reply. In light of this favourable vote on the proposal, we now respectfully request the ICS for a vote on ratification of this proposal.

PROPOSAL: PAIBI (HUNAN PROVINCE, CHINA) AS THE GSSP FOR THE BASE OF THE PAIBIAN STAGE (BASE OF THE FURONGIAN SERIES)

1. Stratigraphic rank of boundary.

Base of the Paibian Stage, and base of the Furongian Stage (Fig. 1). The Paibian Stage is the lowermost stage of the Furongian Series. The Furongian Series is the uppermost series of the Cambrian System. The boundary is a standard stage/age, and series/epoch GSSP.

1.A. ***Paibian Stage and Furongian Series: new names and historical review***.—The Paibian Stage (and Age) is a new name for the lower stage (and age) of the Furongian Series (and Epoch; also a new name). The name Furongian replaces in concept and content the traditional upper Cambrian (e.g., Cowie & Bassett, 1989; Geyer & Shergold, 2000; Remane et al., 2000), and the various concepts of the upper Cambrian used regionally around the world (see Geyer & Shergold, 2000; Fig. 1).

The names Paibian and Furongian are derived from geographic localities in South China, where the base of the *G. reticulatus* Zone is well exposed, and well constrained in stratigraphic position. The name Paibian Stage (and Age) is derived from Paibi, a village near the proposed GSSP site, in Hunan Province, China. The Paibian Stage, proposed for global use, has the same lower boundary as the Waergangian Stage as used in South China (Peng et al., 1999, 2000, 2001c; Geyer et al., 2000; Peng & Babcock, 2001; Fig. 1). The upper boundary of the stage is currently undefined (Fig. 1), and will be defined by the base of the succeeding stage, which has yet to be determined. The name Furongian is derived from Furong, which means lotus, referring to Hunan, the Lotus State. Furong has been used as a nickname for Hunan since about A.D. 800, during the late part of the Tang Dynasty (A.D. 618-907). The Furongian Series is the global equivalent of the Hunanian Series as used in South China (Peng et al., 1999, 2000, 2001c; Geyer et al., 2000; Peng & Babcock, 2001; Fig. 1). The upper boundary of the Furongian Series is the base of the Tremadocian Series (and the Ordovician System).

Numerous stadial and series schemes for the upper part of the Cambrian have been used regionally (e.g., Westergård, 1946; Henningsmoen, 1957; Öpik, 1966, 1967; Rosova, 1968; Robison, 1976; Rushton, 1978; Ergaliev, 1980; Shergold, 1982; Ludvigsen & Westrop, 1985; Zhang & Jell, 1987; Chang, 1988; Ahlberg & Ahlgren, 1996; Palmer, 1998; Peng et al., 1999, 2001c; Geyer & Shergold, 2000; Peng & Robison, 2000; Peng & Babcock, 2001; Fig. 1), but the decision to place the base of a new globally applicable upper Cambrian stage and series boundary at the base of the *G. reticulatus* Zone (Shergold & Geyer, 2001) follows the determination that this is one of the most widely recognizable and distinct horizons in the Cambrian System (e.g., Shergold, 1982; Geyer & Shergold, 2000; Peng et al., 2001c). Correlation of this position is discussed in section 3.C.

2. Proposed GSSP – geography and physical geology

2.A. ***Geographic location***.—The Paibi section (Figs. 2-7), situated in the Wuling Mountains (Wulingshan), Huayuan County, northwestern Hunan Province, China. Its geographic coordinates are latitude 28°23.37′ N, longitude 109º31.54′ E of Greenwich, England. The Paibi section consists of a nearly continuous series of roadcuts, small quarries, and hillside outcrops (Fig. 6A, B) located approximately 35 km west of the city of Jishou along the north side of the Jishou-Huayuan highway (Chinese National Highway 319), and approximately 28 km south of Huayuan. Beginning just west of the village of Sixin (Sixicun), the section extends approximately 1.7 km to just west of the village of Paibi (Figs. 2-5). The Paibi section extends from the middle Cambrian through the Lower Ordovician. The stratotype section is represented on the Paibi topographic map (Hunan Branch of State Topographical Surveying Bureau, Map number H49 G 087025, 1:10,000 scale; Fig. 3). Strata of the Huaqiao Formation extend from road level through the top of a hill that rises approximately 100 m above road level (Fig. 6A). The proposed GSSP is at an elevation of approximately 774 metres (Fig. 6B).

