中国各系界线地层及古生物

奥陶系与志留系界线

（一）

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PREFACE

Gathered together in this volume are eighteen reports, chiefly the papers read at the Symposium of the Cambrian—Ordovician and Ordovician—Silurian boundaries held in Nanjing in October, 1983. Most of them discuss the stratigraphy and palaeontology of the O—S boundary sections in Yichang of Hubei, Jingxian of southern Anhui (actually cental Anhui) and Yuqian of Zhejiang. Yuqian is situated in the northern part (the Jiangnan subregion) of the South China region, Yichang in the Yangtze Region (or Central China Region), while Jingxian on the southern border of the Yangzi Region.

During the late Ordovician and the early Silurian, the Yangzi sea basin was shallow, quiet and redutive in condition; there deposited thin layers of black graptolite shales known as the Wufeng and Lungmachi Formations with a thin shelly bed existing between them. The succession and faunal sequence are continuous and complete, thus forming many good O—S boundary sections commonly found in the Yangzi Region. Since many articles on the O—S boundary published in Chinese during the last ten years can not be fully understood and easily used by foreign colleagues, we have published this volume in English for their convenience.

The graptolite genera *Tangyagraptus* and *Diceratograptus* are the important zonal fossils for W_3 and W_4 of the upper Wufeng Formation respectively. Although widely distributed in China, they are unknown outside China for a long time. Most recently, *Diceratograptus* was discovered in Canada; this discovery is very important for correlation of late Ordovician strata between China and Canada, and therefore the description of this new material is very desirable.

The cephalopods in the O—S boundary sections of the Yichang area are rather poor, but those in the Pagoda limestone Formation (including the Meijiang Formation) are very rich and characteristic in feature. A paper treating of the Pagoda limestone and its fauna is published in this volume as an appendix.

The chitinozoans in the O—S boundary sections of Yichang have not yet been found, but many specimens of them have been discovered from the Fenhsiang and Hunghuayuan Formations of the Huanghuachang area. The description of these chitinozoans is also included in this volume as another

appendix.

No more conodonts have been found in the O—S boundary sections, although a few forms have been discovered from the Wangjiawan section. Conodonts are very rich in the lowest Ordovician and uppermost Cambrian of the Huanghuachang area, thus the Cambrian—Ordovician boundary section of Lianghekou, near Huanghuachang represents a conodont sequence type in China. To make it easy for correlation with other sections, the report on the Lianghekou section will be published in the Cambrian—Ordovician Boundary Volume.

As pointed out in the first paper of this volume, apart from the Yangzi Region, the O—S Boundary sections also are well-defined in some other regions, such as the Tibet-W. Yunnan region, the S. China region and the N. W. China region. Detailed work on the O—S Boundary will be carried out continuously year by year, and the research results also will be successively published in the near future. This volume is only a starting point for the publication of the O—S boundary.

Mu En-zhi

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RESEARCH WORK ON ORDOVICIAN—SILURIAN BOUNDARY IN CHINA

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Historical Review

Although the Ordovician—Silurain boundary has been studied for a long time in China, a systematically detailed study on the boundary started only in 1957, when Wang Yu, Mu En-zhi, Li Ji-jin and Ge Mei-yu investigated the Ordovician and Silurian rocks and their boundary in the Yichang-Zigui area, W. Hubei and later in 1963, Zhang Wen-tang, Chen Xu, Chen Jun-yuan, Lin Yao-kun and others further studied the Ordovician and Silurian rocks and their boundary in the Tongzi-Zunyi area, N. Guizhou. Subsequently to these works the graptolite zones of Upper Ordovician and Lower Silurian were preliminarily established. In 1972, Mu En-zhi, Zhu Zhao-ling, Chen Jun-yuan, Rong Jia-yu and Liu Geng-wu measured three characteristic O—S boundary sections in different locations, namely, the Shuanghe section of Changning, SW Sichuan, the Ganxi section of Yanhe, NE. Guizhou and the Huanhuachang section of Yichang, W. Hubei. The discovery of the *Diplograptus bohemicus* fauna and the rich collections of the *Hirnantia* fauna further complete the faunal sequence of the O—S boundary section. Accordingly, the O—S boundary was defined between the *Glyptograptus persculptus* zone (L_1) at the base of the Lungmachi Formation and the uppermost bed, the *Diplograptus bohemicus* zone (W_e) or the *Hirnantia-Dalmanitina* bed (the Kuanyinchiao bed), of the Wufeng Formation.

