Rivista Italiana di Paleontologia e Stratigrafia	volume 112	no. 2	3 pls.	pp. 177-190	July 2006

CAMBRIAN CONODONTS ACROSS THE PRE-FURONGIAN TO FURONGIAN INTERVAL IN THE GSSP SECTION AT PAIBI, HUNAN, SOUTH CHINA

QI YU-PING [1], GABRIELLA BAGNOLI [2] & WANG ZHI-HAO [1]

Received: October 12, 2005; accepted: March 21st, 2006

Key words: Cambrian, conodonts, Furongian Series, Paibian Stage, China, biostratigraphy.

Abstract. The conterminant base of the Furongian Series and Paibian Stage (Cambrian), as ratified in 2003, is in dark carbonate slope deposits of the Paibi section, Hunan, China, at the FAD of the agnostid trilobite *Glyptagnostus reticulatus*. Sampling in the boundary interval reveals 38 taxa of protoconodonts and paraconodonts, including two new species, *Prosagittodontus telli* and *Furnishina miao*, and some species in open nomenclature. In the investigated interval, *Westergaardodina* is a minor component of the conodont associations, whereas *Furnishina* is common. The interval can be subdivided into two informal assemblages: 1) the *Furnishina miao* assemblage, which extends from the base of the investigated interval to just below the FAD of *G. reticulatus*, followed by 2) the *Furnishina quadrata-Furnishina longibasis* assemblage, which extends from just above the FAD of *G. reticulatus* to the top of the studied interval.

The conodont succession correlates with trilobite biozones, and approximately correlates with conodont zones previously recognized in South China and North China. The occurrence of *Furnishina longibasis* allows long distance correlation because it has a short stratigraphic range and has been reported from Sweden and Poland.

Riassunto. La base della Serie Furongiana e del Piano Paibiano (Cambriano) é stata formalmente istituita nel 2003 in depositi di scarpata carbonatica della sezione di Paibi, Hunan, Cina, in corrispondenza del FAD del trilobite agnostide *Glyptagnostus reticulatus*. La campionatura nell'intervallo comprendente il limite ha prodotto 38 taxa di protoconodonti e paraconodonti, comprendenti due nuove specie: *Prosagittodontus telli* e *Furnishina miao* ed alcune specie in nomenclatura aperta. Nell'intervallo esaminato *Furnishina* è ben rappresentata, mentre *Westergaardodina* costituisce solo una piccola parte della fauna a conodonti.

L'intervallo esaminato può essere suddiviso in due associazioni informali: l'associazione a *Furnishina miao*, dalla base dell'intervallo esaminato fino ad un livello immediatamente precedente al FAD di *G. reticulatus*, seguita dall'associazione a *Furnishina quadrata-Furnishina longibasis*, che si estende da un livello immediatamente successivo al FAD di *G. reticulatus* fino alla sommità della successione studiata.

La successione a conodonti si correla direttamente con le biozone a trilobiti, mentre sono approssimative le correlazioni con le biozone a conodonti precedentemente istituite per la Cina del Sud e della Cina del Nord. La presenza di *Furnishina longibasis* permette correlazioni a grande distanza in quanto questa specie ha una distribuzione stratigrafica molto breve ed é stata rinvenuta anche in Svezia e Polonia in livelli con trilobiti correlabili con la Zona a *G. reticulatus*.

Introduction

Cambrian slope deposits are well exposed in western Hunan Province, China. Strata representing the upper part of the Cambrian comprise, in ascending order the Aoxi, Huaqiao, and Zhuitun formations (Peng 1992; Peng & Robison 2000; Peng et al. 2004d). The Aoxi Formation is mostly composed of laminated gray dolostones. It is followed by the Huaqiao Formation, which consists of interbedded dark argillaceous limestone and calcareous shale with limestone debris beds in the upper part. The Zhuitun Formation consists of massive dolostone. The Aoxi and Zhuitun formations are poorly fossiliferous, whereas the Huaqiao Formation is highly fossiliferous with rich trilobite and conodont faunas.

The trilobite biostratigraphy of the area has been detailed by Peng & Robison (2000), and Peng et al. (2001, 2004a, 2004b, 2004c, 2004d). In 2003 the first intra-Cambrian GSSP (Global Standard Stratotype-section and Point) was ratified by the International Union of Geological Sciences (IUGS), and the Paibi section, Huayuan County, northwestern Hunan Province, was selected as the GSSP marking the base of the Furongian Series and Paibian Stage (Peng & Babcock 2003; Peng et

1 Nanjing Institute of Geology and Palaeontology, the Chinese Academy of Sciences, 39 East Beijing Road, Nanjing, 210008. People's Republic of China. E-mail: ypqi@nigpas.ac.cn

2 Department of Earth Sciences of Pisa University, Via S. Maria, 53 56126 Pisa, Italy. E-mail: bagnoli@dst.unipi.it

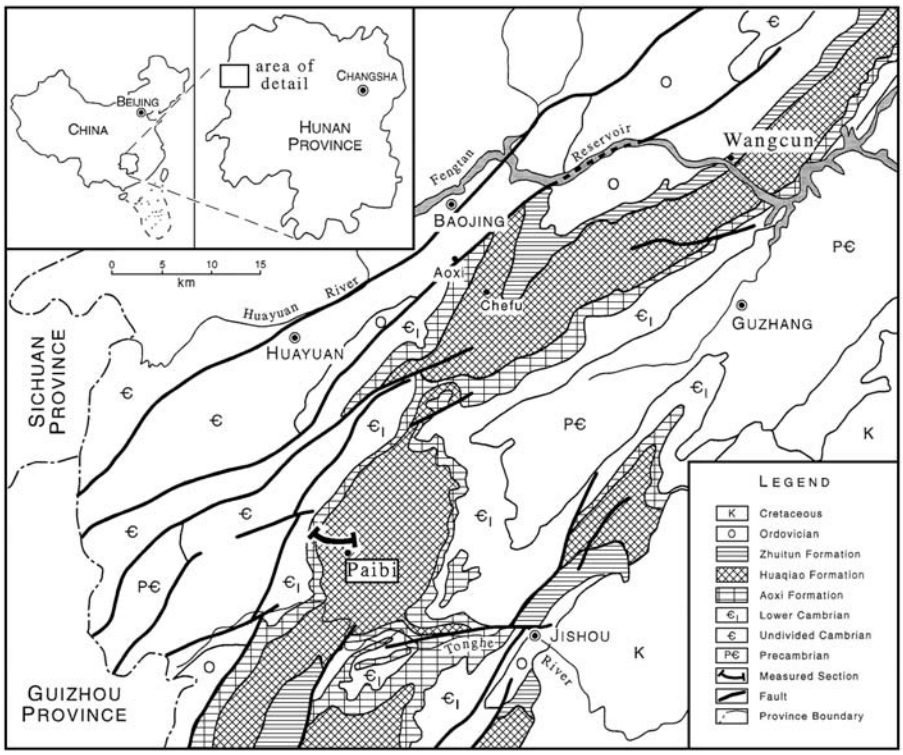

Fig. 1 - Location map of northwestern Hunan, China, showing location of the Paibi section (modified from Peng et al. 2000).

al. 2004a, 2004b) at the FAD of the agnostid trilobite *Glyptagnostus reticulatus*.

Cambrian conodont successions from the Hunan Province were investigated by Dong (1990a, 1990b, 1993) and Dong & Bergström (2001a, b), focusing mainly on the interval spanning the traditional Middle-Upper Cambrian boundary.