2.B. ***Geological location***.—The Wuling Mountains consist of an extensive series of folded and thrusted slices resulting from post-Devonian compressional tectonics that extend through parts of northwestern Hunan, eastern Guizhou, and southeastern Sichuan provinces, China. The Paibi section is located along the northwest limb of the Liexi-Zhuitun Syncline.

Cambrian strata of South China are assigned to three major depositional environments along a platform-to-basin transition (e.g., Pu & Ye, 1991; Peng & Robison, 2000; Peng & Babcock, 2001). Relatively shallow environments of the Yangtze Platform were flanked by deeper environments of the Jiangnan Slope Belt, and still deeper environments of the Jiangnan Basin. The proposed GSSP occurs within the Huaqiao Formation, which consists of a thick succession of carbonate beds deposited in the outer part of the Jiangnan Slope Belt.

2.C. ***Location of level and specific point***.—The base of the first calcilutite layer containing the cosmopolitan agnostoid trilobite *Glyptagnostus reticulatus* in the Huaqiao Formation in the Paibi section (Peng et al., 2001e) is proposed as the GSSP of the Paibian Stage, and of the Furongian Series (Figs. 6-9). Except for containing the lowest occurrence of *G. reticulatus* in the Paibi section, this calcilutite bed is essentially indistinguishable from other beds of similar lithology in this largely monofacial succession. The FAD of G. reticulatus in the Paibi section corresponds to a position 369.06 m above the base of the Huaqiao Formation according to the measured section of Peng et al. (2001c). The base of the Paibian Stage and Furongian Series, as proposed for global chronostratigraphic purposes, corresponds to the base of the Waergangian Stage and Hunanian Series as used in South China (Peng, 1999; Peng et al., 1999a, 2000; Peng & Babcock, 2001).

2.D. *Stratigraphic completeness*.—Detailed bed-by-bed correlation of the middle-upper Cambrian through northwestern Hunan, coupled with detailed biostratigraphy, sedimentology and carbon-isotope chemostratigraphy (e.g., Dong, 1990; Rees et al., 1992; Fu et al., 1999; Peng et al., 2000, 2001a, 2001b, 2001c, 2001d, 2001e; Peng & Robison, 2000; Saltzman et al., 2000; Dong & Bergström, 2001a, 2001b; Peng & Babcock, 2001), clearly demonstrate the stratigraphic continuity of the basal Paibian in the Paibi section. Biostratigraphic studies within Hunan and globally demonstrate that the succession of Glyptagnostus species (e.g., Geyer & Shergold, 2000; Peng & Robison, 2000; Peng & Babcock, 2001; Peng et al., 2001b, 2001c, 2001d, 2001e), other trilobite species (Peng & Babcock, 2001; Peng et al., 2001a, 2001b, 2001c, 2001d, 2001e), and conodont species (Dong, 1990; Dong & Bergström, 2001a) in the Paibi section is undisturbed. The Paibi section lacks evidence of synsedimentary and tectonic disturbances near the proposed GSSP. A few thin and laterally discontinuous matrix-supported calcirudite beds (representing debris flows of shelf-derived intraclasts) are intercalated between calcilutite beds below the boundary, but their bases appear to be non-erosional (compare with the experimental work of Marr et at., 2001), and none is present at the boundary point. The biostratigraphic succession in the section is unaffected by the interbeds. Likewise, evidence of metamorphism and strong diagenetic alteration are absent.