Since then a great deal of detailed work on the O—S boundary has been carried out by members of many geological teams, geological institutions, and geological departments of Colleges and Universities in different places, e. g. Wang Xiao-feng and others in W. Hubei, Jin Chun-tai and others in S. Sichuan, Fu Li-pu and others in S. Shaanxi, Zhao Feng-you and others in C. Gansu,

Yu Jiang-hua and others in N. Jiangxi and Yang Da-quan and others in W. Zhejiang. In the recent years Lin Bao-yu and others and Ni Yu-nan, Xu Han-kui, Chen Ting-en and others investigated the O—S boundary section of the Xainza area, N. Xizang separately. Ni Yu-nan and others studied two important O—S boundary sections in the Luxi and Baoshan districts of W. Yunnan, Li Ji-jin, Qian Yi-yuan and others measured the O-S boundary section of Jingxian, Central Anhui and Ge, Wu and others measured the O—S boundary sections of Yuqian, W. Zhejiang. All those sections may be easily correlated with the standard O—S boundary succession. All the authors are unanimously agreeable that the O—S boundary should be placed between the *persculptus* zone (L_1) and the *bohemicus* zone (W_6) or the *Hirnantia-Dalmanitina* bed.

Distribution

There are six biostratigraphical regions in China, namely, the Northernmost Region (or the Junggar-Khinggan Region), the Northwest Region, the Huanghe Region (or the North China Region), the Yangzi Region (or the Cantral China Region), the Zhujiang Region (or the South China Region) and the Xizang-W. Yunnan Region. In the Yangzi Region the O—S rocks are of the platformal type, small in thickness and rich in fossils, with well defined boundary sections as exposed in S. Sichuan, N. Guizhou, W. Hubei, S. Shaanxi and C. Anhui. Among those important O—S boundary sections there are:

(1) The Shuanghe section of Changning, SW. Sichuan;
(2) The Guanyinqiao section of Qijiang, S. Sichuan;
(3) The Hanjiadian section of Tongzi;
(4) The Honghuayuan section of Tongzi;
(5) The Donggongsi section of Zunyi, N. Guizhou;
(6) The Ganxi section of Yanhe, NE Guizhou;
(7) The Huanghuachang section of Yichang;
(8) The Fenxiang section of Yichang;
(9) The Wangjiawan section of Yichang;
(10) The Tangya section of Yichang;
(11) The Shuifumiao section of Zigui, W. Hubei;
(12) The Bajiaokou section of Ziyang, S. Shaanxi;
(13) The Beigong section of Jingxian, C. Anhui.

In the Xizang-W. Yunnan Region, the O—S strata are chiefly of the

platformal type. The important O—S boundary sections there include:

(14) The Gangmusang section of Xainza, N. Xizang;

(15) The Mangjiu section of Luxi, W. Yunnan;

(16) The Xiangshuiao section of Baoshan, W, Yunnan

In the northern part of the Zhujiang Region(or the Jiangnan Transitional Region), two O—S boundary sections are well defined:

(17) The Xinkailing section of Wuning, N. Jiangxi, and

(18) The Yuqian section of Lin'an, W. Zhejiang.

Only one O—S boundary section is known in the Northwest Region:

(19) The Shichengzi section of Dajing, C. Gansu.

In the Northernmost Region, the O—S starta are great in thickness aud complicated in structure, but are incomplete succession and rare in fossils; thus no ideal O—S boundary section has been found therein so far.