The aim of the present paper is to examine in detail the conodont succession across the interval comprising the base of the Paibian Stage of the Furongian Series from the Paibi section. The upper part (about 30 m) of the Paibi section was closely sampled, and preliminary results were presented by Qi et al. (2004). Unfortunately the conodont yield was low and recovered specimens were mostly fragmentary, thus preventing reliable identifications. The Paibi section was sampled again in October 2004, and a more careful treatment of the samples, especially during the sieving process, produced more abundant and more complete specimens, thus allowing confident taxonomic assignment.

Location and stratigraphy

The Paibi section is located at latitude 28°23.37'N, and longitude 109°31.54'E (Peng et al. 2004b), near the village of Sixin, ca. 35 km northwest the city of Jishou and southeast of the county town of Huayuan (Fig. 1).

Middle and upper Cambrian sediments of the Paibi area were deposited on the western margin of the Jiangnan Slope Belt and consist of the Aoxi, Huaqiao, and Zhuitun formations. The studied interval is within the Huaqiao Formation, whose total thickness in the Paibi section is 388.5 m divided into 39 beds; the upper part of the Huaqiao Formation is not exposed in this section. The base of the Furongian Series and Paibian Stage, at the FAD of the cosmopolitan agnostid trilobite *Glyptagnostus reticulatus*, occurs at 369.06 m above the base of the Huaqiao Formation within the bed 37 (Peng et al. 2004b). The detailed stratigraphic succession is given in Appendix 1.

Conodont fauna

More than 1000 kg of limestone, representing 220 samples, were processed for conodonts from the Huaqiao Formation at Paibi. Of these, 26 samples proved productive, yielding 561 specimens of protoconodonts and paraconodonts. Associated microfossils recovered from the residues are mostly inarticulated brachiopods, sponge spicules (samples PC-37, PC 23, PC43, PC51), and hyolithids (sample PC-46). Sample productiveness varies, increasing in the upper part of the section. The step-like occurrence of several taxa (Fig. 2) in the lower part of the section is most likely a result of the non-productiveness of some levels and perhaps low number of specimens originally.

Of the 38 identified conodont taxa (Fig. 2, Tab.1), some in open nomenclature, two are new species: *Prosagittodontus telli* and *Furnishina miao*. In the investigated interval *Phakelodus* Miller, 1984 is the dominant genus (about 38%) among the protoconodonts, and

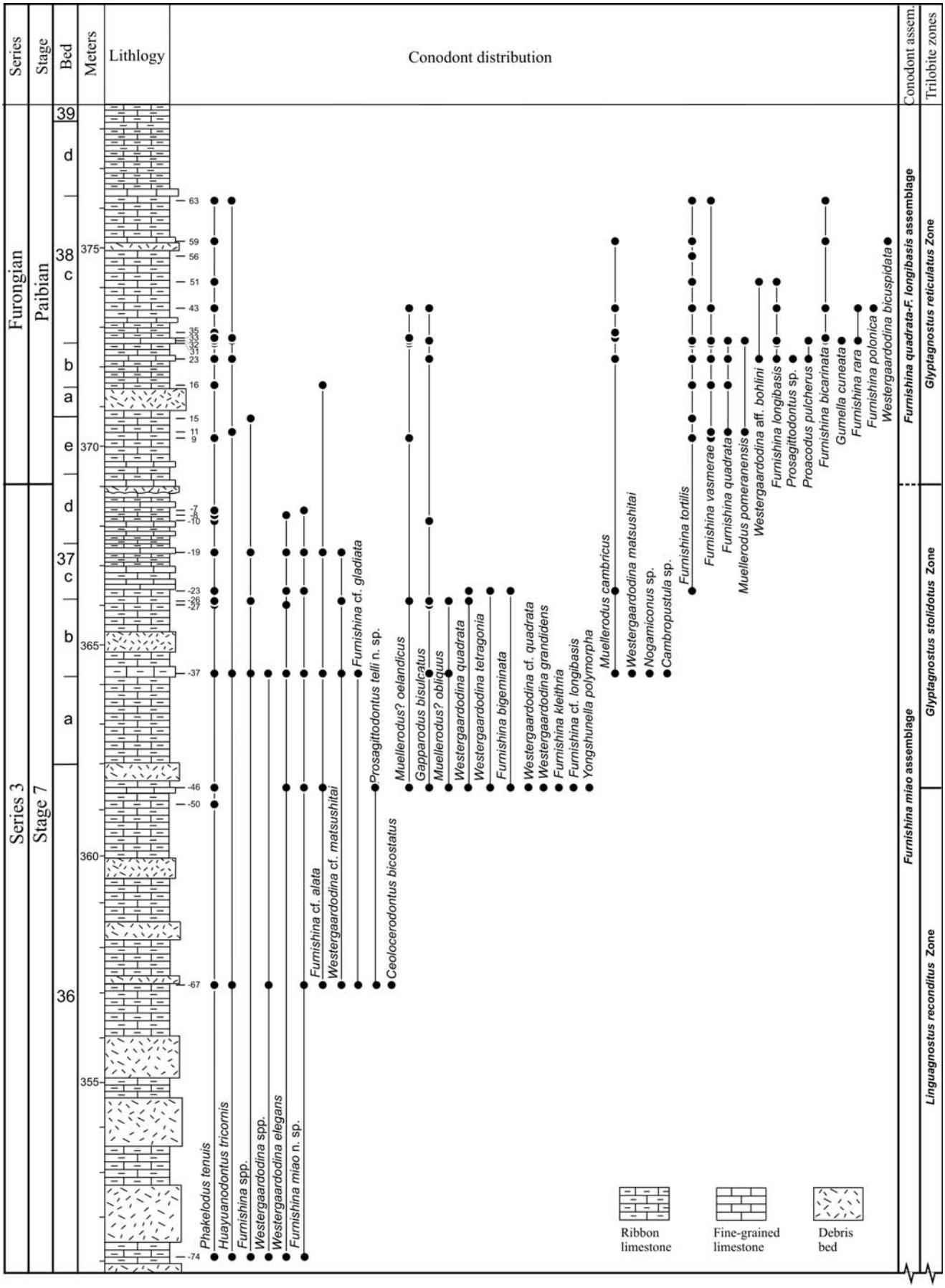

Fig. 2 - Part of the Paibi section, Hunan, China, showing ranges of conodont taxa, and the new conodont biostratigrafic subdivisions. Trilobite zonation after Peng et al. (2001). Meter values reflect position above the base of the Huaqiao Formation. Numbers refer to productive conodont samples.