2.E. *Thickness and stratigraphic extent*.— The basal Paibian contact, proposed as the GSSP, occurs in a mostly monofacial succession of dark grey to black, thin-bedded, calcilutite beds. The contact where *Glyptagnostus reticulatus* first appears is subtle, occurring at the base of a layer of dark grey calcilutite overlying a layer of black calcilutite (Fig. 6C, D). The basal Paibian in the Paibi section is observable in a rather prominent cliff face in a hillside outcrop along a bedding plane length of more than 200 metres.

2.F. *Provisions for conservation, protection, and accessibility*.—The exposure containing the proposed GSSP is not subject to building, landscaping, or other destruction. Rapid vegetative growth is typical in South China, and minor effort is needed to keep vegetative cover off some areas of the Paibi section. However, the near-vertical cliff face containing the proposed GSSP shows significantly less vegetation than most areas of the hillside. In keeping with the usual practice in China, it is expected that the Paibi section will be designated as a national geological reserve, and receive appropriate conservation, if the proposed GSSP at Paibi is ratified. Local authorities have already expressed their willingness to proceed with protection of the section.

Access to the hillside outcrop at the Paibi section is unrestricted in all seasons. Travel to Huayuan County, Hunan Province, China, is open to persons of all nationalities, and travel for scientific purposes is welcomed and encouraged by local authorities. Major highways in Hunan Province are currently under construction, and their completion will significantly enhance access to the Paibi locality in the near future.

3. Motivation for selection of the boundary level and of the stratotype section

3.A. ***Principal correlation event (marker) at GSSP level***.—The agnostoid trilobite *Glyptagnostus reticulatus* has one of the broadest distributions of any Cambrian trilobite, and its first appearance has been acknowledged as the most favourable level for a GSSP defining the base of a global Cambrian series (Robison et al., 1977; Peng & Robison, 2000; Geyer & Shergold, 2000; Peng et al., 2001c; Shergold & Geyer, 2001). Agnostoid trilobites provide the best and most precise tools for intercontinental correlation in the upper half of the Cambrian System (e.g., Robison, 1984; Peng & Robison, 2000). Recent recalibration of radiometric ages for the Cambrian (Grotzinger et al., 1995; Davidek et al., 1998; Landing et al., 1998, 2000), scaled against the number of agnostoid zones now recognized in the upper half of the Cambrian indicates that the average duration of an agnostoid-defined biochron is about one million years (Peng & Robison, 2000). *Glyptagnostus reticulatus* has been identified (Geyer & Shergold, 2000; Peng et al., 2001c) from China, Australia, Antarctica, Kazakhstan, Russia, South Korea, Sweden, Denmark, Norway, the United Kingdom, the United States, Canada, and Argentina, and has been used as a zonal guide fossil in South China, Australia, Kazakhstan, Siberia, and Laurentia (Geyer & Shergold, 2000; Peng & Robison, 2000). Co-occurrences with other trilobites allow correlation into such regions as Baltica (*Homagnostus obesus* Zone; Ahlberg and Ahlgren, 1996; Ahlberg, 1998) and Argentina (lower *Aphelaspis* Zone/lower *G. reticulatus* Zone-equivalent; Shergold et al., 1995).

Stratigraphically, *G. reticulatus* always succeeds *G. stolidotus* (Peng et al., 2001c), and it is desirable to select the position of a GSSP in a section showing a complete succession from the *G. stolidotus* Zone through the *G. reticulatus* Zone. Consistent upsection changes in morphology, notably increased reticulation (Fig. 9), and consistent stratigraphic occurrence below *G. reticulatus* (except where inferred hiatuses exist in Baltica and Avalonia), together strongly suggest that *G. stolidotus* was ancestral to *G. reticulatus*. Selection of the FAD of *G. reticulatus* as the base of the uppermost Cambrian series ensures that the boundary will fall within the stratigraphic interval bearing *Glyptagnostus*, and at an arbitrary, but readily identifiable, point in an evolutionary series. Globally, the stratigraphic interval bearing *Glyptagnostus* species is relatively narrow but widely exposed. This allows the boundary to be tightly constrained as long as *Glyptagnostus*-bearing strata are present in a region.