There are no Silurian deposits in the Huanghe Region (Fig. 1. The solid triangles indicate the continuous sections and the hollow triangles indicate the discontinuous sections. 1, Shuanghe, 2, Guanyinqiao, 3, Hanjiadian, 4, Honghuayuan, 5, Donggongsi, 6, Ganxi, 7, Huanghuachang, 8, Fenxiang, 9, Wangjiawan, 10, Tangya, 11, Shuifumiao, 12, Bajiaokou, 13, Beigong, 14, Gangmusang, 15, Mangjiu, 16, Xiangshuiao, 17, Xinkailing, 18, Yuqian, and 19, Shichengzi)

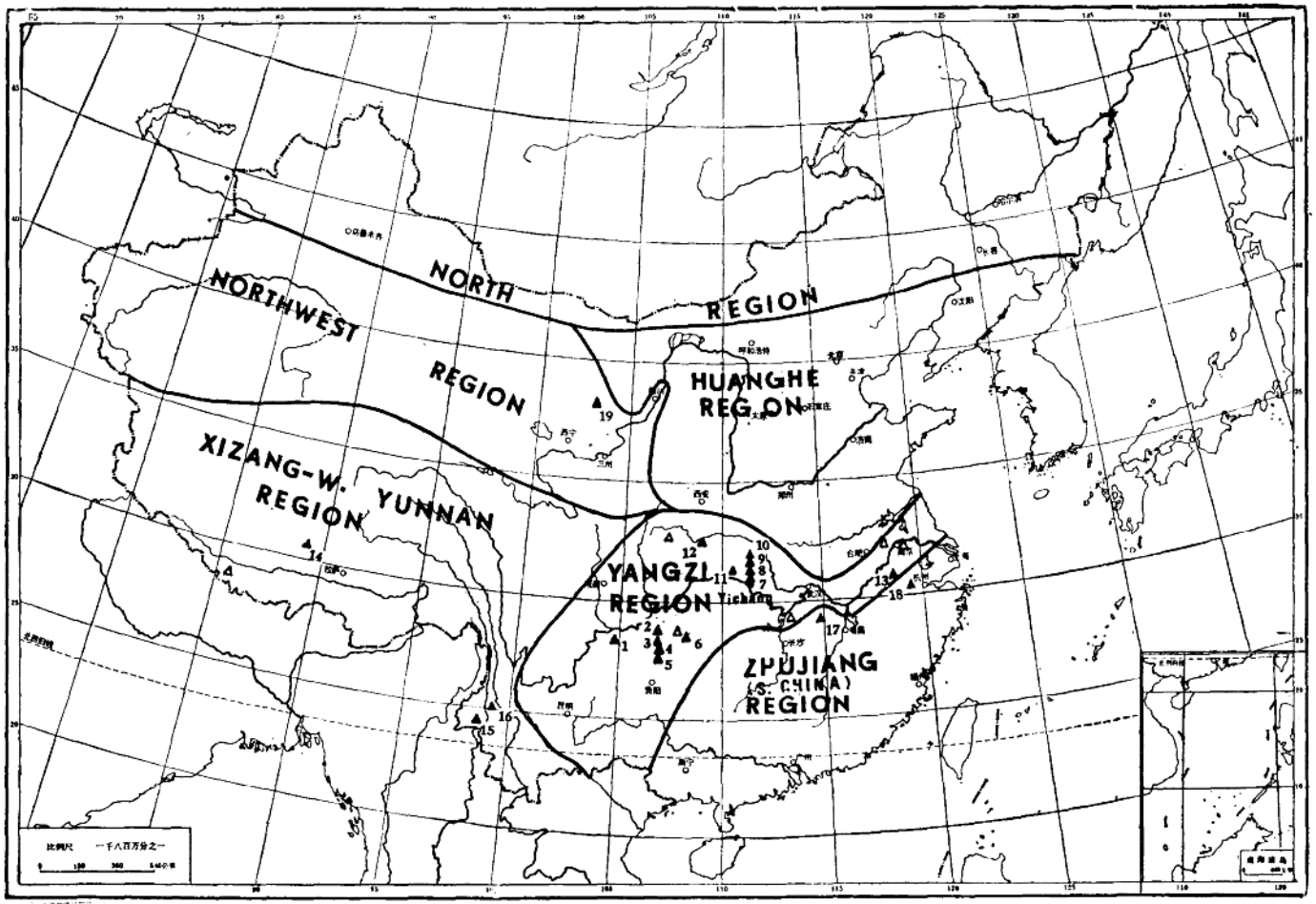


Fig. 1. Distribution of Ordovician-Silurian boundary sections in China

Subdivision

In the Yangzi Region, both the Upper Ordovician Wufeng Formation and the Lower Silurian Lungmachi Formation consist of graptolitic shales with a thin bed of shelly facies, known as the *Hirnantia-Dalmanitina* bed or the Kuanyinchiao bed existing between them. The *Hirnantia* fauna is a universally widespread fauna of the uppermost Ordovician, and is very important in the correlation of the O—S boundary sections.