Species \ Samples	-74	-67	-50	-46	-37	-27	-26	-23	-19	-10	-8	-7	9	11	15	16	23	31	32	33	35	43	51	56	59	63	Total
Ceolocerodontus bicostatus van Wamel, 1974		1																									1
Furnishina cf. *alata* Szaniawski, 1971		2		3	2				1							1											9
Furnishina bicarinata Müller, 1959																			3	2		2			1	1	9
Furnishina bigeminata Dong, 1993				3				1																			4
Furnishina cf. *gladiata* Müller & Hinz, 1991		1			1																						2
Furnishina kleithria Müller & Hinz, 1991				1																							1
Furnishina longibasis Bednarczyk, 1979																	17	4	1			4	1				27
Furnishina cf. *longibasis* Bednarczyk, 1979				2																							2
Furnishina miao n. sp.	1	1		16	5			3	1			1															28
Furnishina polonica Szaniawski, 1971																						4					4
Furnishina quadrata Müller, 1959														2		6	5		4								17
Furnishina rara (Müller, 1959)																			1			1					2
Furnishina tortilis (Müller,1959)								5					3		1	3	24	5	10			8	1	2	1	3	66
Furnishina vasmerae Müller & Hinz, 1991													1	1		1	13	2	6			6				1	31
Furnishina spp.	1				2		1		1						1												6
Gapparodus bisulcatus (Müller, 1959)				2	2	1	1			1							8		1			3					19
Gumella cuneata Müller & Hinz, 1991																			1								1
Huayuanodontus tricornis (Dong, 1993)	1	10			2									1			3		5	1						1	24
Muellerodus cambricus (Müller, 1959)					1			1									2			1	1	1			1		8
Muellerodus ? *obliquus* (An, 1982)				4	2		2																				8
Muellerodus ? *oelandicus* (Müller, 1959)				2			2						1					1	1	1		2					10
Muellerodus pomeranensis (Szaniawski, 1971)														1					5								6
Nogamiconus sp.					1																						1
Phakelodus tenuis (Müller, 1959)	3	38	5	9	60	5	2	1	23	1	2	2	17			3	4	7	18	15	1	4	1		1	1	223
Proacodus pulcherus (An, 1982)																	2		1								3
Prosagittodontus telli n. sp.		2		1																							3
Prosagittodontus sp.																	1										1
Westeergaardodina bicuspidata Müller, 1959																									1		1
Westergaardodina aff. *bohlini* Müller, 1959																	1						1				2
Westergaardodina elegans Dong & Bergström, 2001	2			3	1	1		1	1		1																10
Westergaardodina grandidens Dong, 1993				1																							1
Westergaardodina matsushitai Nogami, 1966					1																						1
Westergaardodina cf. *matsushitai* Nogam, 1966		1			2		2		1																		6
Westergaardodina quadrata (An, 1982)				7			6	1																			14
Westergaardodina cf. *quadrata* (An, 1982)				3																							3
Westergaardodina tetragonia Dong, 1993				1				1																			2
Westergaardodina spp.	1	2			1																						4
Yongshunella polymorpha Dong & Bergström, 2001				1																							1
Total	9	58	5	59	83	7	16	14	28	2	3	3	22	5	2	14	80	19	57	20	2	35	4	2	5	7	561

Tab. 1 - Total numerical occurence of conodont taxa studied in this work.

Furnishina Müller, 1959 is the dominant genus (about 38%) among the paraconodonts.

The preservation is relatively good, but some specimens are covered by small sedimentary particles or show evidence of superficial corrosion. The colour varies from translucent to black. The co-occurrence of translucent and black specimens in the same samples was also noticed by Müller & Hinz (1991) for the Cambrian Swedish material.

Biostratigraphy

In 2001 Dong & Bergström presented a conodont biozonation based on material from the Paibi and Wangcun sections in Hunan Province, focusing on the traditional Middle-Upper Cambrian boundary which was placed at the base of an agnostid trilobite zone, the *Linguagnostus reconditus* Zone. According to Dong & Bergström (2001b, text-fig. 2), in the Paibi section the boundary between the zones of the agnostid trilobites *Glyptagnostus stolidotus* and *Glyptagnostus reticulatus* approximates the boundary between two conodont zones, the *Westergaardodina matsushitai-Westergaardodina grandidens* and *Westergaardodina proligula* zones. The base of the *W. matsushitai-W. grandidens* Zone was indicated as the first occurrence of *W. matsushitai* Nogami, 1966, and the top of the zone was marked by last occurrence of the same species. The *W. proligula* Zone was not defined, and the nominal taxon is a *nomen nudum*. *W. proligula* was not reported from the Paibi section, but it is present in the upper part of the Wangcun section (see text-fig. 3 of Dong & Bergström 2001b). The base of the *G. reticulatus* Zone, marked by the FAD of the nominal species, is within an interval between the last occurrence of *W. matsushitai* and the first occurrence of *W. proligula*.

In 2004 Dong et al. erected the new species *Westergaardodina ani* to replace the *nomen nudum W. proligula*, and presented a comprehensive biostratigraphic scheme based on middle Cambrian to lower Ordovician conodonts from Hunan. In this scheme, the base of the *G. reticulatus* Zone corresponds closely to the boundary between the *W. matsushitai-W. grandidens* Zone and the *W. lui-W. ani* Zone. The definition of the *W. matsushitai-W. grandidens* Zone was also changed. As reconstructed (Dong et al. 2004), the base of the zone is marked by the FAD of *W. matsushitai*, but the top is defined by the FAD of *W. lui* Dong et al., 2004. Dong et al. (2004, p. 1192) noted that the FAD of *W. lui* is a few meters higher than the last occurrence of *W. grandidens* and *W. matsushitai*, and that the *W. lui-W. ani* Zone is "approximately identical with the top of the latter zone". Unfortunately, the interval between the last occurrence of *W. matsushitai* and *W. grandidens* and the first occurrence of *W. lui* spans the *G. stolidotus – G. reticulatus* zonal boundary, and in the Paibi section, neither *W. lui* nor *W. ani* is present. Other important taxa, such as *Muellerodus*? *erectus* An, 1982, are also not recorded from this section. Therefore, based on our new data, assignment of the interval above the last occurrence of *W. matsushitai* and *W. grandidens* to the *W. matsushitai-W. grandidens* Zone or to the *W. lui-W. ani* Zone is problematic.

The interval spanning the *G. stolidotus – G. reticulatus* zonal boundary, which was densely sampled in the present study, exhibits a marked and gradual change in conodont faunal composition. *Westergaardodina*, even though not numerically abundant, has a high specific diversity in the *L. reconditus* and *G. stolidotus* zones, but diversity dramatically decreases in the *G. reticulatus* Zone. *Furnishina* is well represented throughout the investigated succession (Tab. 1 and Fig. 2). The new species *Furnishina miao* ranges from the base of the investigated interval (sample PC-74) up to a level (sample PC-7) just below the FAD of *G. reticulatus*, and *Furnishina quadrata* Müller, 1959 makes its first appearance just above the Paibian Stage base (sample PC11), and is followed immediately thereafter by the first occurrence of *Furnishina longibasis* Bednarczyck, 1979 (sample PC23). It is therefore possible to distinguish two assemblages informally designated as: 1, the *Furnishina miao* assemblage; and 2, the *Furnishina quadrata-Furnishina longibasis* assemblage. These two assemblages cannot be formally defined as zones or subzones, because the lowermost position of *F. miao*, and the uppermost position of the *F. quadrata-F. longibasis* assemblage, is presently unknown.

The *F. miao* assemblage is characterized by the nominal taxon, a species that does not extend into the next assemblage, and by several species of *Westergaardodina*, whose last occurrences are within the upper part of this assemblage. The *F. quadrata – F. longibasis* assemblage is characterized by the first occurrence of either of the nominal taxa and by the sporadic occurrence of *Westergaardodina*. *W.* aff. *W. bohlini* Müller, 1959 and *Proacodus pulcherus* (An, 1982) first occur within this assemblage.

Biostratigraphic correlation with other areas

An (1982) established a Cambrian conodont zonation for North and Northeast China in which the *W. matsushitai* Zone is followed by the *Muellerodus*? *erectus* Zone. The stratigraphic distribution of conodonts reported by An (1982, text-fig. 6) indicates an interval between the last occurrence of *W. matsushitai* and the first occurrence of *Muellerodus*? *erectus* where *Westergaardodina* is generally uncommon. In contrast, *Furnishina*, is relatively abundant, (An 1982). This pattern is similar to that reported here from the Paibi section. Therefore, the *F. quadrata-F. longibasis* assemblage at Paibi is tentatively correlated with the lower part of the An's (1982) *M.*? *erectus* Zone (Fig. 3).