Selection of a GSSP in a slope environment, and particularly a low-latitude Gondwanan slope environment such as the Jiangnan Slope Belt, is desirable because it provides faunal ties (and correlation tools) with low-latitude shelf areas, high-latitude shelf areas, and low- or high-latitude, slope-to-basinal areas. In the latter half of the Cambrian, stratification of the world ocean according to temperature or other factors that covary with depth (e.g., Cook & Taylor, 1975, 1976; Babcock, 1994) led to the development of rather distinct trilobite biofacies in shelf and basinal areas. Low-latitude shelf areas were inhabited mostly by endemic polymeroid trilobites and some pan-tropical taxa. High-latitude shelf areas, and basinal areas of low and high latitudes, were inhabited mostly by widespread polymeroid trilobites and cosmopolitan agnostoid trilobites. Slope areas are characterized by a combination of some shelf-dwelling taxa and basin-dwelling taxa. The combination of cosmopolitan agnostoids, which have intercontinental correlation utility, Gondwanan shelf-dwelling polymeroids, pan-tropical polymeroids, and widespread polymeroids in the Jiangnan Slope Belt (Egorova et al., 1963; Peng & Robison, 2000; Peng et al., 2001a) allows for the precise correlation of the base of the G. reticulatus Zone (and other marker horizons) into such Gondwanan shelf areas as the North China Platform (Zhang & Jell, 1987), and Australia (Öpik, 1963, 1966, 1967; Shergold, 1982; Jago & Brown, 1992); and into such slope areas as Kazakhstan (Ergaliev, 1980, 1990), France (Shergold et al., 2000), Iran (Peng et al., 1999), Oman (Fortey, 1994), and Victoria Land, Antarctica (Cooper et al., 1996). Correlation into high-latitude shelf areas of Baltica (Westergård, 1946; Ahlberg & Ahlgren, 1996), and shelf-edge regions of Laurentia (Palmer, 1999) and Siberia (Ivshin & Pokrovskaya, 1968; Rosova, 1968, 1984) is also precise.

3.B. *Stratotype section*.—The FAD of *G. reticulatus* in the Paibi section, Hunan Province, China, occurs in the Huaqiao Formation (at a level 369.06 m above the base of the formation according to the measured section of Peng et al., 2001c; Figs. 7, 8). At this section, the Huaqiao Formation rests in conformable succession above the Aoxi Formation. Agnostoid trilobite zonation of the Huaqiao Formation in the Paibi section reveals a complete, tectonically undisturbed, marine succession from the *Ptychagnostus* (or *Acidusus*) *atavus* Zone through the upper part of the *G. reticulatus* Zone (Peng & Robison, 2001). Formerly, the FAD of *G. reticulatus* was included in the lower part of the Bitiao Formation in northwestern Hunan, but following revision of stratigraphic nomenclature (Peng & Robison, 2000), the Huaqiao, Chefu, and Bitiao formations of Hunan Province and adjacent areas of Guizhou Province (Peng & Babcock, 2001) have been grouped into a single unit, the Huaqiao Formation. The Huaqiao Formation at the Paibi section (Rees et al., 1992; Peng & Robison, 2000; Peng et al., 2001c, 2001e) is a mostly monofacial succession of alternating thin-bedded, dark grey to black argillaceous- and lime-rich calcisilitites and calcilutites. Thin- to medium-bedded calcarentites containing Bouma divisions, and matrix-rich, clast-supported boulder- to pebble-calcirudites, are sporadically present below the FAD of *G. reticulatus* and are more common above that position. The calcirudites commonly have non-erosive flat bases and uniform thicknesses over distances of tens of metres. Lenticular and channelized calcirudite beds, some of which display downslope textural transformations, are less common. Many calcarenites and calcirudites contain identifiable shelf-derived allochems, as well as resedimented slope deposits. Soft-sediment deformation is extremely rare in the succession, and truncation or slide surfaces are absent, suggesting distal deposition on relatively gentle slopes. Strata enclosing the proposed boundary position, between 361.5 and 376.5 m above the base of the Huaqiao Formation, include five laterally discontinuous calcirudite interbeds ranging from 8 to 66 cm in thickness. None of the calcirudite interbeds occurs at the proposed boundary or disrupts the stratigraphic appearance of taxa in any way. Trilobite sclerites are common in the fine-grained limestones but are absent from the calcirudites. The Huaqiao Formation represents outer-slope deposition in a marine setting, the Jiangnan Slope Belt, which was adjacent to the Yangtze (South China or Southwest China) Platform (e.g., Pu & Yi, 1991; Rees et al., 1992; Peng & Robison, 2000; Peng & Babcock, 2001).