The Wufeng Formation can be divided into six graptolite zones and the Lungmachi Formation into seven zones in ascending order as follows:

Wufeng Formation:

W_1 *Amplexograptus disjunctus yangtzensis* zone or the *Pleurograptus lui* zone

W_2 *Dicellograptus szechuanensis* zone

W_3 *Tangyagraptus typicus* zone

W_4 *Diceratograptus mirus* zone

W_5 *Paraorthograptus uniformis* zone

W_6 *Diplograptus bohemicus* zone

Lungmachi Formation:

L_1 *Glyptograptus persculptus* zone

L_2 *Parakidograptus acuminatus* zone

L_3 *Orthograptus vesiculosus* zone

L_4 *Pristiograptus cyphus* zone

L_5 *Demirastrites triangulatus* zone

L_6 *Demirastrites convolutus* zone

L_7 *Monograptus sedgwickii* zone

The lowest zone of the Wufeng Formation, W_1, is less wide in distribution, usually replaced by the green shelly mudstone or argillaceous limestone, with its zonal fossil *Pleurograptus lui* occurring in some places from W_1 to W_2 and even to the lower part of W_3. Therefore the *Pleurograptus lui* zone is changed to the *Amplexgraptus disjunctus yangtzensis* zone, whose zonal fossil is confined to W_1.

The *Dicellograptus szechuanensis* zone (W_2) has a wide distribution with relatively greater thinkness, forming the main part of the Wufeng Formation. In the aspect of the rhabdosome, *D. szechuanensis* resembles *D. complanatus complexus*

Davies, but differs strikingly in the thecal characters. The thecae of *D. complanatus* Elles et Wood and its subspecies *complexus* described and figured by the British authors are simple, with even aperturel margins forming a shallow apertural excavation just like the climacograptid type. But in *D. szechuanensis*, the thecae are strongly elaborated, and the thecal apertures are highly introverted, forming deep apertural excavations. The specimens described and figured by H. Williams (1983) as *Dicellograptus complanatus complexus* closely resemble *D. szechuanensis* in the thecal character. In case the description and figuration of Elles and Wood (1907) and Davies (1929) mentioned above are all right, then H. Williams' *"D. complanatus complexus"* would be *D. szechuanensis*. However, in case Elles and Wood's description and figuration are right but Davies' is wrong, the thecae of *complexus* are really so strongly introverted as shown by H. Williams, then *D. complexus* is a distinct species, not a subspecies of *D. complanatus* and *D. szechuanensis*, probably a synonym of *D. complexus*. Therefore it is very important to make a re-study of the British type specimens.

The *Tangyagraptus typicus* zone (W_3) together with the three upper zones (W_4—W_6) belongs to the upper part of the Wufeng Formation, while W_3 is the main zone of the upper Wufeng Formation. In this zone occur many new forms such as *Tangyagraptus* with complicated rhabdosomes, Reteograptidae and Archiretiolitidae with reticulated periderms. *Tangyagraptus* is confined to China and is unknown abroad. This genus is regarded by Bulman (1970) as the synonym of *Syndyograptus*, but they are strikingly different in the character of the secondary branches.

The *Diceratograptus mirus* zone (W_4) is very thin but widespread in the Yangzi Region and the Jiangnan Transitional Region, representing a good key bed for correlation, its zonal fossil also seems to be the endemic genus of China (recently Lenz discovered *Diceratograptus* in Yukon, Canada). This genus is regarded by Bulman (1970) as the synonym of *Dicranograptus*, but it differs from the latter in the character of the axial cavity, the thickening of the stipes and the elongation of the thecae in the recumbent part of the stipes.

