The Ordovician–Silurian boundary in China

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Synopsis

After a general account of the Chinese graptolite zones about the boundary, a précis is given of the Chinese type section for the boundary, at Wangjiawan, which includes the faunal characteristics. It is followed by similar details for nine other major Chinese sections and a synthesis of the biofacial types. After a discussion of correlation problems about the boundary, it is concluded that the *ascensus* Zone of some European sections is equivalent to the Chinese *persculptus* Zone, and that the base of the Silurian is best taken above the *bohemicus* Zone and its correlatives, the *Hirnantia–Dalmanitina* fauna.

Introduction

Ordovician and Silurian strata are well developed in China. Many Ordovician–Silurian boundary sections have been defined in the Yangtze Region (or the Central China region) where the Ordovician and Silurian consist of platform deposits. These sections are small in thickness and rich in fossils, mainly graptolites, known as the Ashgill Wufeng Formation and the early Llandovery Lungmachi Formation. Between these two formations there is usually a thin bed of shelly facies, namely the *Hirnantia–Dalmanitina* bed (HD) or the Kuanyinchiao bed. The graptolite sequences of the Wufeng Formation and the Lungmachi Formation are quite complete, and thirteen graptolite zones have been established in descending order as follows:

Lungmachian:
- L_7 *Monograptus sedgwickii* Zone
- L_6 *Demirastrites convolutus* Zone
- L_5 *Demirastrites triangulatus* Zone
- L_4 *Pristiograptus cyphus* Zone
- L_3 *Orthograptus vesiculosus* Zone
- L_2 *Parakidograptus acuminatus* Zone
- L_1 *Glyptograptus persculptus* Zone

Wufengian:
- W_6 *Diplograptus bohemicus* Zone
- W_5 *Paraorthograptus uniformis* Zone
- W_4 *Diceratograptus mirus* Zone
- W_3 *Tangyagraptus typicus* Zone
- W_2 *Dicellograptus szechuanensis* Zone
- W_1 *Amplexograptus disjunctus yangtzeensis* Zone or *Pleurograptus lui* Zone

The establishment of the Wufengian and Lungmachian graptolite zones is of great importance in stratigraphical correlation and in the determination of the exact position of the *Hirnantia–Dalmanitina* bed (HD). The HD bed is underlain by beds of varying age from the *Tangyagraptus typicus* Zone (W_3) to the lower part of the *Diplograptus bohemicus* Zone (W_6^1) in different localities. By comparison, the earliest Silurian shelly facies, known as the '*Eospirigerina*' bed or the Wulipo bed, has a less wide distribution and its upper limit varies in different places and may reach as high as the *Pristiograptus cyphus* Zone (L_4). The relationship between the Ordovician–Silurian boundary graptolite zones and the shelly beds may be shown in Table 1.

As shown in the table, the Ordovician–Silurian boundary should be drawn between the *Diplograptus bohemicus* Zone (W_6)/*Hirnantia–Dalmanitina* bed and the *Glyptograptus persculptus* Zone (L_1)/'*Eospirigerina*' bed. The striking faunal changes from the topmost Ordovician (W_6) and the lowermost of the Silurian (L_1) support this assertion. Therefore, nearly all

Table 1 A correlation between the graptolite and shelly sequences across the Ordovician–Silurian boundary.

L_4	*Pristiograptus cyphus*			
L_3	*Orthograptus vesiculosus*			Wulipo bed
L_2	*Parakidograptus acuminatus*			
L_1	*Glyptograptus persculptus*		'*Eospirigerina*' fauna	
W_6	*Diplograptus bohemicus*	upper (W_6^2) lower (W_6^1)	*Hirnantia–Dalmanitina* fauna (HD)	Kuanyinchiao bed
W_5	*Paraorthograptus uniformis*			
W_4	*Diceratograptus mirus*			
W_3	*Tangyagraptus typicus*			

geologists and palaeontologists in China agree that the Ordovician–Silurian boundary should be placed between the *D. bohemicus* Zone (W_6) (or the *Hirnantia–Dalmanitina* bed (HD)) and the *G. persculptus* Zone (L_1).

Description of the Ordovician–Silurian boundary sections

In 1983 the writer reviewed sixteen Ordovician–Silurian boundary sections distributed in four stratigraphical regions and described nine sections in the Yangtze Region in detail. In recent years, some sections have been revised and some new sections recognized. There are 33 well defined Ordovician–Silurian boundary sections distributed in four regions of China. Among them, 26 are in the Yangtze Region, three in the Xizang (Tibet)–W. Yunnan Region, two in the Zhujiang Region (S. China Region) and one in the Northwest Region, as shown in the map (Fig. 1). In the northernmost region, the Ordovician–Silurian strata are very thick, complicated in structure and fossils are rare, and thus no ideal Ordovician–Silurian boundary section has been found in this region. There are no Silurian deposits in the Huanghe Region (N. China Region).

In the present paper, the type section, the Wangjiawan section of Yichang, W. Hubei, and nine selected sections are described as follows.

1. The Wangjiawan Ordovician–Silurian Boundary section is the type section in China. In 1982, this section was restudied by Mu En-zhi, Zhu Zhao-ling, Lin Yao-kun, Zou Xi-ping, Wu Hong-ji, Chen Ting-en, Geng Liang-yu and Dong Xi-ping. The section is as follows (after Mu *et al.* 1984).

Lower Silurian Lungmachi Formation (basal part):

15. Black argillaceous shale weathered greyish black, yielding (ACC768) *Orthograptus vesiculosus* (Nicholson), *Climacograptus normalis* Lapworth and *C.* cf. *medius* Törnquist more than 1·0 m

14. Brownish-grey siliceous shale intercalated with black shale, with 7 siliceous beds in a distance of 20 cm, yielding (ACC767) *Parakidograptus acuminatus* (Nicholson), *Climacograptus normalis* Lapworth, *C. sinitzini* (Chaletzkaya), *Glyptograptus tamariscus magnus* Churkin & Carter and *Paraorthograptus* sp. 0·60 m

13. Black shale with (ACC766) *Parakidograptus acuminatus* (Nicholson), *Climacograptus bicaudatus* Chen & Lin, *C. normalis* Lapworth, *C. angustus* Perner and *C. sinitzini* (Chaletzkaya). 0·35 m

12. Black shale with sandy shale (0·15 m thick) in the upper part, weathered greyish black, containing (ACC765) *Akidograptus ascensus* Davies, *Glyptograptus sinuatus* (Nicholson), *G. tamariscus magnus*