The proposed GSSP in the Paibi section is placed within a continuous evolutionary sequence of *Glyptagnostus* species (Figs. 8, 10). Successive stratigraphic levels show an evolutionary succession beginning with *G. stolidotus* (Fig. 9A, B), and continuing through weakly reticulated (primitive) *G. reticulatus* (commonly formalized as *G. reticulatus angelini*; e.g., Palmer, 1962; Ergaliev, 1980; Dong, 1990; Fig. 9C-E), to strongly reticulated (derived) *G. reticulatus* (commonly formalized as *G. reticulatus reticulatus*; e.g., Henningsmoen, 1958; Palmer, 1962; Shergold, 1982; Rushton, 1983; Jago & Brown, 1992; Peng, 1992; Ahlberg & Ahlgren, 1996; Clarkson et al., 1998; Fig. 10F-G). Peng & Robison (2000) synonymized the two morphotypes, along with other named morphological variants of the species. Globally, the weakly reticulated morphotype of *G. reticulatus* always precedes the strongly reticulated morphotype of the species in ascending stratigraphic order. The FAD of *G. reticulatus* in the Paibi section, as well as the base of the G. *reticulatus* Zone globally, is taken to be the first appearance of the weakly reticulated morphotype of *G. reticulatus* (Fig. 10C-E). The base of the bed containing the FAD of *G. reticulatus* at the Paibi section is isochronous along its exposed length, although lithologically it is essentially indistinguishable from other layers in a succession of thinly bedded, dark grey to black lime-rich and argillaceous calcilutites (Fig. 6).

Ranges of trilobites across the stratigraphic interval containing the proposed GSSP are summarized in Fig. 8. Besides species of *Glyptagnostus*, a number of other guide fossils, which have utility for correlation on a regional to intercontinental scale, help to constrain the boundary position. They include the agnostoid trilobites *Acmarhachis typicalis*, *Peratagnostus obsoletus*, *Pseudoagnostus josepha*, all of which first appear in the G. stolidotus Zone and range up into (or, in the case of *P. obsoletus*, through) the *G. reticulatus* Zone. Likewise, a polymeroid trilobite, *Proceratopyge fengwangensis*, first appears near the top of the *G. stolidotus* Zone, and ranges through the *G. reticulatus* Zone. The widespread agnostoid trilobites *G. stolidotus*, *Ammagnostus histus*, *Agnostardis amplinatus*, and *Agnostus inexpectans* occur in the *G. stolidotus* Zone but none ranges higher than that zone. Polymeroid trilobites that occur within the stratigraphic interval containing *Glyptagnostus* in northwestern Hunan, China, but that range no higher than the FAD of *G. reticulatus*, include *Chatiania chatianensis*, *Fenghuangella liostracinala*, *Paradamesella typica*, *Protaizehoia yuepingensis*, *Pseudoyuepingia laochatiensis*, and *Teinistion posterocosta*. Zonation of conodonts from the Paibi section (Dong & Bergström, 2001a) shows that the base of the *Westergaardodina proligula* Zone occurs just slightly below the base of the *G. reticulatus* Zone.

