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Conodont-graptolite biostratigraphic relations across the base of the Darriwilian Stage (Middle Ordovician) in the Yangtze Platform and the JCY area in Zhejiang, China

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ABSTRACT – *Although the recently ratified stratotype of the base of the global Darriwilian Stage in China has a magnificent graptolite succession, conodonts in the boundary interval are not very diagnostic biostratigraphically and the precise graptolite/conodont zone relations have not been well established. In an effort to clarify these relations, conodont samples were collected from coeval strata in three Yangtze Platform sections with occurrences of graptolites of the lowermost Darriwilian U. austrodentatus graptolite Zone. Biostratigraphically highly diagnostic Baltic conodonts were found that make it possible to apply the Baltic conodont zone scheme to the study sections. Although the restricted and spotty occurrences of graptolites in these sections make it difficult to recognize the exact level of the base of the Darriwilian, the new data are consistent with the idea that this level may be near the base of the Baltoniodus norrlandicus - Microzarkodina parva Zone.*

RIASSUNTO – [Rapporti biostratigrafici tra conodonti e graptoliti a cavallo della base del Darriwiliano (Ordoviciano Medio) nella Piattaforma dello Yangtze e nell'area JCY dello Zhejiang, Cina] – *Lo stratotipo della base del Darriwiliano è stato recentemente istituito ufficialmente in Cina. Esso presenta una ottima successione di graptoliti, mentre i conodonti non sono particolarmente significativi da un punto di vista biostratigrafico nell'intervallo attorno al limite: ne consegue che le relazioni tra le zone a graptoliti e quelle a conodonti non sono state stabilite con precisione. Per cercare di risolvere questo problema sono stati campionati per conodonti strati coevi in tre sezioni della piattaforma dello Yangtze, dove sono presenti i graptoliti della prima biozona del Darriwiliano, la Zona a U. austrodentatus. Sono stati trovati conodonti ad affinità baltica altamente diagnostici e ciò ha reso possibile l'applicazione a queste sezioni dello schema di biozona a conodonti del Baltico. Anche se in queste sezioni i graptoliti non sono abbondanti e i loro ritrovamenti non sono regolari, tanto da rendere difficoltoso il riconoscimento della base del Darriwiliano, appare verosimile che esso sia molto prossimo alla base della biozona a conodonti a Baltoniodus norrlandicus - Microzarkodina parva.*

INTRODUCTION

Up to recently, there has been little agreement about how to subdivide the Ordovician System into series and stages. Local schemes have been in general use in the major outcrop regions and because of the conspicuous biogeographic differentiation of Ordovician faunas, correlation between these provincial schemes have remained difficult, imprecise, and in many cases controversial. Recognizing the need for a precise, stable and globally applicable series and stage classification (Webby, 1998), The International Subcommission on Ordovician Stratigraphy has during the last decade established several working teams charged with the task of identifying fossil-defined stratigraphic levels with a high global correlation potential that may be useful as series and stage boundaries. A second goal of this effort has been to find sections in which these boundaries are particularly well-defined that may be suitable to serve as global boundary stratotypes (GSSP). The first such Ordovician boundary stratotype approved by the Ordovician Subcommission and recently ratified by The International Commission on Stratigraphy and The International Union of Geological Sciences is defining the base of the lower Middle Ordovician

Darriwilian Stage. It is located at Huangnitang near Changshan in the Zhejiang Province of China. For information about this section, and supplementary sections in the Jiangshan-Changshan-Yushan (JCY) region, see Chen & Bergström (1995), Mitchell & Maletz (1995), Mitchell *et al.* (1997), and Chen *et al.* (1997).