The *F. quadrata-F. longibasis* assemblage correlates with conodont associations reported by Müller & Hinz (1991) from trilobite zone II in Sweden. *F. longibasis* has a short range in Sweden; it is confined to the *Homagnostus obesus* trilobite Zone (zone II in Müller & Hinz 1991), which correlates with the *G. reticulatus* Zone according to Peng et al. (2004b). In Sweden the first occurrence of *F. quadrata* is within the same trilobite zone. Most taxa of the *F. quadrata-F. longibasis* assemblage in the Paibi section are present in associations recorded by Müller & Hinz (1991) from trilobite zone II; among those, *Furnishina tortilis* (Müller, 1959), *F. vasmerae* Müller & Hinz, 1991, and *F. rara* (Müller, 1959) are reported here for the first time from China.

F. longibasis was reported by Bednarczyk (1979) from Poland. We conclude that the interval containing this species in Poland correlates to the *F. quadrata-F. longibasis* assemblage of South China.

Concluding remarks

The GSSP marking the base of the Furongian Series and Paibian Stage in the Paibi section, Hunan, China, is defined on the first appearance of a trilobite, *Glyptagnostus reticulatus*. Although previous conodont records did not show much change in species succession that would be useful for local and regional correlations, our results show that the boundary interval is characterized by a gradual but marked change in conodont faunas. *Westergaardodina* Müller, 1959 exhibits a sharp decrease in abundance and diversity, with all species present in the *L. reconditus* and *G. stolidotus* trilobite zones disappearing below the base of the Paibian Stage.

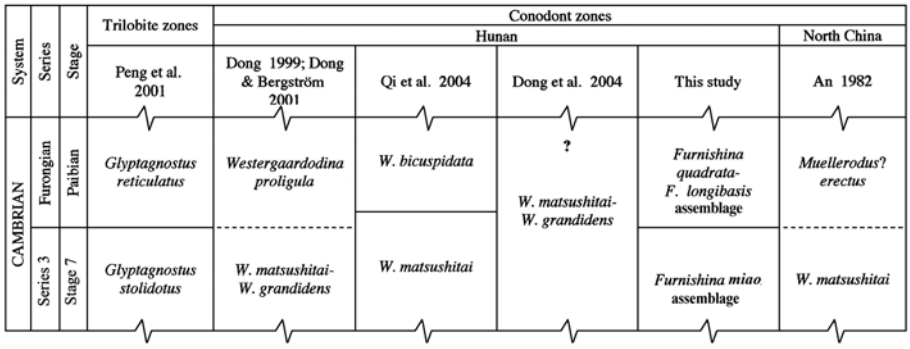

Fig. 3 - Correlation of trilobite and conodont zones across the *Glyptagnostus stolidotus* - *Glyptagnostus reticulatus* boundary in Hunan, South China, and North China.

Furnishina Müller, 1959, which is the dominant genus, provides better stratigraphic resolution. *Furnishina quadrata* Müller, 1959 and *Furnishina longibasis* Bednarczyk, 1979 are good proxies for recognition of the boundary (Fig. 3), and *Furnishina longibasis* has intercontinental correlation utility.

The conodont faunal change coincides with the initial stages of a transgressive event marked by a large positive carbon isotopic excursion (Peng et al. 2004c, with references). Abundance of siliceous sponge spicules in the conodont residues from the *F. quadrata-F. longibasis* assemblage may be related to the sea level change.

Repository

Figured specimens are housed in the collection of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, with catalogue numbers 140351 – 140398.

Systematic palaeontology

Genus *Furnishina* Müller, 1959

Type species: *Furnishina furnishi* Müller, 1959

Furnishina cf. **F. alata** Szaniawski, 1971

Pl. 2, fig. 15

cf. 1971 *Furnishina alata* Szaniawski, pp. 406-407, pl. 1, figs 3-4; pl. 3, figs 3-5.

1991 *Furnishina* cf. *alata* - Müller & Hinz, p. 16, pl. 1, figs 18, 20.

1993 *Furnishina* cf. *alata* - Dong, p. 350, pl. 2, figs 11, 13, 15.

2001b *Furnishina* cf. *alata* – Dong & Bergström, p. 960, pl. 1, figs 1, 3, 10.

Remarks. Differs from *Furnishina alata* Szaniawski, 1971 in having a poorly developed posterior keel only along the cusp.

Material and occurrence. 9 specimens; beds 36-38a.

Furnishina cf. **F. gladiata** Müller & Hinz, 1991

Pl. 1, fig. 12

cf. 1991 *Furnishina gladiata* Müller & Hinz, p. 20, pl. 16, figs 1-13; text-fig. 8S.

Remarks.The general morphology is very similar to *F. gladiata*, from which it differs in having deep indentions between the posterior tunnel-like carina and the antero-lateral laminae.

Material and occurrence. 2 specimens; bed 36-37b.

Furnishina longibasis Bednarczyk, 1979

Pl. 2, figs 1-4

1979 *Furnishina longibasis* Bednarczyck, p. 427, pl. 1, figs 1, 4.

1991 *Furnishina longibasis* – Müller & Hinz, pp. 21-22, pl. 11, figs 10, 12.

Emended diagnosis. Subsymmetrical to asymmetrical proclined elements with a posteriorly extended base. Anterior side flat. Antero-lateral costae/laminae fading away on the cusp. Oral edge of the base roundly arched. In asymmetrical elements, the cusp is slightly laterally deflected. The symmetrical elements are more laterally extended than the asymmetrical ones.

Description. The sub-symmetrical and asymmetrical elements of *Furnishina longibasis* Bednarczyck, 1979 have a short and proclined cusp with oval cross section.

The posterior side of the cusp is rounded. Two antero-lateral costae extend from the antero-basal corners and fade away on the cusp. Costae may develop as laminae. Anterior side of the elements is flat. Base is posteriorly extended and constricted in the middle part to expand again distally. Basal oral edge is roundly arched. The sub-symmetrical elements (Pl. 2, fig. 3) are laterally extended. The cusp of the asymmetrical elements is slightly laterally deflected, and the constriction is more prominent on the same side towards which the cusp is deflected.

Asymmetrical elements outnumber the sub-symmetrical ones.

Material and occurrence. 27 specimens; bed 38c.

Furnishina cf. **F. longibasis** Bednarkzyk, 1979

Pl. 2, fig. 5

cf. 1979 *Furnishina longibasis* Bednarczyk, p. 427, pl. 1, figs 1, 4.

2001b *Furnishina* cf. *longibasis* – Dong & Bergström, p. 961, pl. 1, fig. 2.

Remarks. The specimens at hand closely conform to those illustrated by Dong & Bergström (2001b).

Material and occurrence. 2 specimens; bed 36.

Furnishina miao n. sp.

Pl. 1, figs 1-3

Derivation of name. After the Miao minority that inhabits the Paibi area.

Type locality and type stratum. Paibi section, Hunan Province, 361.50 m above the base of the Huaqiao Formation, Sample P-46: *Glyptagnostus stolidotus* trilobite Zone.

Types. Holotype: Cat. no. 140352, Pl.1, figs 2a, 2b, Sample PC-46. Paratypes: Cat. no. 140351, Pl. 1, figs. 1a – 1c, Sample PC-46; Cat. no. 140353, Pl. 1, fig. 3,Sample PC-37.

Diagnosis. Subsymmetrical to strongly asymmetrical elements with antero-lateral laminae that extend up to 2/3 of the cusp. Posterior side of the base long and compressed. In the asymmetrical elements the distal end of the base is clearly deflected towards the right side.

Description. Gently recurved elements with flat anterior side and circular cross-section of the cusp. The cusp is long and slender. Prominent lateral laminae extend from the antero-basal corners up to 2/3 of the cusp. The base is posteriorly extended. The posterior side is rounded with a broad carina at the base-cusp junction. In symmetrical elements, the basal opening is sub-rectangular and the lateral laminae are of equal extent. In asymmetrical elements, the cusp is slightly deflected to the left side, and the long and narrow distal end of the base is deflected to the right side. The lamina of the right side is slightly more developed than the left one.