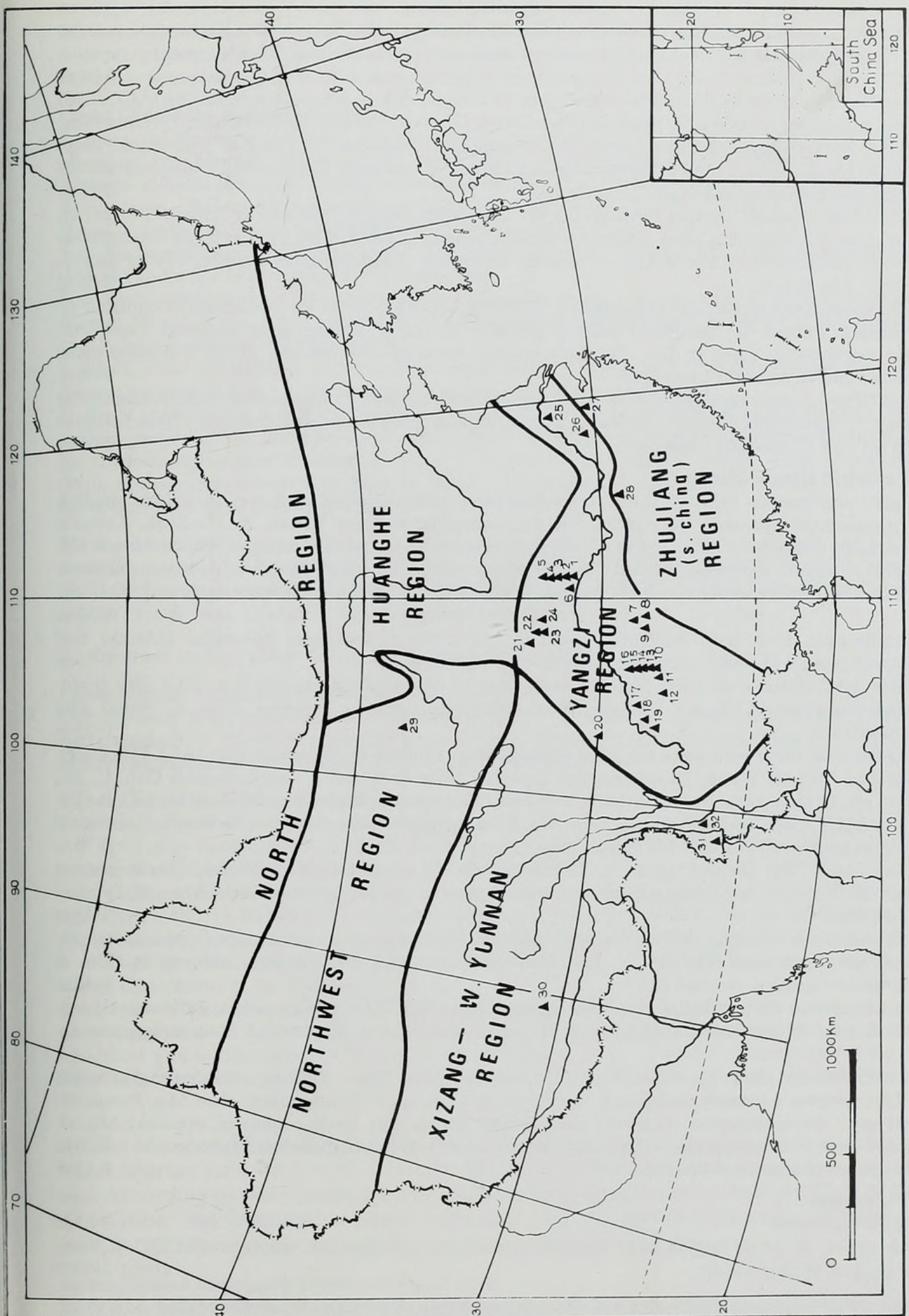

Fig. 1 Ordovician–Silurian boundary outcrops in China. 1 Huanghuachang, Yichang, W. Hubei; 2 Fenxiang, Yichang; 3 Wangjiawan, Yichang; 4 Tangya, Yichang; 5 Maliangping, Baokang, W. Hubei; 6 Xintan, Zigui, W. Hubei; 7 Xiushan, SE Sichuan; 8 Songtao, NE Guizhou; 9 Ganxi, Yanhe, NE Guizhou; 10 Donggonsi, Zunyi, N. Guizhou; 11 Renhuai, N. Guizhou; 12 Yanzikou, Bijie, NW Guizhou; 13 Huanghuayuan, Tongzi, N. Guizhou; 14 Laingfengya, Tongzi; 15 Hanjiandian, Tongzi; 16 Guanyinqiao, Qijiang, S. Sichuan; 17 Shuanghe, Changning, SW Sichuan; 18 Yanjin, NE Yunnan; 19 Daguan, NE Yunnan; 20 Laokuangshan, Hongya, W. Sichuan; 21 Liangshan, Nanzheng, S. Shaanxi; 22 Xixiang, S. Shaanxi; 23 Zhenba, S. Shaanxi; 24 Bajaokou, Ziyang, S. Shaanxi; 25 Tangshan near Nanjing, Jiangsu; 26 Beigong, Jingxian, S. Anhui; 27 Tangjia, Yuqian, W. Zhejiang; 28 Xinkailing, Wuning, NW Jiangxi; 29 Shichengzi, Dajing, Gansu; 30 Xainza, Xizang (Tibet); 31 Mangjiu, Luxi, W. Yunnan; 32 Shahechang, Baoshan, W. Yunnan.

Churkin & Carter, *G. tamariscus linearis* Perner, *G.* ex gr. *tamariscus* Nicholson, *Climacograptus angustus* Perner, *C. bicaudatus* Chen & Lin and *C. normalis* Lapworth 0·20 m

(ACC764a) *Glyptograptus sinuatus* (Nicholson), *G. tamariscus linearis* Perner, *Climacograptus angustus* Perner, *C. wangjiawanensis* Mu & Lin, *Diplograptus modestus* Lapworth and *Rhaphidograptus minutus* Chen & Lin 0·04 m

11. Black argillaceous shale weathered brownish grey in colour, rich in graptolites including (ACC763d) *Glyptograptus persculptus* (Salter), *G. sinuatus* (Nicholson), *G.* ex gr. *tamariscus* Nicholson, *G. tamariscus linearis* Perner, *Diplograptus modestus* Lapworth, *Orthograptus guizhouensis* Chen & Lin, *Paraorthograptus innotatus* (Nicholson), *Climacograptus angustus* Perner, *C. normalis* Lapworth, *C. wangjiawanensis* Mu & Lin and *Rhaphidograptus minutus* Chen & Lin 0·16 m

(ACC763c) *Glyptograptus sinuatus* (Nicholson), *G. lunmaensis* Sun, *G. tamariscus linearis* Perner, *G. tamariscus magnus* Churkin & Carter, *Diplograptus* cf. *coremus* Chen & Lin, *Orthograptus angustifolius* Chen & Lin, *O. guizhouensis* Chen & Lin, *O. bellulus* Törnquist, *Climacograptus angustus* Perner and *C. wangjiawanensis* Mu & Lin 0·08 m

(ACC763b) *Glyptograptus sinuatus* (Nicholson), *G. lunmaensis* Sun, *G.* ex gr. *tamariscus* Nicholson, *G. tamariscus linearis* Perner, *G. tamariscus magnus* Churkin & Carter, *Diplograptus modestus* Lapworth, *Orthograptus angustifolius* Chen & Lin, *Paraorthograptus innotatus* (Nicholson), *P.* sp., *Climacograptus angustus* Perner and *C. normalis* Lapworth 0·06 m

(ACC763a) *Glyptograptus persculptus* (Salter), *G. sinuatus* (Nicholson), *G. lungmaensis* Sun, *G. tamariscus linearis* Perner, *G. tamariscus magnus* Churkin & Carter, *Diplograptus modestus* Lapworth, *Climacograptus angustus* Perner and *C. normalis* Lapworth 0·06 m

Upper Ordovician Wufeng Formation:

10. Bluish grey argillaceous calcareous silicolites weathered whitish-yellow and greyish-yellow, yielding abundant brachiopods and trilobites: (ACC762) *Leptaenopoma trifidum* Marek & Havlíček, *Kinnella kielanae* (Temple), *Dalmanella testudinaria* (Dalman), '*Paracraniops*' *patillis* Rong, *Cliftonia* cf. *oxoplecioides* Wright, *Hirnantia sagittifera* (M'Coy), *Draborthis* cf. *caelebs* Marek & Havlíček, *Aphanomena ultrix* (Marek & Havlíček), *Aegiromena* cf. *ultima* Marek & Havlíček and *Dalmanitina yichangensis* Lin, *D.* sp. 0·33 m

9. Black argillaceous shale and mudstone, yielding (ACC761) *Diplograptus bohemicus* (Marek) and *Paraothograptus typicus* Mu with a few brachiopods and cephalopods 0·26 m

8. Black shale intercalated with a few siliceous shale beds of the same colour, yielding: (ACC760) *Diplograptus bohemicus* (Marek), *D.* sp., *Glyptograptus* sp., *Climacograptus supernus* Elles & Wood and *Paraorthograptus* sp. 0·23 m

7. Black argillaceous shale with siliceous shale intercalation, yielding in the upper part (ACC759) *Dicellograptus ornatus* Elles & Wood, *Climacograptus supernus* Elles & Wood, *C. longicaudatus* Geh, C. sp., *Glyptograptus* sp., *Orthograptus truncatus* Lapworth and *Paraorthograptus uniformis* Mu & Li 0·42 m

Middle part (ACC758) *Tangyagraptus typicus* Mu, *Climacograptus supernus* Elles & Wood, *C. venustus* Hsu, *Amplexograptus suni* (Mu) and *Paraplegmatograptus* sp. 0·70 m

Lower part (ACC758a) *Dicellograptus szechuanensis* Mu, *D. ornatus* Elles & Wood, *Climacograptus supernus* Elles & Wood, *C.* sp., *Orthograptus truncatus* Lapworth, *Orthograptus maximus* Mu and *Amplexograptus suni* (Mu) 1·73 m

6. Black carbonaceous siliceous shale, yielding (ACC757) *Dicellograptus szechuanensis* Mu, *Amplexograptus disjunctus yangtzensis* Mu & Lin, *Pseudoclimacograptus* sp., *Orthograptus abbreviatus* Elles & Wood and *Parareteograptus sinensis* Mu 0·40 m

5. Black carbonaceous shale, yielding abundant graptolites: (ACC756) *Amplexograptus disjunctus yangtzeensis* Mu & Lin, *A. suni* (Mu), *Orthograptus* cf. *pauperatus* Elles & Wood and *Parareteograptus* sp. 0·43 m

4. Black carbonaceous shale intercalated with a few siliceous beds, yielding abundant graptolites (ACC755) *Leptograptus extremus modestus* Chen, *Dicellograptus* sp., *Climacograptus chiai* Mu, *Pseudoclimacograptus* spp., *Amplexograptus disjunctus yangtzeensis* Mu & Lin, *Orthograptus* cf. *maximus* Mu, *O. truncatus* Lapworth, *O.* cf. *pauperatus* Elles & Wood and *O.* sp. and inarticulate brachiopods 0·20 m

3. Dark grey to greyish green mudstone 0·12 m

Linhsiang Formation:

2. Dark yellow mudstone 0·05 m

1. Yellowish green to green argillaceous nodular limestone, yielding the trilobites (ACC754) *Hammatocnemis* sp. and *Microparia* sp. about 2·00 m

2. 'Baoshan' (the 'Treasure Hill') section, Huanghuachang, Yichang, W. Hubei (after Mu *et al.* 1984).