The *Paraorthograptus uniformis* zone (W_5) is characterized by the predominance of *Paraorthograptus* which is derived from the *Orthograptus* of *truncatus* type due to the origination of the paired ventral thecal spines, forming a geniculate aspect. The specimens referred to *Pacificograptus pacificus* from Kazakhstan by Koren and others and those referred to *Paraorthograptus pacificus* from Dob's Linn by H. Williams are all the members of *Paraorthograptus*. Providing the

identification of *Pacificograptus pacificus* is correct, then *Pacificograptus* should be a synonym of *Paraorthograptus*. If the American specimens of *Climacograptus innotatus pacificus* Redemann bear only single but not paired ventral thecal spines as mentioned by Lenz and McCracken (1982), then *Pacificograptus* should be a valid genus. Moreover if the thecae of *pacificus* are of the climacograptid type, then *Pacificograptus* should be synonymous with Pribyl's *Paraclimacograptus*. Therefore, it also is necessary to make a detailed study of the American specimens of *pacificus*.

The *Diplograptus bohemicus* zone is characterized by the predominance of diplograptids of the *bohemicus* type in association with *Dicellograptus*, *Paraplegmatograptus*, *Paraorthograptus*, *Climacograptus supernus* etc.

Marek first described the zonal fossil *Diplograptus bohemicus* (Marek) as *Glyptograptus bohemicus*, but later he was inclined to place this species in the genus *Amplexograptus* after discovering the well-developed thecal genicula. As it has been pointed out by the writer (Mu, 1983), the thecae in the proximal portion are of the amplexograptid type whereas those in the distal part are of the glyptograptid type, this species is really one of the *Diplograptus*.

The lowest graptolite zone of the Lungmachi Formation known as the *Glyptograptus persculptus* zone (L_1) is worldwide in distribution. Although the name of its zonal fossil frequantly appeared in Chinese geological literatures, it was rarely described. This species has been described in detail from the *G. persculptus* zone of the Lungmachi Formation in Yichang, W. Hubei by Chen and Lin who pointed out that some of the described specimens belong to *persculptus-sinuatus* group, for the identification of the film preserved specimens is rather difficult.

The *Parakidograptus acuminatus* zone (L_2) also has a worldwide distribution, but its zonal fossil *P. acuminatus* has been referred to *Cephalograptus*, *Orthograptus* or *Akidograptus* by different authors. Based on its peculiar character Li and Ge proposed a new genus *Parakidograotus* for this species, which is restricted to only this zone, while *Akidograptus ascensus* occurs from the upper part of the *G. persculptus* zone to this zone or even to a higher horizon. This zone is characterized by the presence of those forms with bifurcated virgella belonging to different genera, such as *Akidograptus*, *Climacograptus*, *Diplograptus*, *Glyptograptus* and *Orthograptus*. The other characteristic form of this zone is a species of *Climacograptus* with four well-developed genicular spines in each thecae.

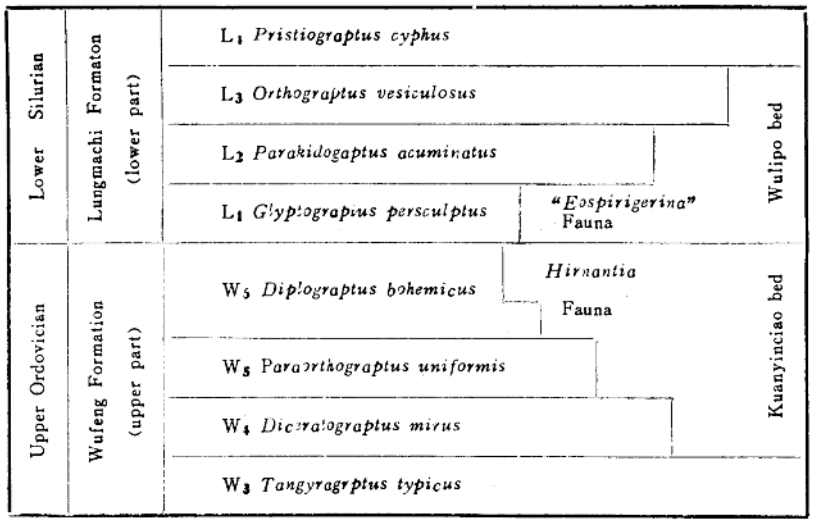
The *Orthograptus vesiculosus* zone (L_3) is widely distributed in China,

with a thinkness greater than that of the ***persculptus*** zone (L_1) and the ***acuminatus*** zone (L_2). It is still uncertain whether the zonal fossil ***vesiculosus*** is an ***Orthograptus*** or a ***Cystograptus***, this needs a more detailed study on the well preserved specimens of this species in China.