The asymmetrical elements outnumber the symmetrical ones.

Remarks. The symmetrical elements of *Furnishina miao* differ from *Furnishina kleithria* Müller & Hinz, 1991 because the flanks are not concave producing a different outline of the basal opening.

Material and occurrence. 28 specimens; beds 36-37d.

Genus *Prosagittodontus* Müller & Nogami, 1971

Type species: *Sagittodontus dahlmani* Müller, 1959.

Prosagittodontus telli n. sp.

Pl. 3, figs 9-11

Derivation of name. After Guglielmo Tell, the famous archer.

Type locality and type stratum. Paibi section, Hunan Province, 361.50 m above the base of the Huaqiao Formation, Sample P-46; *Glyptagnostus stolidotus* trilobite Zone.

Types. Holotype: Cat. no. 140390, Pl. 3, fig. 10, Sample PC-46. Paratypes: Cat. no. 140389, Pl. 3, fig.9, Sample PC-67; Cat. no. 140391, Pl. 3, Fig. 11, Sample PC-67.

Diagnosis. A species of *Prosagittodontus* with an extremely short cusp and a posterior keel.

Description. The symmetrical elements of *Prosagittodontus telli* n. sp. are gently recurved, with an apical angle of about 50 degrees. Lateral projections are longer than the median lobe. A sharp keel extends from the distal end of the median lobe up to the cusp. Lateral projections can be quite long (Pl. 3, fig. 11).

Remarks. *Prosagittodontus telli* n. sp. differs from *Prosagittodontus dahlmani* (Müller, 1959) by the narrow keel on the median lobe.

Material and occurrence. 3 specimens; bed 36.

Genus *Westergaardodina* Müller, 1959

Type species: *Westergaardodina bicuspidata* Müller, 1959

Westergaardodina aff. **W. bohlini** Müller, 1959

Pl. 3, fig. 8

aff. 1959 *Westergaardodina bohlini* Müller, p. 469, pl. 15, fig. 8.

Remarks. The general outline is similar to the outline of *Westergaardodina bohlini*, but differs in having a flat and smooth anterior side that lacks the typical prominent callosities and the comarginal folds.

Material and occurrence. 2 specimens; beds 38b-c.

Westergaardodina cf. **W. matsushitai** Nogami, 1966

Pl. 3, fig. 3

cf. 1966 *Westergaardodina matsushitai* Nogami, p. 360, pl. 10, figs 6-8.

2001b *Westergaardodina* cf *matsushitai* – Dong & Bergström, p. 978, pl. 6, fig. 2.

Remarks. The specimens at hand closely conform to those illustrated by Dong and Bergström (2001b).

Material and occurrence. 6 specimens; beds 36-37c.

Westergaardodina cf. **W. quadrata** (An, 1982)

Pl. 3, fig. 2

cf. 1982 *Westergaardodina moessebergensis quadrata* An, p. 153, pl. 6, figs 5-8, 10.

2001b *Westergaardodina* cf. *quadrata* (An) - Dong & Bergström p. 979, pl.1, figs 22-23.

Remarks. The specimens at hand agree with those described and figured by Dong & Bergström (2001b) in having a V-shaped angle between the two projection.

Material and occurrence. 3 specimens; bed 36.

*Acknowledgements.*The research was supported by the National Natural Science Foundation of China (NSFC 40272003, 40072003, 40332018) and by the University of Pisa, Italy (Fondi di Ateneo 2003 to G. Bagnoli). We thank Loren E. Babcock (Ohio State University, Columbus) for critically reviewing the manuscript.

PLATE 1

Figs. 1-3 - *Furnishina miao* n. sp.:
1) Paratype, asymmetrical element, Sample PC-46, Cat. no. 140351. 1a) x70: 1b) lateral view, x80; 1c) postero-oral view, x80;
2) Holotype, asymmetrical element, Sample PC-46, Cat. no.140352. 2a) postero-lateral view, x70; 2b) postero-oral view, x70;
3) Paratype, symmetrical element, Sample PC-37, x70, Cat. no. 140353.

Fig. 4 - *Furnishina polonica* Szaniawski, 1971: Sample PC43, oral view, x70, Cat. no. 140354.

Figs. 5-9 - *Furnishina tortilis* (Müller, 1959): Sample PC23;
5) x50, Cat. no. 140355;
6) x65, Cat. no. 140356;
7) x65, Cat. no. 140357;
8) x50, Cat. no. 140358;
9) postero-lateral view, x70, Cat. no. 140359.

Figs. 10-11, 15- *Furnishina vasmerae* Müller & Hinz, 1991:
10) Sample PC23, lateral view, x70, Cat.no. 140360;
11) Sample PC31, lateral view, x80, Cat. no. 140361;
15) Sample PC11, oral view, x70, Cat. no. 140362.

Fig. 12 - *Furnishina* cf. *F. gladiata* Müller & Hinz, 1991: Sample PC-37, x100, Cat. no. 140363.

Figs. 13-14 - *Furnishina quadrata* Müller, 1959:
13) Sample PC23, x70, Cat. no. 140364;
14) Sample PC 16, x70, Cat. no. 140365.

(Specimens shown in posterior view, if not specified)

PLATE 2

Figs. 1-4 - *Furnishina longibasis* Bednarczyk, 1979:
1) Sample PC31, Cat. no. 140366, 1a) lateral view, x80, 1b) oral view, x70;
2) Sample PC23, x70, Cat. no. 140367;
3) Sample PC23, sub-symmetrical element, x70, Cat. no. 140368;
4) Sample PC23, lateral-oral view, x80, Cat. no. 140369.

Fig. 5 - *Furnishina* cf. *F. longibasis* Bednarczyk, 1979: Sample PC-46, lateral view, x100, Cat. no. 140370.

Fig. 6 - *Furnishina bigeminata* Dong, 1993: Sample PC-46, antero-lateral view, x80, cat. no. 140371.

Fig. 7 - *Furnishina kleithria* Müller & Hinz, 1991: Sample PC-46, postero-lateral view, x80, Cat. no. 140372.

Fig. 8 - *Furnishina bicarinata* Müller, 1959: Sample PC32, x60, Cat. No. 140373.

Fig. 9 - *Furnishina rara* (Müller, 1959): Sample PC32, x120, Cat. no. 140374.

Figs. 10-11 - *Muellerodus*? *obliquus* (An, 1982): sample PC-46, lateral view, x80, Cat. no. 140375, 140376.

Fig. 12 - *Muellerodus*? *oelandicus* (Müller, 1959): Sample PC9, lateral view, x100, Cat. no. 140377.

Fig. 13 - *Muellerodus pomeranensis* (Szaniawski, 1971): sample PC32, x90, Cat. no. 140378.

Fig. 14 - *Muellerodus cambricus* (Müller, 1959): Sample PC23, x70, Cat. no. 140379.

Fig. 15 - *Furnishina* cf. *F. alata* Szaniawski, 1971: Sample PC-37, x100, Cat. no. 140380.

(Specimens shown in posterior view, if not specified)

PLATE 3

Fig. 1 - *Westergaardodina quadrata* (An, 1982): Sample PC-46, x50, Cat. no. 140381.

Fig. 2 - *Westergaardodina* cf. *quadrata* (An, 1982): Sample PC-46, x70, Cat. no. 140382

Fig. 3 - *Westergaardodina* cf. *W. matsushitai* (Nogami, 1966): Sample PC-37, x70, Cat. no. 140383.