Lower Silurian Lungmachi Formation (basal part):
9. Black siliceous rock weathered greyish-yellow, yielding: (ACC744) *Parakidograptus acuminatus* (Nicholson), *Climacograptus normalis* Lapworth, *C. sinitzini* (Chaletzkaya) 0·10 m
8. Black carbonaceous shale, black siliceous shale weathered blackish grey, containing: (ACC743) *Glyptograptus persculptus* (Salter), *G. sinuatus* (Nicholson), *Climacograptus* sp. (cf. *normalis* Lapworth) 0·45 m

Upper Ordovician Wufeng Formation:
7. Black calcareous argillaceous siliceous mudstone weathered greyish-white to greyish-yellow, yielding abundant brachiopods, trilobites and other fossils, including (ACC742) *Hirnantia sagittifera* (M'Coy), *Kinnella kielanae* (Temple), *Aphanomena ultrix* (Marek & Havlíček), *Cliftonia* cf. *psittacina* (Wahlenberg), *Triplesia* sp., *Dalmanella testudinaria* (Dalman), *Aegiromena* cf. *ultima* (Marek & Havlíček), *Meristina crassa incipiens* (Williams) and *Dalmanitina yichangensis* Lin 0·10 m
5–6. Black argillaceous siliceous shale, weathered dark grey, yielding (ACC741) *Diplograptus bohemicus* (Marek) and a few brachiopods in the upper part 0·45 m
3–4. Black siliceous shale intercalated with argillaceous shale, containing (ACC740) *Dicellograptus ornatus* Elles & Wood, *D.* sp., *Glyptograptus* sp., *Climacograptus supernus* Elles & Wood, *C. hastatus* Hall, *C.* sp. and *Paraorthograptus uniformis* Mu & Li 0·51 m
2. Black shale intercalated with black siliceous shale, yielding (ACC739) *Diceratograptus mirus* Mu, *D. ornatus brevispinus* Chen, *Glyptograptus* sp., *Climacograptus hastatus* Hall 0·20 m
1. Black shale with a few siliceous shale intercalations, rich in graptolites including (ACC737) *Tangyagraptus uniformis* Mu, *Dicellograptus ornatus* Elles & Wood, *D. ornatus brevispinus* Chen, *Glyptograptus* sp., *Climacograptus supernus* Elles & Wood, *C. supernus longus* Geh, *C. tumidus* Geh, *Amplexograptus suni* (Mu), *Orthograptus abbreviatus* Elles & Wood, *Yinograptus disjunctus* (Yin & Mu), *Y. brevispinus* Mu, *Paraplegmatograptus connectus* Mu 0·15 m

Black shale with siliceous shale intercalation, yielding abundant graptolites, including (ACC737a) *Tangyagraptus typicus* Mu, *T. uniformis* Mu, *T.* sp., *Climacograptus supernus* Elles & Wood, *C. supernus longus* Geh, *Orthograptus truncatus* Lapworth, *Glyptograptus* sp., *Amplexograptus suni* (Mu), *Yinograptus disjunctus* (Yin & Mu), *Y. grandis* Mu, *Paraplegmatograptus* sp. [ ]

3. Renhuai section (after Geng Liang-yu *et al.* 1984).

Lower Silurian Lungmachi Formation (basal part):
Greyish-black silty, carbonaceous shale (0·05 m thick in single bed), cream-coloured sandy shale (in basal part), yielding an abundant graptolite fauna of *Glyptograptus kaochiapienensis* Hsu, *G.* cf. *lungmaensis* Sun and *Orthograptus* sp. etc. associated with some brachiopods 1·8 m

Upper Ordovician Wufeng Formation:
2. Kuanginchiao bed, including the following units:
c. dark grey thick-bedded bioclastic limestone in upper part (ADR557-3) with numerous solitary corals such as *Brachylasma* sp., *Crassilasma* sp. and *Dansiphyllum*? sp. 1·14 m
b. Dark greyish thin-bedded bioclastic limestone in the middle part (ADR557-2) including *Hirnantia sagittifera* (M'Coy), *Dalmanella testudinaria* (Dalman), *Aphanomena ultrix* Marek & Havlíček, *Dalmanitina* sp., *Modiolopsis* sp., rugose corals, and the chitinozoan *Conochitina* cf. sp. A of Achab 0·29 m
a. Dark greyish medium-bedded limestone in lower part (ADR557-1) with the monotomous chitinozoan *Conochitina* cf. sp. A of Achab 0·67 m
1. Greyish-black carbonaceous shale with a minor quantity of clayey shale in the upper part, dark greyish dolomitic limestone in the lower part and 4 cm greyish black carbonaceous shale in basal part, yielding abundant graptolites such as *Climacograptus hastatus* Hall, *C.* sp., *Paraorthograptus typicus* Mu, *P.* sp., *Dicellograptus ornatus* Elles & Wood, *D. tenuisculus* Mu *et al.*, *D. szechuanensis* Mu and *Pleurograptus lui* Mu 4·1 m

4. The Nanzheng Formation of Liangshan, Nanzheng county, S. Shaanxi, was considered to be basal Silurian for a long time. However Zhu *et al.* (1986) have revised this to a late Ordovician age. According to their detailed work, the Nanzheng Formation is the equivalent of the Wufeng Formation and indicates a mixed biofacies. The Liangshan Ordovician–Silurian boundary section, Nanzheng, measured by them may be summarized as follows:

Lower Silurian Lungmachi Formation (basal part):
11. Brownish grey shales with *Climacograptus angustus* (Perner), *Diplograptus uniformis* Li, *Glyptograptus lungmaensis* Sun, *G. tamariscus distans* Packham, *G. tamariscus linearis* Perner 0·5 m

10. Brownish grey and pinkish shale with a few cephalopods and brachiopods (NZ10) and *Climacograptus normalis* Lapworth, *C. miserabilis* Elles & Wood, *C. angustus* (Perner), *Diplograptus* ex gr. *modestus* Lapworth, *D. uniformis* Li, *Glyptograptus lungmaensis* Sun 0·27–0·32 m

Upper Ordovician Nanzheng Formation:

9. Brownish-yellow calcareous shale rich in (NZ9) *Climacograptus angustus* (Perner), *Orthograptus* sp., *Glyptograptus* sp., *Platycoryphe sinensis* (Lu), *Dalmanitina* sp.; the bivalve *Deceptrix* sp. and some compressed cephalopods 0·17–0·22 m

8. Brownish-grey medium-bedded argillaceous limestone with (NZ8) *Diplograptus* cf. *bohemicus* (Marek), *Orthograptus* sp., *Climacograptus* sp., *Pleurorthoceras shanchongense* Zou, *P. jingxianense* Zou, *P. slendertubulatum* Zou, *P.* cf. *clarksvillense* (Foerste), *Michelinoceras* sp., *Aegiria*? sp., *Platycoryphe sinensis* (Lu) and *Dalmanitina nanchengensis* Lu 0·74 m

7. Brownish argillaceous limestone, containing (NZ7) *Dalmanitina nanchenensis* Lu, *Platycoryphe sinensis* (Lu), the gastropod *Rhaphistomina*? sp., and brachiopod fragments 0·46 m