The Huangnitang section has a marvellous graptolite succession (Zhang, 1995; Mitchell & Chen, 1995), clearly the best known in that interval anywhere in the world, and limestone interbeds in the dominantly shaly succession contain relatively numerous conodonts (Wang & Bergström, 1995; Bergström & Wang, 1995), including several biostratigraphically useful species. However, the species diversity is somewhat limited, especially compared with that reported (Ni & Li, 1987) from coeval shallower-water strata in the Yangtze Platform about 700 km to the northwest and north (for the geographic relations between the JCY area and the central Yangtze Platform, see Chen, 1995, text-fig. 2). In the absence of conodont index species, the zonal assignment of the lower Darriwilian Stage in the Huangnitang stratotype has remained uncertain (Wang & Bergström, 1995, text-fig. 35) although based on what was known about the Yangtze conodont succession (Ni & Li, 1987), the base of the Darriwilian

was correlated with a level near the base of the *Microzarkodina parva* Zone (Wang & Bergström, 1995, text-fig. 36). Although a substantial amount of conodont work has been carried out in Lower and Middle Ordovician sections in the Yangtze Platform (see, e.g., An, 1981, 1987; An *et al.*, 1981, 1985; An & Ding, 1982; Chen, Chen & Zhang, 1983; Chen & Zhang, 1984, 1989; Ni, 1981; Ni & Li, 1987; Wang, 1993; Zhang, 1998), its lower Darriwilian conodont succession has remained incompletely known. Additional study was clearly warranted, especially for the clarification of the conodont/graptolite biostratigraphic relations across the base of the Darriwilian Stage. This is of critical importance for the correlation of this global stage boundary into the non-graptolitic shelly facies that characterizes most of the cratonic successions. The goal of the present study was to try to pin down the exact position of the base of the Darriwilian Stage in the conodont zone succession using new and carefully stratigraphically located conodont collections from a few Yangtze Platform sections that also contain zonal graptolites.

YANGTZE PLATFORM CONODONTS

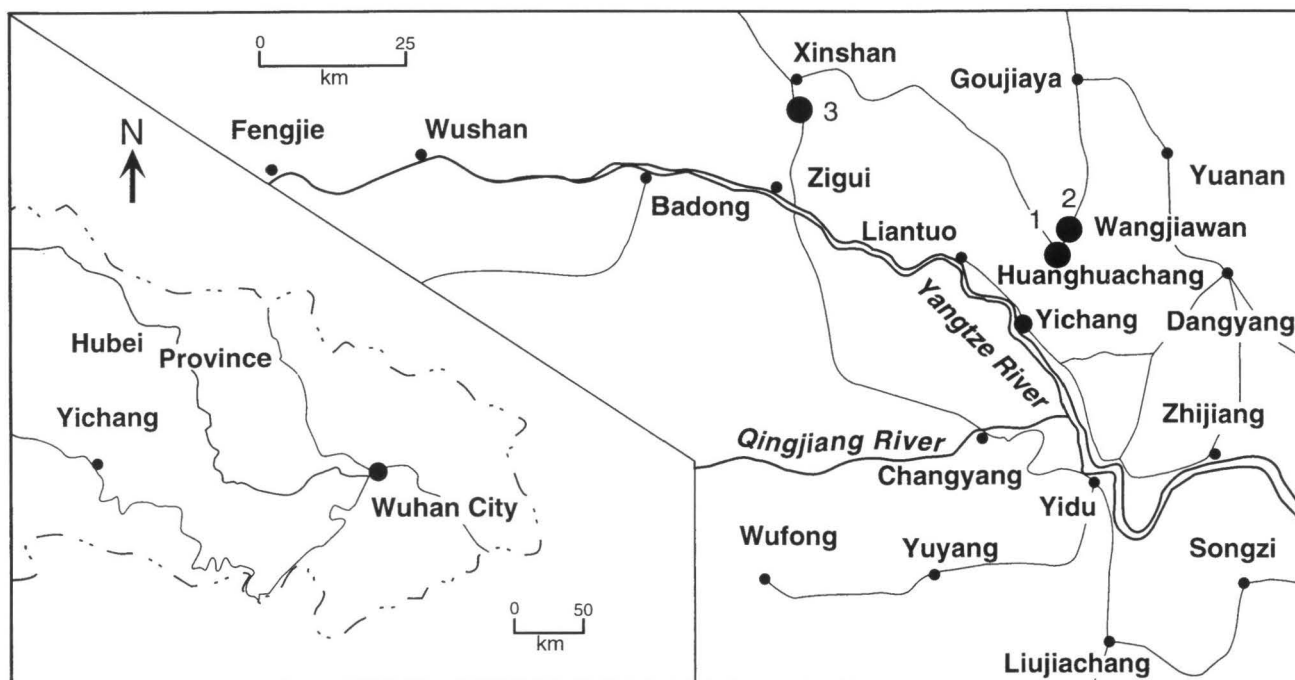
SECTIONS AND COLLECTIONS

Ordovician strata are excellently exposed in numerous road cuts and other sections in the Yangtze Platform region in Hubei Province, south-eastern