Fig. 4 - *Westergaardodina W. matsushitai* (Nogami, 1966): Sample PC-37, x50, Cat. no. 140384.

Figs. 5, 7 - *Westergaardodina elegans* Dong & Bergström, 2001:
5) Sample PC-74, x60, Cat. no. 140385;
7) Sample PC-23, x65, Cat. no. 140386.

Fig. 6 - *Westergaardodina tetragonia* Dong, 1993: Sample PC-46, x50, Cat. no. 140387.

Fig. 8 - *Westergaardodina* aff. *W. bohlini* Müller, 1959: Sample PC51, anterior view, x60, Cat. no. 140388.

Figs. 9-11 - *Prosagittodontus telli* n. sp.:
9) Paratype, Sample PC-67, x125, Cat. no. 140389;
10) Holotype, Sample PC-46, x140, Cat. No. 140390;
11) Paratype, Sample PC-67, 50x, Cat. no. 140391.

Fig. 12 - *Nogamiconus* sp.: Sample PC-37, lateral view, x60, Cat. no. 140392.

Figs. 13-14 - *Huayanodontus tricornis* (Dong, 1993):
13) Sample PC43, x70, Cat. no. 140393;
14) Sample PC-74, x60, Cat. no. 140394.

Fig. 15 - *Gapparodus bisulcatus* (Müller, 1959): Sample PC-10, lateral view, x60, Cat. no. 140395.

Fig. 16 - *Yongshunella polymorfa* Dong & Bergström, 2001: Sample PC-46, postero;lateral view, x70, Cat. no. 140396.

Fig. 17 - *Coelocerodontus bicostatus* van Wamel, 1974: Sample PC-67, lateral view, x125, Cat. no. 140397.

Fig. 18 - *Proacodus pulcherus* (An, 1982): Sample PC23, lateral view, x70, Cat. no. 140398.

(Specimens shown in posterior view, if not specified)