6. Brownish to light grey, coarse quartzitic sandstone 0·83 m

5. Light brown shale intercalated with sandstone containing bivalve fragments in the top part (NZ6) 2·30 m

4. Greyish shale containing a few graptolites (NZ5) including *Climacograptus* sp. 0·25 m

3. Grey clayey and aluminal shale rich in fossils (NZ4) with *Orthograptus maximus* Mu, *O.* cf. *abbreviatus* Elles & Wood, *Climacograptus normalis* Lapworth, *Diplograptus* sp., *Parareteograptus* sp., *Dictyonema* sp., *Orbiculoidea*, *Euklesdenella*, the bryozoans *Stictopora*, *Hallopora* and *Escharopora*; *Conularia* and *Metoconularia* (?) *proteica* (Barrande) 0·28 m

2. Light grey siliceous shale containing (NZ2) *Orthograptus maximus* Mu, *Climacograptus angustus* (Perner) in the lower part 0·15 m

1. Light grey and brownish siltstone and shale 0·5 m

Linhsiang Formation:

Light green and brownish argillaceous limestone, with *Nankinolithus* sp. and *Protopanderodus insculptus* (Branson & Mehl) in the upper (NZ2) and *Paraceraurus* cf. *longisulcatus* Lu in the lower (NZ1) 1·10 m

5. Gaojiawan section, Xixiang, S. Shaanxi. A most detailed Ordovician–Silurian section was measured by Yu *et al.* (1986) as follows:

Lower Silurian Lungmachi Formation:

10. Black siliceous and carbonaceous shale containing (XF162–155) *Orthograptus vesiculosus* (Nicholson), *Climacograptus transgrediens* Waern and *C. medius* Törnquist. 2·77 m

9. Black siliceous shale interbedded with carbonaceous shale rich in graptolites (XF154–135) with *Parakidograptus acuminatus* (Nicholson), *Akidograptus ascensus* Davies, *A. xixiangensis* Yu, Fang & Zhang, *A. parallelus* Li & Jiao, *Climacograptus sinitzini* (Chaletzkaya) and *Orthograptus lonchoformis* Chen & Lin 4·63 m

8. Black siliceous shale intercalated with black carbonaceous shale rich in graptolites (XF134–125) with *Glyptograptus persculptus* Salter, *G. persculptus–sinuatus* transient, *G. tamariscus* (Nicholson), *G. lungmaensis* Sun, *G. zhui* Yang, *Climacograptus normalis* Lapworth, *Orthograptus lonchoformis* Chen & Lin, *Akidograptus ascensus* Davies and *A. xixiangensis* Yu, Fang & Zhang 0·89 m

Upper Ordovician Wufeng Formation:

7. Black siliceous shale weathered purplish brown in colour, containing (XF124–118) *Diplograptus bohemicus* (Marek), *D. orientalis* Mu, *Climacograptus normalis* Lapworth, *Glyptograptus* sp. 0·64 m

6. Greyish to pale siltstone and quartzitic sandstone containing (XF117–115) *Dalmanitina wuningensis* Liu, *Leonaspis* (*Eoleonaspis*) *olinini* (Troedsson), *Hirnantia sagittifera* (M'Coy), *Kinnella kielanae* (Temple) 0·22 m

5. Black siliceous and carbonaceous shale rich in graptolites (XF114–112) with *Paraorthograptus uniformis* Mu & Li, *Orthograptus truncatus* Lapworth, *Climacograptus hastatus* Hall, *Paraplegmatograptus* sp. and *Dicellograptus* sp. 0·26 m

4. Black carbonaceous shale and siliceous shale containing graptolites (XF111–110) *Paraorthograptus typicus* Mu, *Climacograptus supernus* Elles & Wood, *C. hastatus* Hall, *Paraplegmatograptus* sp., *Dicellograptus graciliramosus* Yin & Mu 0·17 m

3. Black shale weathered brown, containing (XF109–107) *Tangyagraptus typicus* Mu, *Paraorthograptus typicus* Mu, *Climacograptus hastatus* Hall, *C. venustus* Hsu, *Amplexograptus suni* (Mu), *Dicellograptus ornatus* Elles & Wood, *Yinograptus disjunctus* (Yin & Mu), *Parareteograptus* sp. 0·33 m

2. Dark grey shale with (XF106–104) *Dicellograptus szechuanensis* Mu, *D. excavatus* Mu, *Pleurograptus lui* Mu, *Climacograptus supernus* Elles & Wood, *Parareteograptus sinensis* Mu, *Orthoreteograptus denticulatus* Mu 0·42 m

1. Dark grey to black shale, containing (XF103–101) *Pleurograptus lui* Mu, *Dicellograptus elegans* Carruthers, *Climacograptus supernus* Elles & Wood, *Pseudoclimacograptus* sp., *Glyptograptus* sp., *Parareteograptus sinensis* Mu, *Orthoreteograptus denticulatus* Mu 0·44 m

Jiancaogou Formation:
Grey and yellowish green mudstone with *Nankinolithus*, etc.

In the section listed above, unit 1 is the *Pleurograptus lui* Zone which is equivalent to the *Amplexograptus disjunctus yangtzensis* Zone (W_1). Unit 2 is the *Dicellograptus szechuangensis* Zone (W_2) and unit 3 is the *Tangyagraptus typicus* Zone (W_3). Unit 4 is the equivalent of the *Diceratograptus mirus* Zone (W_4) but *D. mirus* itself has not been found. Unit 5 is the *Paraorthograptus uniformis* Zone (W_5), unit 6 is the *Hirnantia–Dalmanitina* bed (HD) and unit 7 is the *Diplograptus bohemicus* Zone (W_6). Unit 8 is the *Glyptograptus persculptus* Zone (L_1) characterized by the occurrence of *G. persculptus*, *G. persculptus–sinuatus* transient, *G. zhui* and *G. lungmaensis*. It is noteworthy that *Akidograptus ascensus* first appears in the lower part of this zone and *A. xixiangensis* appears in the upper part. Unit 9 is the *Parakidograptus acuminatus* Zone (L_2) characterized by the incoming of *P. acuminatus* and *Climacograptus sinitzini* in association with *A. ascensus* and *A. xixiangensis*. Unit 10 is the *Orthograptus vesiculosus* Zone (L_3) characterized by the incoming of *O. vesiculosus*.

6. Bajaokou Ordovician–Silurian boundary section, Ziyang county, S. Shaanxi. The Lower Silurian Banjuguan Formation and the Upper Ordovician Bajaokou Formation are all in graptolite facies, without shelly beds. They are composed of dark grey to black carbonaceous and siliceous slate and rich in graptolites, which were deposited in deep water on the south slope of the East Qinling trough and on the north margin of the Yangtze platform. The thickness of the basal Silurian is much greater than that of the uppermost Ordovician. The section measured by Fu and others may be outlined as follows.

Lower Silurian Banjiuguan Formation (basal part). Black carbonaceous and siliceous slate:

L_3 *Orthograptus vesiculosus* Zone with *O. vesiculosus*, *Neodicellograptus*, *Rhaphidograptus*, and *Atavograptus* 27·4 m

L_2 *Parakidograptus acuminatus* Zone with *P. acuminatus* and *Climacograptus sinitzini* (F14) 20·8 m

L_1 *Glyptograptus persculptus–sinuatus* transient zone 10·5 m

4. *G. persculptus–sinuatus* transient, and *G. tamariscus* (F13)

3. *Akidograptus ascensus*, *Climacograptus miserabilis*, *Orthograptus*, and *Atavograptus* (F12)

2. *Glyptograptus* cf. *persculptus*, *Orthograptus lonchoformis* and *Diplograptus* cf. *modestus* (F11)

1. *G.* cf. *persculptus*, *G. sinuatus*, *G. gracilis*, *Diplograptus modestus*, *Climacograptus normalis*, and *C. miserabilis* (F10)

Upper Ordovician Bajaokou Formation (upper part). Dark grey to black carbonaceous and siliceous slate:

W_6^2 *Diplograptus* spp., *Climacograptus* sp., *Orthograptus* sp. (F9, F8) 2 m

W_6^1 *Climacograptus extraordinarius*, *Diplograptus* spp. (F7, F6) 1·5 m

W_5 *Paraorthograptus uniformis* (F4) 1·2 m

W_4 *Diceratograptus mirus* (F3) 0·6 m

7. Tangshan Ordovician–Silurian boundary section near Nanjing (Jiao & Zhang 1984).

Lower Silurian Kaochiapien Formation (basal part):

10. Greyish and yellowish shale with chert (ND8), containing *Glyptograptus caudatus* Ge, *Climacograptus normalis* Lapworth, and *Orthograptus* sp. 0.30 m