The erection of the Wufengian and Lungmachian graptolite zones is of great help in making stratigraphical correlations and in determining the exact position of the ***Hirnantia-Dalmanitina*** bed (HD bed). This bed is underlain by different graptolite zones in different places, for example, it is underlain by the ***Tangyagraptus typicus*** zone (W_3) at Ganxi of Yanhe, NE. Guizhou, by the ***Diceratograptus mirus*** zone (W_4) at Honghuayuan of Tongzi, N. Guizhou, etc. In general, the HD bed lies between the ***D. bohemicus*** zone (W_6) and ***G. persculptus*** zone (L_1) in many places of the Yangzi Region, such as the Yichang Region in W. Hubei and the Changning Region in SW. Sichuan. It also occurs in the middle or upper part of the ***bohemicus*** zone (W_6), but not in the ***persculptus*** zone (L_1).

Relatively, the earliest Silurian shelly facies known as the ***"Eospirigerina"*** bed or the Wulipo bed is less wide in distribution. Its top limit varies in different places and may reach to as high as the ***Pristiograptus cyphus*** zons (L_4).

From the above statement, the relationship between the O—S boundary graptolite zones and the shelly beds is shown in the following table.



As shown in the table, the O—S boundary should be drawn between the ***Diplograptus bohemicus*** zone (W_6) or the ***Hirnantia-Dalmanitina*** bed and the

Glyptograptus persculptus zone (L_1) or the *"Eospirigerina"* bed. The striking faunal changes at the top part of the Ordovician (W_3) and the basal part of the Silurian (L_1), support this assertion. The different assemblages of the two graptolite zones, W_3 and L_1 are listed as below:

Diplograptus bohemicus zone (W_3)

Dicellograptus sp., *Climacograptus supernus*,

C. cf. *normalis*, *C.*? *extraordinarius*, *Diplograptus bohemicus*,

D. orientalis, *Paraorthograptus* sp., and *Paraplegmatograptus* sp..

Glyptograptus persculptus zone (L_1):

Glyptograptus persculptus, *G. sinuatus*, *Diplograptus modestus*, *Climacograptus normalis*, *Akidograptus ascensus* and monograptids.

Obviously the graptolites of the *D. bohemicus* zone(W_3)bear strong Ordovician aspects, while those of the *G. persculptus* zone (L_1), exclusive of the *Climacograptus normalis* group which survived from the Ordovician, are the commonest elements of the Silurian. The occurrence of *Akidograptus*, especially of monograptids in the *G. persculptus* zone (L_1) of Qingyang, Anhui and Qijiang, Sichuan, as well as in the *G. persculptus* zone of Britain and Denmark further affirms that the *persculptus* zone is closely related to the overlying graptolite zone, the *acuminatus* zone. Thus the *persculptus* zone represents the beginning of a new stage, the monograptid fauna in the development of graptolite faunas.

Correlation

The Upper Ordovician and Lower Silurian graptolite zones and the *Hirnantia-Dalmanitina* bed provide a standard for correlation of the O—S boundary sections, thus making it easy to recognize the facies changes of these sections. The O—S boundary sections of China fall into four types: 1, The Uppermost Ordovician graptolitic facies in contact with the Lowest Silurian graptolitic facies; the *bohemicus* zone (W_3) directly underlying the *persculptus* zone (L_1) in the Ganxi section of Yanhe, NE. Guizhou, in the Xiangshuiao section of Baoshan, W. Yunnan and in the Xinkailing sectiion of Wuning, N. Jiagxi. 2, The Uppermost Ordovician shelly facies in contact with the Lowest Silurian graptolitic facies; the *Hirnantia-Dalmanitina* bed directly underlying the *persculptus* zone (L_1) in many O—S boundary sections in the Yangzi Region and the Xizang-W. Yunnan Region, such as the Shuanghe section of Changning, SW. Sichuan, the Guanyinqiao section of Qijiang, S. Sichuan, the Hanjiadian section of Tongzi, N. Guizhou,