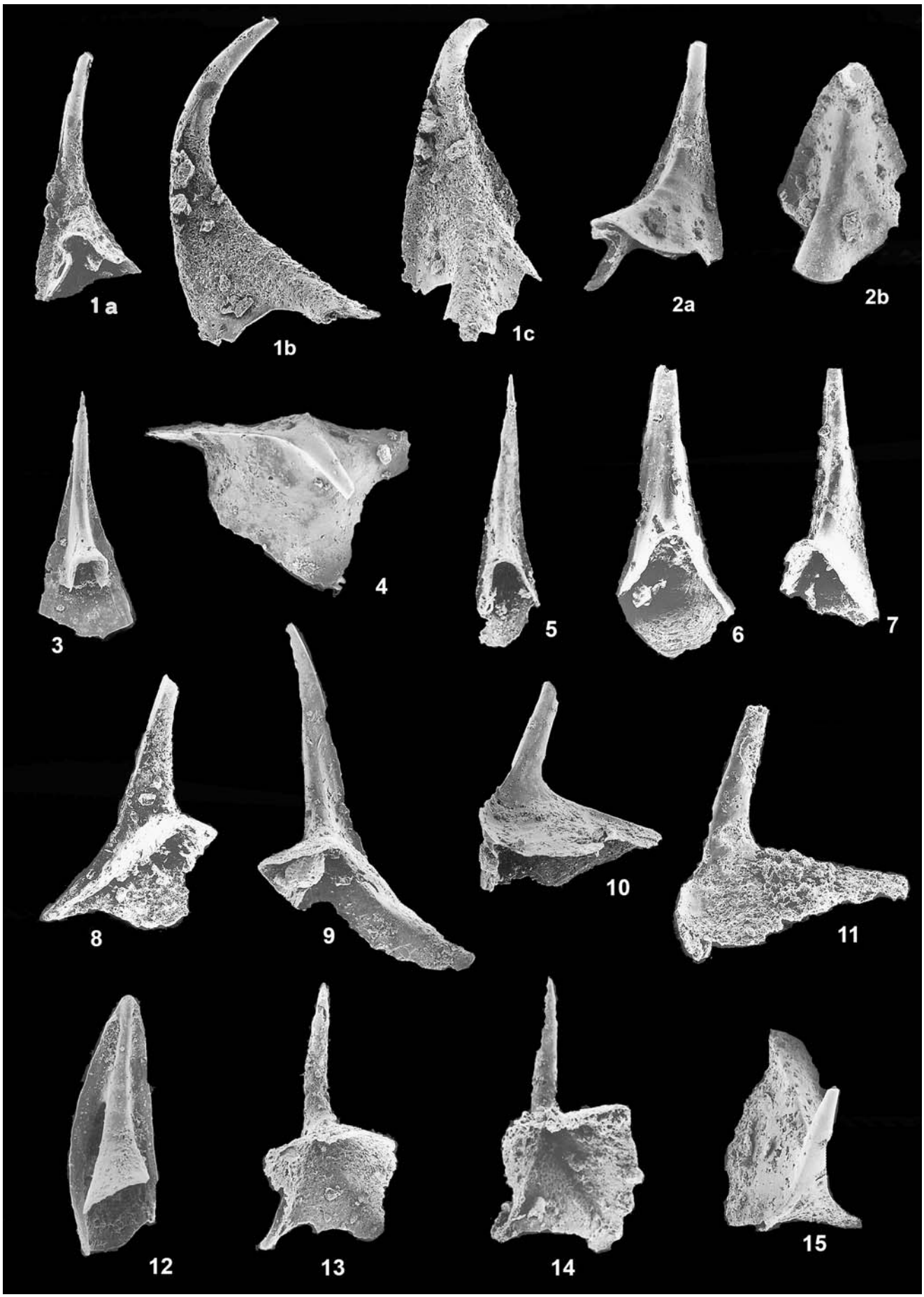

PLATE 1

PLATE 2

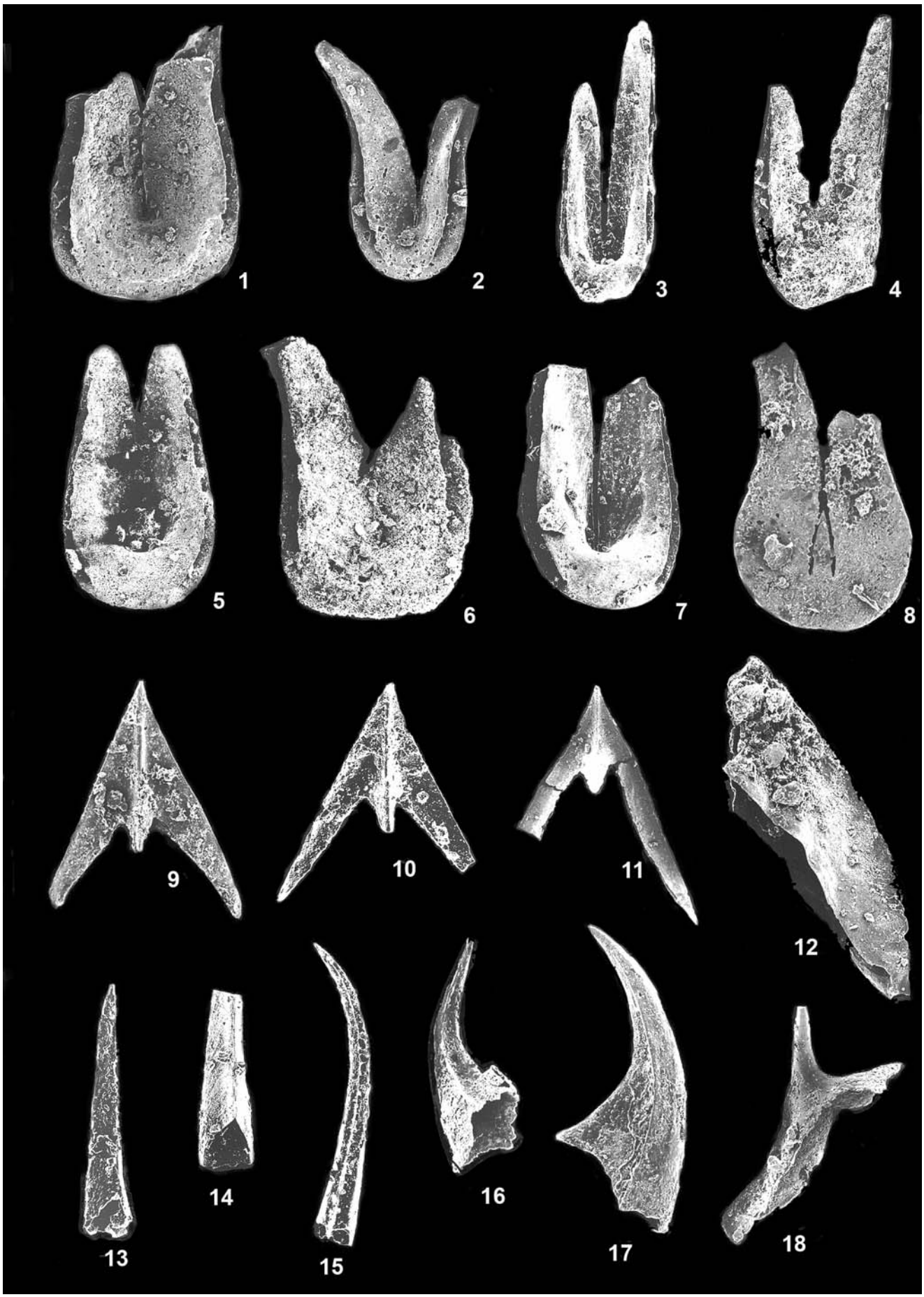

PLATE 3

REFERENCES

An Tai-xiang (1982) - Study of the Cambrian conodonts from north and northeast China. *Science Rep. Inst. Geosci., Section B,* 3: 113-159, Tsukuba.

Bednarczyk W. (1979) - Upper Cambrian to Lower Ordovician conodonts of Leba Elevation, NW Poland, and their stratigraphic significance. *Acta Geol. Pol.*, 29(4): 409-442, Warszawa.

Dong Xi-ping (1990a) - A potential candidate for the Middle-Upper Cambrian Boundary stratotype - an introduction to the Paibi section in Huayuan, Hunan. *Acta Geol. Sin.*, 64: 62-79, Beijing (In Chinese).

Dong Xi-ping (1990b) - Both agnostid and conodont-based Middle-Upper Cambrian boundary in Huayuan, Hunan. *Abstracts Third Intern. Symp. Cambrian System, 1-9 August 1990*: 96-98, Novosibirsk.

Dong Xi-ping (1993) - Late Middle and early Late Cambrian conodonts from Huayuan, Hunan. *Acta Micropalaeont. Sin.*, 10: 345-362, Beijing.

Dong Xi-ping (1999) - Succession of Cambrian conodonts from South China. *Science in China, Series D*, 29: 317-327, Beijing.

Dong Xi-ping & Bergström S. M. (2001a) - Stratigraphic significance of Middle and Upper Cambrian protoconodonts and paraconodonts from Hunan, South China. *Palaeoworld*, 13: 307-309, Hefei.

Dong Xi-ping & Bergström S M. (2001b) - Middle and Upper Cambrian protoconodonts and paraconodonts from Hunan, South China. *Palaeontology*, 44(5): 949-985, Tulsa.

Dong Xi-ping, Repetski J. E. & Bergström S. M. (2004) - Conodont biostratigraphy of the Middle Cambrian through lowermost Ordovician in Hunan, South China. *Acta Geol. Sin.*, 78(6): 1185-1206 Beijing.

Miller J. F. (1984) - Cambrian and earliest Ordovician conodont evolution, biofacies and provincialism. *Geol. Soc. America, Special Paper,* 196: 43-68, Boulder.

Müller K. J. (1959) - Kambrische Conodonten. *Zeit. Deutschen Geolog. Gesell.*, 111: 434-485, Stuttgart.

Müller K. J. & Hinz I. (1991) - Upper Cambrian conodonts from Sweden. *Fossils and Strata*, 28: 1-153, Oslo.

Müller K. J & Nogami Y. (1971) - Über den Feinbau der Conodonten. *Mem. Fac. Science, Geology and Mineralogy*, 38(1): 87 pp. Kyoto.

Nogami Y. (1966) - Kambrische Conodonten von China, Teil 1, Conodonten aus den oberkambrischen Kushan-Schichsten. *Mem. College Science, Series B*, 32(4): 351-366. Kyoto.

Peng Shanchi (1992) - Upper Cambrian Biostratigraphy and Trilobite Faunas of Cili-Taoyuan area, north-western Hunan, China. *Mem. Ass. Australasian Palaeontologists*, 13: 1-119, Brisbane.

Peng Shanchi & Babcock L.E. (2003) - The first "Golden Spike" within Cambrian. *Episodes*, 26: 326, Beijing.

Peng Shanchi, Babcock, L. E., Lin Huan-ling, Chen Yong-an & Zhu Xue-jian (2001) - Potential Global Stratotype Section and Point for the base of an Upper Cambrian Series defined by the first appearance of the trilobite *Glyptagnostus reticulatus*, Hunan Province, China. *Acta Palaeont. Sin.*, 40 (Suppl.): 157-172, Beijing.

Peng Shanchi & Robison R. A. (2000) - Agnostoid biostratigraphy across the Middle-Upper Cambrian boundary in China. *Palaeontol. Soc. Mem. 53, supp. of J. Palaeont.*, 74(4): 1-104, Boulder.

Peng Shanchi, Lin Huan-ling & Zhu Xue-jian (2004a) - The first Global Standard Stratotype Section and Point of Cambrian System for Paibian Stage and Furongian Series in China. *J. Strat.*, 28(1): 92-94, Beijing (In Chinese).

Peng Shanchi, Babcock, L. E., Lin Huan-ling, Chen Yong-an, Qi Yu-ping & Zhu Xue-jian (2004b) - Global Standard Stratotype-Section and Point for the Paibi Stage and Furongian Series of Cambrian System. *J. Strat.*, 28(2): 104-113, Beijing (In Chinese).

Peng Shanchi, Babcock L. E., Robison R. A., Lin Huanling, Rees M. N. & Saltzman M. R. (2004c) - Global Standard Stratotype-section and Point (GSSP) of the Furongian Series and Paibian Stage (Cambrian). *Lethaia*, 37: 365-379, Oslo.

Peng Shanchi, Babcock L. E. & Lin Huanling (2004d) - Polymerid trilobites from the Cambrian of northwestern Hunan, China, Volume 1, 333 pp.; Volume 2, 355 pp., Science Press, Beijing.

Qi Yu-ping, Wang Zhihao & Bagnoli G. (2004) - Conodont biostratigraphy of the GSSP of the base of the Furongian Series and Paibian Stage. *J. Strat.*, 28(2): 114-119, Beijing (In Chinese, with English abstract).

Szaniawski H. (1971) - New species of upper Cambrian conodonts from Poland. *Acta Palaeont. Pol.*, 16(4): 401-413, Warszawa.

Appendix 1

Part of the stratigraphic section at Paibi, Hunan, China, together with fossils identified from productive intervals. Trilobite records from Peng et al. (2004b). HP, Gr, and Gs refer to the trilobite samples; PC refer to the conodont productive samples.