3.C. *Demonstration of regional and global correlation*.—A position at or closely corresponding to the FAD of *Glyptagnostus reticulatus* in the Paibi section is one of the most easily recognizable horizons on a global scale in the Cambrian (e.g., Palmer, 1962; Geyer and Shergold, 2000; Peng and Robison, 2000; Saltzman et al., 2000; Peng et al., 2001c; Figs. 1, 9). Papers discussing the suitability of the FAD of this species for marking a global stage and series boundary have been summarized by Geyer and Shergold (2000). Key correlation tools (Fig. 9) are as follows:

3.C.i. Agnostoid trilobite biostratigraphy.—*Glyptagnostus reticulatus* is recognized worldwide (e.g., Kobayashi, 1949; Öpik, 1966; Rosova, 1968; Jago, 1974; Robison et al., 1977; Shergold, 1982 and references therein; Shergold et al., 1995; Geyer & Shergold, 2000; Figs. 1, 9). It has been identified (Geyer & Shergold, 2000; Peng et al., 2001c) from China (northwestern Hunan, eastern Guizhou, southern Anhui, northwestern Gansu, Xinjiang, western Zhejiang), Australia (western Queensland, Tasmania), Antarctica (Ellsworth Mountains), Kazakhstan (Lesser Karatau), Russia (northwestern Siberian Platform, northeastern Siberian Platform), South Korea, Sweden, Denmark, Norway, the United Kingdom, the United States (Alabama, Alaska, Nevada, Tennessee, Texas), Canada (British Columbia, Northwest Territories), and Argentina. The species is used as a zonal guide fossil in South China (Jiangnan Slope area), Australia, Kazakhstan, Siberia, and Laurentia (Geyer & Shergold, 2000; Peng & Robison, 2000). Co-occurrences with other trilobites allow correlation into Avalonia (*Homagnostus obesus* Zone; Rushton, 1983), and Argentina (lower *Aphelaspis* Zone/lower *G. reticulatus* Zone-equivalent; Shergold et al., 1995).

3.C.ii. Polymeroid trilobite biostratigraphy.—The base of the *G. reticulatus* Zone coincides with turnovers in polymeroid trilobite faunas recognized at the base of the Waergangian Stage and the Hunanian Series in South China (Peng et al., 1999, 2001c; Peng & Babcock, 2001; Fig. 8), the base of the Changshanian (Paishanian) in North China (Walcott, 1913; Öpik, 1967; Qian, 1994), the base of the Idamean Stage in Australia and Tasmania (Öpik, 1960, 1963, 1967; Jago, 1974; Shergold, 1982; Jago & Brown, 1992), the base of the Sackian Stage and base of the Upper Cambrian Series in Kazakhstan (Ergaliev, 1990), and the base of the Kugorian (Kutugunian) Stage in Siberia (Rosova, 1984). The base of the *G. reticulatus* Zone corresponds to the base of the Steptoean Stage and Millardan Series (Palmer, 1965; 1998, 1999; Ludvigsen & Westrop, 1985) in Laurentia. However, shelf successions lack the appropriate lithofacies for *G. reticulatus*. On the Laurentian shelf, the FAD of the trilobite *Coosella perplexa*, at the base of the

Aphelasis Zone, corresponds closely to the base of the *G. reticulatus* Zone. The *Aphelaspis* Zone can be recognized across much of the Laurentian shelf (see Palmer, 1999) and in Argentina (Shergold et al., 1985). The *G. reticulatus* Zone corresponds to the lower part of the *Homagnostus obesus* Zone (*Olenus gibbosus* Zone) in Scandinavia (Westergård, 1946, 1947; Henningsmoen, 1957; Ahlberg & Ahlgren, 1996; Ahlberg, 1998), eastern Avalonia (central England; Rushton, 1983), and western Avalonia (southeastern Newfoundland; Hutchinson, 1962).