China (Zeng *et al.*, 1987). The numerous studies carried out on the geology and paleontology of these rocks have made this area a classical one in not only Chinese but international Lower Paleozoic geology. The lower Darriwilian and immediately subjacent strata are represented in the Dawan Formation (Bergström & Wang, 1995, text-fig. 1) that consists of green shales, nodular limestones, and reddish biocalcarenites. For a detailed lithologic description of the Dawan Formation at Chenjiahe (Daping) 4 km north of Huanghuachang, where it is about 37 m thick, see Lindström, Chen & Zhang (1991). The Dawan Formation contains numerous fossils. Of special interest for the present study is the occurrence of graptolites of the basal Darriwilian *Undulograptus austrodentatus* Zone and, probably, the subjacent *Exigraptus clavus* Zone in the upper member of the formation (Chen, Zhang & Mitchell, 1995).

For the purpose of the present study, 63 stratigraphically precisely located conodont samples were collected at three sections through the middle and upper members of the Dawan Formation and the lowermost part of the overlying Kuniutan (Guniutan) Formation. These are the Huanghuachang and Chenjiahe (Daping) sections located about 18 km north-northeast of Yichang, and the Jianyangping section which is situated about 6 km south of Xinshan (Text-fig. 1). All samples were processed using standard conodont separation methods at the Institute of Geology and Palaeontology, Academia Sinica, in Nanjing.

Conodonts proved to be moderately common in



Text-fig. 1 - Sketch-map showing the location of study section northwest and north-northeast of Yichang, Hubei Province. 1) Huanghuachang; 2) Chenjiahe (Daping); 3) Jianyangping. For location of the JCY area in relation to the Yangtze Platform, see Chen (1995, Text-fig. 2).

these samples but the species diversity is not very great in parts of the study interval. The state of preservation of the conodont elements is, by and large, good but many specimens are broken. The fact that reasonably complete, and positively identifiable, platform elements are rare makes it sometimes difficult to establish the precise level of the base of both the *Lenodus anti-variabilis* Zone and the *Lenodus variabilis* Zone. The conodonts have been moderately heated as shown by the fact that they exhibit a CAI (Color Alteration Index; Epstein, Epstein & Harris, 1977) of 2.5-3. This agrees well with the CAI values of 2-3 of conodonts from the Kunyuan Formation in the same region reported by Zhang (1998). Representative conodonts are illustrated in Plates 1 and 2. Most of these taxa are well-known from descriptions in the literature, and there is no need to re-describe them herein. All specimens are deposited in the collections of the Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing. AFA203, etc. in the plate legends refers to sample number, and 130367, etc. indicates repository number of illustrated specimens.

PROVINCIAL CHARACTER OF THE CONODONT FAUNA

Previous studies of Middle Ordovician conodonts from the Yangtze Platform have shown the presence of many species best known from what was referred to as the Baltic Province by Bergström (1990). Hence, in a recent study of the conodonts of the Kuniutan Formation, Zhang (1998) found that more than 90% of the species were previously known from Baltoscandia. Hence, it is not surprising that our Dawan and lowermost Kunyuan collections are completely dominated by such taxa. This striking similarity, which includes the occurrence of several taxa used as zone indices in Baltoscandia, makes it possible to recognize the Baltoscandic conodont zones in our sections.