9. Variegated siliceous shale with (ND7) *Glyptograptus lungmaensis* Sun, *Orthograptus* sp. and *Akidograptus*? sp. 0·40 m

8. Purple siliceous shale rich in graptolites (ND6) with *Diplograptus* sp., *Glyptograptus* sp. and *Climacograptus* sp. 0·02 m

Upper Ordovician Wufeng Formation:
7. Kuanyinchiao bed: greyish siliceous mudstone rich in shelly fossils (ND5) with *Dalmanitina yichangensis* Lin, *Leonaspis sinensis* Chang, *Platycoryphe* sp., *Paromalomena polonica* (Temple), *Aegiromena ultima* Marek & Havlíček, *Triplesia*? sp., *Holopea*? sp., *Loxonema* sp., *Nuculoidea* sp. and *Hyolithes*? 0·19 m
6. Black sandy shale (ND4), containing *Diplograptus* cf. *bohemicus* (Marek) and *Climacograptus extraordinarius* (So6) 0·28 m
5. Variegated calcareous mudstone 0·09 m
4. Purple greyish siliceous shale with graptolites (ND3) *Diplograptus* sp. and *Climacograptus* sp. 0·09 m
3. Brownish yellow shale (ND2) with the brachiopod *Manosia* sp., the gastropod *Planetochidea* and trilobite and crinoid fragments. 0·30 m
2. Grey siliceous pale-weathered shale 0·45 m
1. Black siliceous shale with (ND1) *Dicellograptus* sp. and *Climacograptus supernus* Elles & Wood 0·83 m

8. Xainze area, Northern Xizang (Tibet) (after Mu & Ni, 1983).

Lower Silurian Dewukaxia Formation (basal part):
Black graptolitic shale with *Climacograptus normalis* Lapworth, *C. miserabilis* Elles & Wood, *C. xainzaensis* Mu & Ni, *Glyptograptus elegantulus* Mu & Ni, *G. nanus* Mu & Ni, *G. asthenus* Mu & Ni, *Diplograptus lacertosus* Mu & Ni, *D. spanis* Mu & Ni and *D. temalaensis* (Jones).

Upper Ordovician Xainza Formation:
Grey argillaceous limestone with *Hirnantia*, *Kinnella*, *Cliftonia*, *Paromalomena*, *Hindella*, *Aphanomena* and dalmanitid trilobite 8·82 m
Greyish-yellow shale with *Glyptograptus asthenus* Mu & Ni, *G. daedalus* Mu & Ni, *G. elegantulus* Mu & Ni, *G. nanus* Mu & Ni, *Diplograptus bohemicus* (Marek), *D. charis* Mu & Ni, *D. flustrianus* Mu & Ni, *D. maturatus* Mu & Ni, *D. ojsuensis* (Koren & Mikhaylova), *D. orientalis* Mu *et al.*, *D. spanis* Mu & Ni, *D. viriosus* Mu & Ni, *Climacograptus* cf. *extraordinarius* (Sobolevskaya), *C. miserabilis* Elles & Wood, *C. normalis* Lapworth, *C. xainzaensis* Mu & Ni, *C. xizangensis* Mu & Ni and *Orthograptus* sp. 5·27 m

Upper Ordovician Gangmusang Formation:
Limestone with shelly fauna.

9. Mangjiu section of Luxi (after Ni *et al.*, 1983).

Lower Silurian Lower Jenhochiao Formation (basal part):
4. Black shale with *Climacograptus normalis* Lapworth, *C. miserabilis* Elles & Wood, *C. trifilis lubricus* Chen & Lin, *Akidograptus ascensus* Davies, *Orthograptus guizhouensis* Chen & Lin, *Diplograptus bifurcus* Mu *et al.*, etc. 4·1 m
3. Sandy mudstone with *Climacograptus normalis* Lapworth and *C.* sp. c. 0·5 m

Upper Ordovician Wanyaoshu Formation (top part):
2. Greyish-white mudstone with *Hirnantia sagittifera* (M'Coy), *Hindella crassa incipiens* (Williams), *Coolinia* cf. *dalmani* Bergström, *Plectothyrella* cf. *crassicosta* (Dalman), *Paromalomena polonica* (Temple), *Aphanomena ultrix* Marek & Havlíček and *Dalmanitina* sp. c. 2 m
1. Black shale, containing *Climacograptus latus* Elles & Wood, *C. angustus* Perner and *Orthograptus maximus* Mu.

10. The Ordovician–Silurian boundary strata are well developed at the locality of Shahechang, about 15 km NW of Baoshan, Yunnan, where a number of graptolites were collected from the uppermost Ordovician by Ni Yu-nan, Cai Cong-yang, Chen Ting-en, Li Guo-hua, and Wang Ju-de. The stratigraphical sequence is as follows (in descending order):

Lower Silurian Lower Jenhochiao Formation (basal part):
3. Upper part: Black siliceous shale with *Pristiograptus* sp. and *Climacograptus* sp.
Lower part: Greyish white sandy shale with *Climacograptus normalis* Lapworth, *C. xainzaensis* Mu & Ni and *Glyptograptus* sp. (ex gr. *persculptus*) in the basal 2 m.

Upper Ordovician:
2. Greyish black sandy shale, rich in graptolites, the top part with *Diplograptus bohemicus* (Marek), *Diplograptus ojsuensis* (Koren & Mikhaylova), *Climacograptus normalis* Lapworth (ACJ196), *Cli-*

macograptus cf. *normalis* Lapworth, *C. xainzaensis* Mu & Ni, *C. extraordinarius* (Sobolevskaya), *Diplograptus* cf. *orientalis* Mu *et al.*, *D. yunnanensis* Ni (ACJ195). The middle part yields *Glyptograptus daedalus* Mu & Ni and *Climacograptus extraordinaris* (Sobolevskaya) (ACJ194); and the basal part *Glyptograptus* cf. *elegantulus* Mu & Ni, *G. daedalus* Mu & Ni, *Diplograptus maturatus* Mu & Ni, *D. ojsuensis* (Koren & Mikhailova) and *D. temalaensis* (Jones) (ACJ193).

1. Yellow argillaceous limestone with *Nankinolithus*? sp., *Cyclopyge* sp., etc.

Analysis of the boundary sections

The strata across the Ordovician–Silurian boundary in China fall into different biofacies types as follows.

1. Where the graptolitic *Glyptograptus persculptus* Zone (L_1) lies upon the graptolitic *Diplograptus bohemicus* Zone (W_6) without intervening shelly beds, as in the Bajaokou section, Ziyang, S. Shaanxi.

2. Where the graptolitic *Glyptograptus persculptus* Zone or its equivalents (L_1) lies upon the graptolitic *Diplograptus bohemicus* Zone (W_6) with a shelly bed below, as in the Xixiang section, Xixiang, S Shaanxi; the Ganxi section, Yanhe, NE Guizhou; and the Shahechang section, Baoshan, W Yunnan.

3. Where the graptolitic facies with the *Glyptograptus persculptus* Zone or its equivalents (L_1) lies upon shelly *Hirnantia–Dalmanitina* beds (HD) with a graptolitic facies below, as at the Wangjiawan, Huanghuachang, Fenxiang and Tangya Sections, all in Yichang, W Hubei; the Sintan section, Zigui, W Hubei; the Shuanghezhen section, Changning, SW Sichuan; the Guanyiqiao section, Qijiang, S Sichuan; the Xiushan section, SE Sichuan; the Songtao section, NE Guizhou; the Hanjiadian and Liangfengya sections, Tongzi, N Guizhou; the Renhuai and Bijie sections, NW Guizhou; the Yanjin and Daguan sections, NE Yunnan; the Luxi section, W Yunnan; and the Xainza sections of Xizang (Tibet).

4. Where the graptolitic facies with *Glyptograptus persculptus* or its equivalents (L_1) lies upon a mixed facies with graptolitic facies below, such as in the Honghuayuan section, Tongsi, N Guizhou; the Liangshan section, Nanzheng, S Shaanxi; the Xinkailing section, Wuning, NW Jiangxi; the Shanchong section, Jingxian, S Anhui; and the Tangjia section, Yuqiau, W Zhejiang.

5. Where the shelly Wulipo bed with an '*Eospirigerina*' fauna lies upon the shelly *Hirnantia–Dalmanitina* bed with graptolitic facies below, as at Donggongsi, Zunyi, in N Guizhou.