3.C.iii. Conodont biostratigraphy.—The base of a conodont biozone, the *Westergaardodina proligula* Zone (Dong & Bergström, 2001a), occurs just slightly below the base of the *G. reticulatus* Zone. The intercontinental correlation potential of other biostratigraphic tools, such as brachiopods, near the base of the *G. reticulatus* Zone has not been extensively tested.

3.C.iv. Chemostratigraphy..—The base of the *G. reticulatus* Zone closely corresponds with the onset of a large positive shift in δ13C values referred to as the Steptoean positive carbon isotope excursion (SPICE excursion; Brasier, 1993; Runnegar & Saltzman, 1998; Saltzman et al., 1998, 2000, 2001; Perfetta et al., 1999). The precise base of the SPICE excursion is subjective, as the excursion follows a monotonic positive shift in δ13C values from values that are indistinguishable from background values. The SPICE excursion reaches peak values of about +4 ‰ δ13C between the FAD of *G. reticulatus* and the FAD of *Irvingella* (Saltzman et al., 2000), at a position roughly corresponding to the interval of peak biotic diversity in the Pterocephaliid Biomere of Laurentia (Rowell & Brady, 1976), and to an important sea level fall represented in Laurentia by the Sauk II-Sauk III hiatus (see Palmer, 1981; Saltzman et al., 2000). The excursion has been documented from sections in South China (Paibi and Wa'ergang), Kazakhstan (Kyrshabakty River section, Malayi Karatau), Australia (Queensland), and the United States (Great Basin). Carbonate environments yielding the SPICE excursion range from slopes where dark, thin-bedded limestones predominate, through shallow platforms where a variety of carbonate lithofacies (boundstones, oolitic grainstones, and fenestral limestones) are present (Saltzman et al., 2000). A rise in seawater $^{87}Sr/^{86}Sr$ values, coinciding with the SPICE excursion has been documented from Laurentia (Montañez et al., 1996, 2000; Denison et al., 1998), and presumably has global expression.

3.C. v. Sequence stratigraphy.—Work in the Jiangnan Slope Belt of Hunan Province, China, shows that the base of the *G. reticulatus* Zone coincides with the initial stages of a transgressive event (Yang & Xu, 1997a, 1997b, 1997c). Transgression coinciding with the lower part of the *G. reticulatus* Zone is followed by a highstand phase and then a shallowing that is expressed in South China, North China, and Laurentia (Palmer, 1981; Yang and Xu, 1997a); the eustatic sea level fall is represented in Laurentia as the Sauk II-Sauk III hiatus (Palmer, 1981; Osleger & Read, 1993; Fig. 9).

4. Selection process

4.A. ***Relation of the GSSP to historical usage***.—The Paibian Stage (and Age) is a new name for the lower stage (and age) of the Furongian Series (and Epoch; also a new name). The name Furongian replaces in concept, and content, the traditional upper Cambrian (e.g., Cowie & Brasier, 19879; Geyer & Shergold, 2000; Remane et al., 2000), and the various concepts of the upper Cambrian used regionally around the world (see Geyer & Shergold, 2000; Fig. 1). The Paibian Stage has the same lower boundary as the Waergangian Stage as used in South China (Peng et al., 1999, 2000, 2001c; Geyer et al., 2000; Peng & Babcock, 2001; Fig. 1). The relationship of the Paibian Stage and Furongian Series to other regional stage and series concepts is discussed in section 3.C.ii, and summarized in Fig. 1.

4.B. ***Other candidates and reasons for rejection***.—Following extensive discussion by members of the Cambrian Stage Subdivision Working Group of the ISCS, meeting in Zhijin, China, in September 2001, only two sections emerged as viable candidates for designation of a stage and series GSSP: 1, the Paibi section, China (Peng & Robison, 2000; Peng et al., 2001c, 2001e; Figs. 4-7, 10A-C); and 2, the Kyrshabakty River section, Kazakhstan (Ergaliev, 1980, 1990). Review of available published information and our collective experience leads us to conclude that the Paibi section is superior to the Kyrshabakty River section, and to all other sections in northwestern Hunan, China (Paibi-2 section, Peng et al., 2001c; Wangcun section, Peng et al., 2001d; and Wa'ergang section, Peng et al., 2001b).