CONODONT SPECIES RANGES AND CONODONT ZONES

The vertical distribution of conodont species in the study sections is shown in Text-figs. 3-5 in which we also classify the succession in terms of conodont zones. The Lower-Middle Ordovician Baltoscandic

Age	This paper (Yangtze Gorges)		Wang & Bergström 1995 (JCY area)		Lindström 1971 (Europe)	Löfgren 1978,1993 1994,1995 (Sweden)	Bagnoli & Stouge 1997 (Sweden)	Albanesi <i>et al.</i> 1998 (Argentina)
	Conodont zonation	Graptolite zonation	Conodont zonation	Graptolite zonation	Conodont zonation	Conodont zonation	Conodont zonation	Conodont zonation
Darrivilian	<i>Eoplacognathus crassus</i>	? — <i>U. austrodentatus</i>	<i>Amorphognathus variabilis</i>	<i>N. fasciculatus</i>				<i>L. variabilis</i>
	<i>Lenodus variabilis</i>			<i>A. ellesae</i>				
	<i>L. antivariabilis</i>		?	<i>U. austrodentatus</i>	<i>Microzarkodina parva</i>	<i>M. parva</i>	<i>Lenodus antivariabilis</i>	<i>M. parva</i>
	<i>Baltoniodus nortlandicus</i> — <i>Microzarkodina parva</i>						<i>B. nortlandicus</i>	
Yushanian	<i>Paroistodus originalis</i>		<i>Paroistodus originalis</i>	<i>E. clavus</i> <i>I. caduceus imitatus</i>	<i>P. originalis</i>	<i>P. originalis</i>	<i>M. parva</i> <i>B. navis (part)</i>	

Text-fig. 2 - Conodont zones used in the present paper compared with those employed in some other regions.

conodont zone scheme introduced by Lindström (1971) has subsequently undergone only relatively minor modification and refinement (Text-fig. 2). However, because some zones have been given a somewhat different scope by different authors, it is appropriate to briefly comment on the zone definitions used in the present paper.

The Eoplacognathus crassus Zone

This zone was first proposed by Zhang (1996) and has subsequently been used by Bergström & Wang (1998) and Zhang (1998). Its base is taken to be the level of the first appearance of the zone index, *E. crassus*. Other important species include *Lenodus variabilis*, *Baltoniodus norrlandicus*, *B. medius*, *B. prevariabilis*, *Protopanderodus calceatus*, *Paroistodus horridus*, and *Periodon aculeatus* (cf. Zhang, 1998). As indicated in Text-fig. 2, this zone represents an interval that was formerly included in the *Lenodus* (or *Amorphognathus*) *variabilis* Zone.

The Lenodus variabilis Zone

First introduced by Lindström (1971), this zone designation is now used in a more restricted sense and includes only the lower portion of Lindström's (1971) unit. The base is defined as the level of first appearance of *Lenodus variabilis*. Other important species include *Baltoniodus norrlandicus*, *Protopanderodus cooperi*, *P. calceatus*, *Scolopodus rex*, *Periodon aculeatus*, *Drepanoistodus basiovalis*, and *Erraticodon balticus* (cf. Zhang, 1998).

The Lenodus antivariabilis Zone

Following Bagnoli & Stouge (1997), the base of this zone is defined as the level of first appearance of *L. antivariabilis*. The scope of this zone corresponds to the upper part of the *Microzarkodina parva* Zone of Löfgren (1994, 1995). Apart from the zone index, important species include *Baltoniodus norrlandicus*, *Protopanderodus calceatus*, *Scolopodus rex*, *Tripodus? brevibasis*, *Drepanoistodus basiovalis*, and *Microzarkodina parva* (cf. Zhang, 1998).