Strata of the first type are only known in the transitional belt between the Yangtze basin and the East Qinling trough to the north, whereas the last type is only known in the southern marginal belt of the Yangtze basin. The Ordovician–Silurian boundary sections of the second and fourth types are important for the correlation of the *Diplograptus bohemicus* Zone (W_6) and the *Hirnantia–Dalmanitina* fauna (HD). The Ordovician–Silurian boundary sections of the third type are most common and widespread in the Yangtze region. The Wufengian (Ashgill) Yangtze sea was bounded by surrounding lands and swells and became a semi-enclosed sea under aerobic conditions, but the surface water above the anoxic layer was oxygenated. The strata of the third type are rich in organic matter and graptolites flourished.

The diversity of the Wufeng graptolitic fauna increases upwards stratigraphically from the *Amplexograptus disjunctus yangtzeensis* Zone (W_1) to the *Tangyagraptus typicus* Zone (W_3). More than twenty genera occur in the *Dicellograptus szechuanensis* Zone (W_2), apart from the dendroids. The decline of graptolite diversity took place from the *Diceratograptus mirus* Zone (W_4) to the *Diplograptus bohemicus* Zone (W_6) (Table 2). At the end of the Ordovician, all the axonolipous graptoloids were nearly extinct except for a few *Dicellograptus* which remained in China. In contrast, the Wufengian benthic shelly fauna increased in diversity. The well-known, cosmopolitan *Hirnantia* fauna first appeared in the equivalents of the *Diceratograptus mirus* Zone (W_4) with 7 genera, and increased gradually to 23 genera in the uppermost Ordovician *Hirnantia–Dalmanitina* bed (Table 3). The sea level was lowered in late Ordovician due to the formation of the ice cap in North Africa. In the late Wufengian W_4–W_6, a shallow and better aerated environment occurred due to ventilation of sea waters. The maximum glaciation was

Table 2 Stratigraphical range of graptolite genera in the Wufeng Formation

	W_1	W_2	W_3	W_4	W_5	W_6
Leptograptus	+	+	+	—	—	—
Pleurograptus	+	+	+	—	—	—
Dicellograptus	+	+	+	+	+	+
Diceratograptus	—	—	—	+	—	+
Dicranograptus	—	+	—	—	—	—
Tangyagraptus	—	—	+	—	—	—
Glyptograptus	+	+	+	+	+	+
Amplexograptus	+	+	+	+	+	+
Climacograptus	+	+	+	+	+	+
Pseudoclimacograptus	+	+	—	—	—	—
Diplograptus	—	+	+	+	+	+
Orthograptus	+	+	+	+	+	—
Paraorthograptus	—	+	+	+	+	+
Parareteograptus	+	+	+	—	—	—
Orthoreteograptus	+	+	—	—	—	—
Sinoreteograptus	+	—	—	—	—	—
Neurograptus	+	+	—	—	—	—
Nymphograptus	+	+	—	—	—	—
Arachniograptus	—	+	+	—	—	—
Phormograptus	—	+	+	—	—	—
Plegmatograptus	+	—	—	—	—	—
Paraplegmatograptus	—	+	+	+	+	+
Yinograptus	—	+	+	—	—	—
Yangzigraptus	—	—	+	+	—	—

Table 3 Stratigraphical range of brachiopod genera in the Upper Wufeng Formation

	W_4	W_5	W_6^1	W_6^2
Paracraniops	+	+	+	+
Dalmanella	+	+	+	+
Paromalomena	+	+	+	+
Leptaena	+	+	+	+
Aphanomena	+	+	+	+
Coolinia	+	+	+	+
Hindella	+	+	+	+
Trematis	—	+	—	—
Hirnantia	—	+	+	+
Cliftonia	—	+	+	+
Plectothyrella	—	+	+	+
Dorytreta	—	+	+	+
Philhedra	—	—	+	+
Philhedrella	—	—	+	+
Acanthocrania	—	—	+	+
Kinnella	—	—	+	+
Draborthis	—	—	+	+
Mirorthis	—	—	+	+
Aegiromena	—	—	+	+
Leptaenopoma	—	—	+	+
Toxorthis	—	—	—	+
Dysprosorthis	—	—	—	+
Trucizetina	—	—	—	+
Onychoplecia	—	—	—	+

reached at the end of the Ordovician (W_6) and the whole Yangtze basin became a nearly normal shallow sea in which the *Hirnantia–Dalmanitina* fauna flourished.

At the beginning of the Silurian a new graptolite fauna occurred, notably with monograptids and typical Silurian diplograptids such as the *Diplograptus* cf. *modestus* and *Glyptograptus* cf. *tamariscus* groups during the *Glyptograptus persculptus* Zone (L_1) time interval. A new brachiopod fauna, known as the '*Eospirigerina*' fauna, appeared above the *Hirnantia* fauna in the nearshore region. The rapid change in biofacies and faunal composition is due to the rising of sea level caused by rapid melting of the ice cap.

Correlation of the Ordovician–Silurian boundary sections

All the Ordovician–Silurian boundary sections may be easily correlated in China by the standard of the Wufengian–Lungmachian graptolite zones and the *Hirnantia–Dalmanitina* bed. In order to define the Ordovician–Silurian boundary throughout the world, a precise correlation of the *Diplograptus bohemicus*, *Glyptograptus persculptus* and *Parakidograptus acuminatus* Zones with shelly faunas is necessary. Thus, the subdivision and correlation of the *Diplograptus bohemicus* Zone with the *Hirnantia–Dalmanitina* bed is of great importance.

In the Yichang sections, Western Hubei, the uppermost *Hirnantia–Dalmanitina* bed is underlain by the *Diplograptus bohemicus* Zone (W_6) and overlain by the *Glyptograptus persculptus* Zone (L_1), whereas in the Xixiang section, S. Shaanxi, the *Hirnantia–Dalmanitina* bed is underlain by the *Paraorthograptus uniformis* Zone (W_5) and overlain by the *Diplograptus bohemicus* Zone (W_6), which is succeeded by the *Glyptograptus persculptus* Zone (L_1). Therefore, the *D. bohemicus* Zone of Yichang is equivalent to the lower part of the *D. bohemicus* Zone (W_6^1), and the *D. bohemicus* Zone of Xixiang is equivalent to the upper part of the *D. bohemicus* Zone (W_6^2). Thus the *Hirnantia–Dalmanitina* bed of Yichang is the equivalent of the upper part of the *D. bohemicus* Zone (W_6^2), and that of Xixiang is the equivalent of the lower part of the *D. bohemicus* Zone (W_6^1). *Climacograptus extraordinarius* and *Diplograptus orientalis* usually occur in the lower part of the *D. bohemicus* Zone (W_6^1).

The *Glyptograptus persculptus* Zone (L_1) is marked by the incoming of *Glyptograptus persculptus*, *G. sinuatus*, *G. lungmaensis*, *G. gracilis*, *Diplograptus modestus*, *Akidograptus ascensus* and monograptids. It represents the beginning of a new developmental stage of graptolite faunas, the fifth (or monograptid) fauna as defined by the writer (Mu 1984). Thus the base of the *G. persculptus* Zone should be considered an important stratigraphical boundary, that between the Ordovician and Silurian.

It is noteworthy that the *Akidograptus ascensus* Zone, directly overlying the *Hirnantia–Dalmanitina* beds of Europe, is usually regarded as the equivalent of *Parakidograptus acuminatus* by some foreign colleagues. For defining the Ordovician–Silurian boundary the correlation of the *Akidograptus ascensus* Zone with the *Glyptograptus persculptus* Zone and the boundary between the *Glyptograptus persculptus* Zone and the *Parakidograptus acuminatus* Zone must be clarified.

The *Parakidograptus acuminatus* Zone (L_2) is marked by the incoming of *P. acuminatus* in association with *Climocograptus sinitzini* which also characterizes the *P. acuminatus* Zone. *Akidograptus ascensus* itself first appeared in the *persculptus* Zone (L_1), much earlier than *P. acuminatus*, although the two forms may be present together in the *P. acuminatus* Zone (L_2), whereas *P. acuminatus* is confined to the *P. acuminatus* Zone. Yu and his colleagues are of the opinion that *Parakidograptus acuminatus* is directly derived from *Akidograptus ascensus* and a transitional form *Akidograptus xixiangensis* Yu *et al.* was described and illustrated from the basal Lungmachi formation of Xixiang, S. Shaanxi. *A. xixiangensis* appears higher than *A. ascensus* and lower than *P. acuminatus*. It posseses akidograptid thecae in the proximal portion of the rhabdosome and parakidograptid thecae in the distal portion. A similar form *Akidograptus giganteus* was described by Yang (1964) from the basal Silurian of W. Zhejiang. Li & Ge (1981) and Fu (1983) tried to propose a new genus for these transitional forms between *Akidograptus* and *Parakidograptus*.