the Huanghuachang, Fenxiang and Wangjiawan sections of Yichang, W. Hubei, the Mangjiu section of Luxi, W. Yunnan and the Gangmusang section of Xainza, Xizang. 3, The Uppermost Ordovician shelly facies in contact with the Lowest Silurian shelly facies, the ***Hirnantia-Dalmanitina*** bed being directly overlain by the ***"Eospirigerina"*** bed in the Donggongsi section of Zunyi, N. Guizhou. 4, The Uppermost Ordovician mixed facies in contact with the Lowest Silurian graptolitic facies; the ***Diplograptus bohemicus-Hirnantia-Dalmanitina*** zone being directly overlain by the ***G. gracilis*** zone which is equivalent to the ***persculptus*** zone in the Beigong section of Jingxian, Central Anhui.

By this standard the hiatus between Ordovician and Silurian deposits in a discontinuous O—S boundary section. In southwest Hubei and northwest Hunan, there are no shelly beds between the Wufeng Formation and the Lungmachi Formation. The ***Pristiograptus cyphus*** zone (L_4) directly overlies the ***szechuanensis*** zone (W_2) wanting 7 graptolite zones, i.e. W_3-L_3., between them.

By this standard, the O—S boundary sections of the flysch type in the Zhujiang Region (or South China Region) may be easily correlated with the Yichang O-S boundary sections. In southern Anhui and western Zhejiang, the Wufengian and Lungmachian strata are great in thickness, with many barren beds. The Wufengian deposits in this Region are about 1000m in thickness, but their graptolite sequence is similar to that of the Wufeng Formation only 5-10m thick in the Yangzi Region. The Wufengian graptolite zones W_1—W_6 of the two Regions may be compared with each other as follows:

Yangzi Region (C. China Region)	Zhujiang Region (S. China Region)
W_6 *Diplograptus bohemicus* zone	*D. bohemicus* zone
W_5 *Paraorthograptus uniformis* zone	*P. uniformis* zone
W_4 *Diceratograptus mirus* zone	*D. mirus* zone
W_3 *Tangyagraptus typicus* zone	*Climacograptus venustus* zone
W_2 *Dicellograptus szechuanensis* zone	*D. szechuanensis* zone
W_1 *Amplexograptus disjunctus yangtzensis* zone	*Pseudoclimacograptus anhuiensis* zone

The *D. bohemicus* zone of W. Zhejiang is more than 50 m in thickness with the ***Hirnantia-Dalmanitina*** fauna in the middle part as reported by Ge and Wu (1983).

By this standard it is possible to correlate the Dob's Linn O—S boundary section, the best O—S boundary section in the British Isles, with the Yichang O—S boundary sections. Unfortunately there are many barren beds between the graptolite bands without any *Hirnantia* fauna or conodonts in the Dob's Linn section. The *G. persculptus* zone at the basal part of the Birkhill shale may be correlated with the *G. persculptus* zone (L_1) of China. The *extraordinarius* band is part of the *D. bohemicus* zone (W_6), while the *anceps* bands belong to the *D. szechuanensis* zone (W_2) and the lower part of the *Tangyagraptus typicus* zone (W_3), because *Dicellograptus anceps* is restricted to the *D. szechuanensis* zone (W_2) and *Pleurograptus lui* ranges from the *Amplexograptus disjunctus yangtzensis* zone (W_1) to the lower part of the *Tangyagraptus typicus* zone (W_3) in China.

By this standard the Anticosti section of Canada may be correlated with the Yichang sections when more conodont specimens can be found from the Yichang sections. In the Wangjiawan section conodonts have been found by Wang and others from two horizons i.e. the top of the *szechuanensis* zone (W_2) yielding *Propanderodus liripipus* Kennedy et al., and *Drepanoistodus venustus* (Stauffer), and the top of the *bohemicus* zone (W_6) yielding *Amphognathus* cf. *ordovicicus* Branson et Mehl and *Birksgeldis wufengensis* Ni et Li. It is difficult to correlate these conodont bearing horizons with the conodont sequence of the Anticosti section at present until more conodonts are found in the near future.

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