Bed No.	Description	Thickness m	Distance from the base of the Huaqiao Formation m
	Huaqiao Formation (388.50 m)		
39	Dark grey thin-bedded wackestones and packstones, 5-8 cm in thickness for each flat layer. Trilobites: 378.25 m (HP31): *Baikadamaspis paibiensis, Fenghuangella laochatianensis, Glyptagnostus reticulatus, Paraacidaspis hunanica Prochuangia granulosa, Prochuangia* cf. *leiocephala, Prochuangia licinispinata, Pseudomapania cylindrica, Shengia wannanensis, Stigmatoa yangziensis*	2.80	378.20-381.00
38	Dark grey thin-bedded wackestones, 5-8 cm in thickness for each flat layer, intercalated with several layers of dark grey ribbon fine-grained limestones and one layer of debris-bearing limestone. This bed is subdivided into 4 units.	7.44	370.76-378.20
38d	Dark grey thin-bedded wackestones, intercalated with one layer of dark grey fine-grained limestones. Trilobites: 376.22 m (Gr6): *Acmarhachis typicalis, Chuangia subquadrangulata, Glyptagnostus reticulatus, Peratagnostus obsoletus, Proceratopyge fenghuangensis* #PC63: 376.22 m	1.88	
38c	Dark grey thin-bedded wackestones, intercalated with two layers of dark grey thin-bedded fine-grained limestones and one layer of debris-bearing limestone that is 0.25 m in thickness. Trilobites: 375.22 m (Gr5): *Glyptagnostus reticulatus, Peratagnostus obsoletus* 374.90 m (HP30c): *Chuangia subquadrangulata*, *Dorypyge perconvexalis, Placosema bigranulosa*, *Prochuangia* cf. *leiocephala* 373.22 m (Gr4): *Baikadamaspis paibiensis, Glyptagnostus reticulatus* 372.62 m (Gr3): *Glyptagnostus reticulatus, Proceratopyge fenghuangensis* #PC59: 375.22 m #PC56: 374.76 m #PC51: 374.20 m #PC43: 373.50 m #PC35: 372.84 m #PC33: 372.68 m #PC32: 372.65 m #PC31: 372.62 m	3.70	
38b	Dark grey thin-bedded wackestones, intercalated with two layers of dark grey thin-bedded fine-grained limestones. Trilobites: 372.12 m (Gr2): *Glyptagnostus reticulatus, Peratagnostus obsoletus, Proceratopyge fenghuangensis*, *Pseudagnostus josepha* 371.42 m (Gr1): *Glyptagnostus reticulatus, Proceratopyge fenghuangensis* #PC23: 372.12 m #PC16: 371.42 m	1.20	
38a	Grey thick-bedded breccia limestones no fossils discovered	0.66	
37	Dark grey thin-bedded packstones, intercalated with several layers of grey ribbon fine-grained limestones and two layers of debris-bearing limestone. This bed is subdivided into 5 units.	8.76	362.00-370.76
37e	Dark grey thin-bedded wackestones, yielding conodonts and rare inarticulate brachiopods. #PC15: 370.76 m #PC11: 370.48 m #PC9: 370.21m	1.23	

(*segue*)

Bed No.	Description	Thickness m	Distance from the base of the Huaqiao Formation m
37d	Dark grey thin-bedded wackestones, interbedded with grey thin-bedded fine-grained limestones, and intercalated with one layer of thin-bedded haricot bean debris-bearing limestone near the top. Trilobites: 369.06 m (Gr0): *Acmarhachis typicalis, Baikadamaspis paibiensis, Glyptagnostus reticulatus, Idolagnostus agrestis*?, *Peratagnostus obsoletus*, *Shengia wannanensis* 368.49 m (Gs7): *Glyptagnostus stolidotus, Peratagnostus obsoletus* 367.99 m (Gs6): *Agnostardis amplinatis, Fenghuangella liostracinala, Glyptagnostus stolidotus*, *Lisogoragnostus* sp., *Palaeadotes* sp., *Peratagnostus obsoletus, Proceratopyge fenghuangensis*, *Pseudagnostus josepha, Tienistion posterocosta* 367.76 m (Gs5): *Acmarhachis typicalis, Agnostardis amplinatis, Agnostus inexpectans, Fenghuangella liostracinala, Glyptagnostus stolidotus, Liostracina bella, Peratagnostus obsoletus*, *Proceratopyge fenghuangensis, Pseudagnostus josepha* #PC-7: 368.43 m #PC-8: 368.34 m #PC-10: 368.20 m	1.77	
37c	Dark grey thin-bedded wackestones, interbedded with grey thin-bedded fine-grained limestones. Trilobites: 367.26 m (Gs4): *Agnostardis amplinatis, Chatiania chatianensis, Glyptagnostus stolidotus, Peratagnostus obsoletus, Pseudagnostus josepha*, *Pseudoyuepingia laochatianensis* 366.86 m (Gs3): *Glyptagnostus stolidotus, Pseudagnostus josepha* 366.56 m (Gs2): *Agnostardis amplinatis, Glyptagnostus stolidotus* 366.36 m (Gs1): *Glyptagnostus stolidotus, Pseudagnostus josepha* #PC-19: 367.30 m #PC-23: 366.40 m	1.40	
37b	Dark grey thin-bedded wackestones, with one layer of 5 cm in thickness fine-grained limestones at the bottom, and intercalated with one layer of 0.60 m thickness debris-bearing limestone in the middle lower part. Trilobites: 364.20 m (Gs0): *Glyptagnostus stolidotus, Lisogoragnostus* sp., *Pseudagnostus josepha*, *Paradamesella typica, Peratagnostus obsoletus*, *Protaizehoia yuepingensis, Pseudoyuepingia laochatianensis, Tienistion posterocosta* #PC-26: 366.15 m #PC-27: 366.08 m #PC-37: 364.30 m	2.16	
37a	Dark grey thin-bedded wackestones and packstones. Trilobites: 363.50 m (HP30, GS-1): *Agnostardis amplinatis, Acmarhachis apicula, Ammagnostus histus, Luyanhaoaspis decorosa, Peratagnostus obsoletus, Placosema bigranulosa, Pseudoyuepingia laochatianensis*, *Pseudagnostus prolongus, Rhyssometopus zhonguoensis*, *Tienistion posterocosta* 362.45 m (HP29g): *Agnostardis typicalis, Glyptagnostus stolidotus. Peratagnostus obsoletus*	2.20	
36	Dark grey thin-bedded wackestones, interbedded or intercalated with medium-thick-bedded packstones and debris-bearing limestone; each layer of 0.4 m thickness debris-bearing limestone at both the bottom and the top; in total 10 layers from 30 cm to 90 cm in thickness of this bed. Trilobites: 361.60 m (HP29c): *Ammagnostus histus, Glyptagnostus stolidotus, Paratamesella typicalis* 361.50 m (HP29b): *Chatiania chatianensis, Glyptagnostus stolidotus* 356.50 m (HP29a): *Chatiania chatianensis, Peratagnostus obsoletus, Proceratopyge* sp., *Rhyssometopus zhonguoensis* 353.70 m (HP29-1): *Ajrikina hunensis, Agnostogonus incognitus, Chatiania chatianensis, Pseudoyuepingia laochatianensis* 348.00 m (HP29): *Ammagnostus sinnensis*, *Fenghuangella laochatianensis, Liostracina bella*, *Neoanonocarella asiatica, Palaeadotes hunanensis*, *Paradamesella typica, Rhyssometopus zhonguoensis*, *Protaizizehoia* sp., *Tienistion posterocosta* #PC-46: 361.50 m #PC-50: 361.12 m #PC-67: 357.10 m #PC-74: 351.15 m	16.40	346.60-362.00