It is clear that the *Akidograptus ascensus* Zone of Europe may be correlated with the *Glyptograptus persculptus* Zone in China. This view was confirmed by the works of Nilsson (1984) in Sweden, and Storch (1982) in Bohemia. The same is true, in my view, for the Mirny Creek section, northeast USSR, studied by Koren *et al.* (1983). The Mirny Creek Ordovician–Silurian boundary section of mixed biofacies measured by Koren and her colleagues may be outlined mainly by graptolites as follows:

Members 65 and 66 *Paraorthograptus pacificus* Zone
Members 67 and 68 *Climacograptus extraordinarius* Zone with *Hirnantia–Dalmanitina* fauna
Members 69 to 72 *Diplograptus bohemicus* Zone (='*persculptus*' Zone) with *Hirnantia–Dalmanitina* fauna
Members 73 and 74 *Akidograptus ascensus* Zone, incoming of *Diplograptus* of *modestus* group, *Glyptograptus* of the *tamariscus* group and *Akidograptus ascensus.*
Members 75 to basal part of member 78 *Parakidograptus acuminatus* Zone, incoming of *P. acuminatus* and *Climacograptus sinitzini..*
Member 78 *Orthograptus vesiculosus* Zone, incoming of *Orthograptus vesiculosus.*

It is obvious that the *Paraorthograptus pacificus* Zone (65–66) corresponds to the *Paraorthograptus uniformis* Zone (W_5), that the *Climacograptus extraordinarius* Zone (67–68) corresponds to the lower part of the *Diplograptus bohemicus* Zone (W_6^1), and the *Diplograptus bohemicus* Zone (='*persculptus*' Zone, 69–72) corresponds to the upper part of the *Diplograptus bohemicus* Zone (W_6^2). The lower part of the '*acuminatus–ascensus* Zone' (members 73–74) of Koren and others is equivalent to the *Akidograptus ascensus* Zone of Europe, and corresponds to the *Glyptograptus persculptus* Zone (L_1) of China, whereas the upper part of the '*acuminatus–ascensus* Zone' (75–basal 78) is the *Parakidograptus acuminatus* Zone, corresponding to the *Parakidograptus acuminatus* Zone (L_1) of China and Europe.

I am convinced that the *Akidograptus ascensus* Zone of the European continent is equivalent to the *Glyptograptus persculptus* Zone of Britain and Denmark. The *Parakidograptus acuminatus* Zone and the *Glyptograptus persculptus* Zone of the Dob's Linn section of Britain correspond to the *P. acuminatus* Zone (L_2) and *G. persculptus* Zone (L_1) of China respectively. The *C. extraordinarius* band of the Dob's Linn section falls within the lower part of the *Diplograptus bohemicus* Zone (W_6^1), and the blind dalmanitid band of Dob's Linn possibly falls within the upper part of the *D. bohemicus* Zone (W_6^2). It seems to me that the *G. persculptus* Zone of Dob's Linn as well as elsewhere represents the beginning of the Silurian transgression due to the rapid melting of the ice-cap in North Africa.

Conclusions

1. The Ordovician–Silurian boundary sections are widely distributed in China. Many Ordovician–Silurian boundary sections have been defined in the Yangtze platform of the Central China Region.

2. The graptolite sequence of the upper Ordovician (Wufengian W_1–W_6) and the Lower Silurian (Lungmachian L_1–L_7) affords a valuable standard for correlation. The position of the *Hirnantia–Dalmanitina* bed is confined to W_4–W_6. The *Diplograptus bohemicus* Zone (W_6) is the highest level reached by the well-known and cosmopolitan *Hirnantia* fauna.

3. By this standard all the Ordovician–Silurian boundary sections may be easily correlated in China and even outside China.

4. The *acuminatus* Zone is marked by the incoming of *Parakidograptus acuminatus.* The underlying *Akidograptus ascensus* Zone of Europe is equivalent to the *Glyptograptus persculptus* Zone, which is the beginning of the Silurian transgression due to the rapid melting of the ice-cap in north Africa. The *G. persculptus* Zone was also the beginning of the monograptid fauna stage in the history of the development of the graptolite faunas. It is reasonable to place the Ordovician–Silurian boundary between the *G. persculptus* Zone (L_1) or '*Eospirigerina*' bed and the *D. bohemicus* Zone (W_6) or the *Hirnantia–Dalmanitina* bed (HD).

5. The *C. extraordinarius* Zone of the north-east USSR or the *C. extraordinarius* band of Dob's Linn, Scotland, correspond to the lower part of the *D. bohemicus* Zone (W_6^1). The '*G.*

persculptus' (= *D. bohemicus*) Zone of the north-east USSR corresponds to the upper part of the *D. bohemicus* Zone (W_6^2) of China.

6. Many kinds of fossils have been found in the Ordovician–Silurian boundary sections such as graptolites, brachiopods, trilobites, ostracods, corals, bivalves, cephalopods, gastropods, bryozoa, crinoids, conularia, conodonts, chitinozoa, and so on. The increasing number of finds of conodonts is of great importance for correlation with the Anticosti section of Canada. At present, the correlation with Anticosti is difficult. Unfortunately there are many weak points in the Dob's Linn section, and it is difficult to use as an international Ordovician–Silurian boundary stratotype.

References

Apollonov, M. K., Bandaletov, S. M. & Nikitin, I. F. 1980. [The Ordovician–Silurian boundary in Kazakhstan]. 300 pp. Alma Ata [In Russian].

Baillie, P. W., Banks, M. R. & Rickards, R. B. 1978. Early Silurian graptolites from Tasmania and their significance. *Search*, Sydney, **9** (1–2): 46–47.

Berry, W. B. N. & Boucot, A. J. 1973. Glacio-eustatic control of late Ordovician–early Silurian platform sedimentation and faunal changes. *Bull. geol. Soc. Am.*, New York, **84:** 275–284.

—— **& Wilde, P.** 1978. Progressive ventilation of the oceans—an explanation for the distribution of the Lower Paleozoic black shales. *Am. J. Sci.*, New Haven, **278:** 257–275.

Bjerreskov, M. 1975. Llandoverian and Wenlockian graptolites from Bornholm. *Fossils Strata*, Oslo, **8:** 1–94, pls 1–13.

Chen Xu 1983. Influence of the Late Ordovician glaciation on basin configuration of the Yangtze platform in China. *Lethaia*, Oslo, **17:** 51–59.

—— 1984. Silurian graptolites from southern Shaanxi and northern Sichuan with special reference to classification of Monograptidae. *Palaeont. Sin.*, Peking, (N.S., B) **20:** 1–102, 19 pls. [In Chinese, English summary].

—— 1984*a*. The Silurian graptolite zonation of China. *Can. J. Earth Sci.*, Ottawa, **21:** 241–257.

—— **& Lin Yao-kun** 1978. Lower Silurian graptolites from Tongzi, northern Guizhou. *Mem. Nanjing Inst. Geol. Palaeont. Acad. Sin.* **12:** 1–76.

—— —— 1984. On the material of *Glyptograptus persculptus* (Salter) from the Yangtze Gorges, China. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 191–202. Anhui Sci. Tech. Publ. House.

Davies, K. A. 1929. Notes on the graptolite faunas of the Upper Ordovician and Lower Silurian. *Geol. Mag.*, London, **66:** 1–27.

Fu Li-pu 1983. Silurian stratigraphy in Bajiaokou, Ziyang, Shaanxi. *Bull. Xian Inst. Geol. Min. Res.* **6:** 1–18.

Ge Mei-yu 1984. The graptolite fauna of the Ordovician–Silurian boundary section in Yuqian, Zhejiang. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 389–454. Anhui Sci. Tech. Publ. House.

Geng Liang-yu, Hu Zhao-xun & Gong Lian-zan 1984. Upper Ashgillian Chitinozoa from Renhuai, Northern Guizhou. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 259–266. Anhui Sci. Tech. Publ. House.

Ho Xin-yi 1980. Tetracoral fauna of the Late Ordovician Guanyinqiao Formation, Bijie, Guizhou province. *Prof. Pap. Stratigr. Palaeont.*, Peking, **6:** 1–45.