4.B.i. Other regional candidates.—Besides the Paibi section, the only South China section nominated and fully documented as a possible GSSP is that known as Paibi-2 (Peng et al., 2001c, 2001e), which occurs on a hillside adjacent to the Paibi section (Figs. 3- 5). The base of the Paibi-2 section is in the *G. stolidotus* Zone; it continues through the *G. reticulatus* Zone, into the overlying *Irvingella angustilimbata* Zone, and through to the base of the Ordovician. Similar to the Paibi section, the first appearance of *G. reticulatus* is in the Huaqiao Formation. The lithology of the Huaqiao Formation in the Paibi-2 section is the same as in the Paibi section. The Paibi-2 section is considered to be less suitable for a GSSP than the Paibi section because the full evolutionary succession from the FAD of *G. stolidatus* through the FAD of *G. reticulatus* is not preserved, and because the FAD of *G. reticulatus* occurs about 16 cm above the top of a thick (60 cm) rudstone interbed. The interbed does not appear to have disrupted the biostratigraphic succession. Paibi-2 is best regarded as a reference section for the base of the Paibian Stage and Furongian Series (Peng et al., 2001e).

Other sections in Hunan Province, China, that show the lower part of the *G. reticulatus* Zone are considered unsuitable as GSSP candidates because of structural complications or poor exposure. In the section near Wangcun (Peng et al., 2001d), a fault is present in the interval of the Huaqiao Formation between the last observed occurrence of *G. stolidotus* and the first observed occurrence of *G. reticulatus*. In the section near Wa'ergang (Peng et al., 2001b), poor exposure hinders easy access to the interval between the upper *G. stolidotus* Zone and the lower *G. reticulatus* Zone.

4.B.ii. Other extra-regional candidate.—The Kyrshabakty River section, Kazakhstan, is a potential candidate for a GSSP. Published information on the section (Ergaliev, 1980, 1990) indicates that *G. reticulatus* occurs in a thick succession of dark grey to black limestones and argillaceous limestones with numerous rudstone interbeds beginning well below the first appearance of *G. reticulatus* and persisting to the base of the Ordovician. Similar to the Huaqiao Formation at Paibi, China, the Kyrshabakty River section records deposition in an outer slope fan environment. The best available zonation of the Kyrshabakty section (Ergaliev, 1980, 1990) is by trilobite assemblages, and the first observed appearance of *G. reticulatus* (reported as *G. reticulatus angelini*) is within the *G. stolidotus* Zone (Ergaliev, 1990, p. 18, 19). There is an indication that the normal biostratigraphic succession has been disrupted in the interval between the *G. stolidotus* Zone and the superjacent *G. reticulatus*-*Eugonocare* Zone according to Ergaliev (1980). *Hadragnostus modestus* (reported as *Formosagnostus formosus*; Ergaliev, 1980), *Kormagnostella longa*, and *Blackwelderia* sp., are all present above the first observed appearance of *G. reticulatus* (reported as *G. reticulatus angelini*; Ergaliev, 1980) in the Kyrshabakty section. In all other occurrences globally, none of these taxa ranges above the *Linguagnostus reconditus* Zone. These occurrences could represent either significant upward range extensions from the *L. reconditus* Zone to the *G. reticulatus* Zone (as used herein; corresponding to the *G. stolidotus*

Zone of Ergaliev, 1980, 1990), or a mixing of faunas representing different agnostoid zones. In addition, Ammagnostus sp. has been reported from the *G. reticulatus* Zone in the Kyrshabakty section (Ergaliev, 1980). Elsewhere in the world, the genus has not been shown to range above the *G. stolidotus* Zone.

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