Huang Zhi-gao 1982. Latest Ordovician and Earliest Silurian graptolite assemblages of Xainza district, Xizang (Tibet) and Ordovician–Silurian boundary. *Geol. Papers of Qinghai-Xizang Plateau* **7:** 27–52.

—— **& Lu Yan-min** 1983. Lower Silurian graptolites from Xainza. *Geol. Papers of Qinghai-Xizang plateau* **2:** 121–168.

Jiao Shi-ding 1984. Discovery of *Dalmanitina–Hirnantia* fauna in Tangshan region near Nanjing, Jiangsu province and comment on Ordovician–Silurian boundary. *Bull. Nanjing Inst. Geol. M.R., Chinese Acad. Geol. Sci.* **5** (4): 66–77.

Jin Chun-tai, Ye Shao-hua, He Yuan-xiang, Wan Zheng-quan, Wang Shu-bei, Zhao Yu-ting, Li Shau-ji, Xu Xing-qi & Zhang Zhong-qui 1982. *The Silurian stratigraphy and palaeontology in Guanyinqiao, Qijiang, Sichuan.* People's Publishing House of Sichuan, Chengdu, China.

Koren, T. N., Oradovskaya, M. M., Pylma, L. J., Sobolevskaya, R. F. & Chugaeva, M. N. 1983. *The Ordovician and Silurian boundary in the Northeast of the USSR.* 208 pp., 48 pls. Leningrad, Nauka [In Russian].

—— **& Sobolevskaya, R. F.** 1977. A new standard succession of graptolite assemblages of the Ordovician–Silurian boundary (Northeastern USSR). *Dokl. Akad. Nauk SSSR* **236** (4): 950–955.

——, ——, **Mikhailova, N. F. & Tzai, D. T.** 1979. New evidence on graptolite succession across the Ordovician–Silurian boundary in the Asian part of the USSR. *Acta palaeont. pol.*, Warsaw, **24:** 125–136.

Lai Cai-gen 1979. New advances on the lower and upper boundary of Ordovician system in China. *Acta geol. sin.*, Peking, **53** (4): 180–187.

Lespérance, P. J. 1985. Faunal distributions across the Ordovician–Silurian boundary, Anticosti Island and Percé, Québec, Canada. *Can. J. Earth Sci.*, Ottawa, **22:** 838–849.

Li Ji-jin 1984. Graptolites across the Ordovician–Silurian boundary from Jingxian, South Anhui. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 309–388. Anhui Sci. Tech. Publ. House.

—— **& Ge Mei-yu** 1981. Development and systematic position of *Akidograptus. Acta palaeont. sin.*, Peking, **20** (1): 225–234.

——, **Qian Yi-yuan & Zhang Jun-ming** 1984. Ordovician–Silurian boundary section from Jingxian, South Anhui. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 287–308. Anhui Sci. Tech. Publ. House.

Lin Bao-yu 1979. The Silurian system of China. *Acta geol. sin.*, Peking, **53** (3): 179–181.

Lin Yao-kun & Chen Xu 1984. *Glyptograptus persculptus* Zone—the earliest Silurian Graptolite Zone from Yangtse Gorges, China. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 203–232. Anhui Sci. Tech. Publ. House.

Mu En-zhi 1974. Evolution, classification and distribution of Graptoloidea and Graptodendroids. *Scientia sin.*, Peking, **17** (2): 227–238.

—— 1983. Ordovician–Silurian boundary in China. *In*: *Studies on Stratigraphic boundaries in China*: 108–154. Beijing, Sci. Press.

—— 1984. Research work on Ordovician–Silurian boundary in China. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 1–13. Anhui Sci. Tech. Publ. House.

—— 1984*a*. Developmental stages of graptolites and stratigraphic boundaries. *In: Developments in Geoscience, Contribution to 27th Intern. Geol. Congr.* Beijing, Sci. Press.

—— **& Lin Yao-kun** 1984. Graptolites from the Ordovician–Silurian boundary section of Yichang area, W. Hubei. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 45–82. Anhui Sci. Tech. Publ. House.

—— **& Ni Yu-nan** 1983. Uppermost Ordovician and Lower Silurian graptolites from the Xainza area of Xizang (Tibet) with discussion on the Ordovician–Silurian boundary. *Palaeontologia Cathayana* **1:** 155–180.

—— **& Rong Jia-yu** 1983. On the international Ordovician and Silurian boundary. *J. Stratigr.*, Nanking, **7** (2): 81–91.

——, **Zhu Zhao-ling, Lin Yao-kun & Wu Hong-yi** 1984. The Ordovician–Silurian boundary in Yichang, Hubei. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 15–41. Anhui Sci. Tech. Publ. House.

Ni Yu-nan 1978. Lower Silurian graptolites from Yichang, western Hubei. *Acta palaeont. sin.*, Peking, **17** (4): 387–416.

—— 1984. Upper Ordovician Graptolites from Baoshan, western Yunnan. *Acta palaeont. sin.*, Peking, **23** (3): 320–327.

——, **Chen Ting-en, Cai Chong-yang, Li Guo-hua, Dun Yan-xue & Wang Jue-de** 1982. The Silurian rocks in western Yunnan. *Acta palaeont. sin.*, Peking, **21** (1): 119–132.

——, ——, **Zhou Zhi-yi, Lin Huan-ling, Geng Liang-yu & Mu Dao-chen** 1983. Boundary of Ordovician and Silurian in Western Yunnan. *In: Special Papers in Scientific Expedition of the Heng Duan Mountain* **1:** 43–47.

——, **Xu Han-kui & Chen Ting-en** 1981. Boundary of Ordovician and Silurian in the Xainza area, Xizang. *J. Stratigr.*, Nanking, **5** (2): 146–147. [In Chinese].

Rickards, R. B. & Hutt, J. E. 1970. The earliest monograptid. *Proc. geol. Soc.*, London, **1663:** 115–119.

Rong Jia-yu 1979. The *Hirnantia* fauna of China, with comments on the Ordovician–Silurian boundary. *Acta Strat. Sin.* **3** (1): 1–28.

—— 1984. Brachiopods of Latest Ordovician in the Yichang district, western Hubei, central China. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of*

systemic boundaries in China. Ordovician–Silurian boundary **1:** 111–190, pls 1–14. Anhui Sci. Tech. Publ. House.

Štorch, P. 1982. Ordovician–Silurian boundary in the northernmost part of the Prague basin (Barrandian, Bohemia). *Věst. ústř. Ust. geol.*, Prague, **57** (4): 231–236.

Wang Xiao-feng, Zeng Quing-luan, Zhou Tian-mei, Sun Quan-ying, Li Zhi-hong, Xiang Li-wen & Lai Cai-gen 1983. Latest Ordovician and Earliest Silurian faunas from the eastern Yangtze Gorges with comments on Ordovician–Silurian boundary. *Bull. Yichang Inst. Geol. Min. Res.* **6:** 57–163.

Williams, S. H. 1983. The Ordovician–Silurian boundary graptolite fauna of Dob's Linn, Southern Scotland. *Palaeontology*, London, **26** (3): 605–639.

Wu Hong-ji 1984. A species of *Dalmanitina* (trilobite) from Deqing and Yuqian counties, western Zhejiang. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 455–466. Anhui Sci. Tech. Publ. House.

Yang Da-quan 1964. Some Lower Silurian graptolites from Anji, northeastern Zhejiang (Chekiang). *Acta palaeont. sin.*, Peking, **12** (4): 628–636.

—— 1983. Latest Ordovician graptolites from Northwestern Zhejiang. *Acta palaeont. sin.*, Peking, **22** (6): 595–605.

Yu Jian-hua, Fang Yi-ting, Liang Shi-jing & Liu Hua-bao 1984. On the Ordovician–Silurian boundary in Wuning county, Jiangxi Province. *J. Nanjing Univ., Nat. Sci. Edn* **3:** 533–542.

——, —— **& Zhang Da-liang** 1986. The Ordovician–Silurian boundary in Xixiang, S. Shaanxi. *J. Nanjing Univ., Nat. Sci. Edn.*

Zhu Zhao-ling, Lin Yao-kun, Chen Ting-en, Zhang Sen-gui & Yu Chang-min 1986. Review on the age of 'Nanzheng Shale'. *J. Stratigr.*, Nanking, **10** (2): 98–107.

—— **& Wu Hongji** 1984. The *Dalmanitina* fauna (Trilobite) from Huanghuachang and Wangjiawan, Yichang county, Hubei province. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of systemic boundaries in China. Ordovician–Silurian boundary* **1:** 83–110. Anhui Sci. Tech. Publ. House.