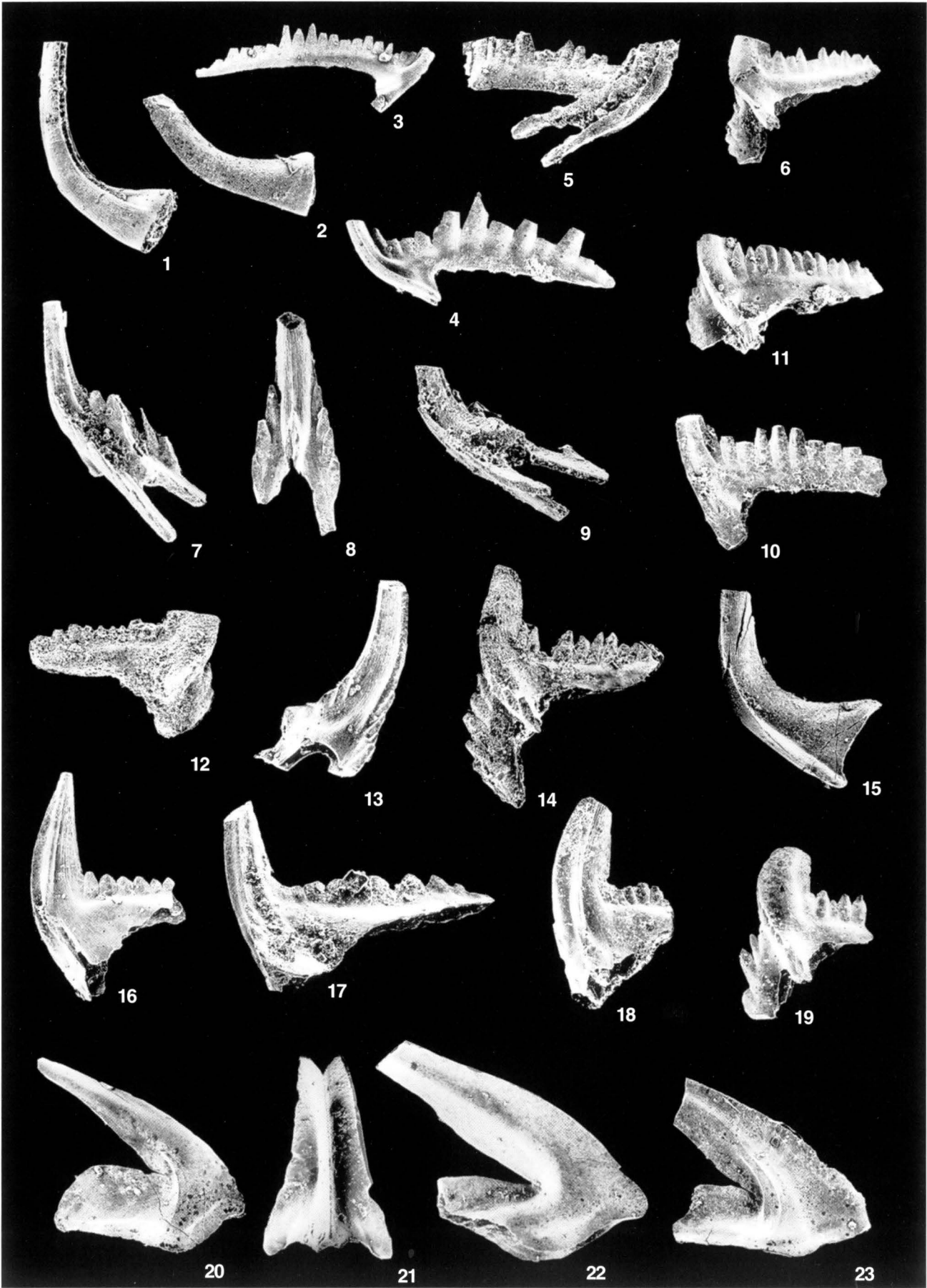
The Baltoniodus norrlandicus - Microzarkodina parva Zone

The base of this zone is taken to be the level of the first occurrence of *B. norrlandicus*, which is the same horizon as the base of the *B. norrlandicus* interval Zone of Bagnoli & Stouge (1997). The scope of this zone corresponds to the lower portion of the *Microzarkodina parva* Zone of Löfgren (1994, 1995) and to the *B. norrlandicus* interval Zone of Bagnoli & Stouge (1997). In the Yangtze Platform sections, the fauna of this zone is relatively diverse and includes, among others, *Paroistodus originalis*, *Oistodus lanceolatus*, *Periodon flabellum*, *Tripodus? brevibasis*, *Protopanderodus calceatus*, *Paroistodus parallelus*, and *Microzarkodina flabellum*.

The Yangtze Platform sequence immediately beneath this zone is referred to the *Paroistodus originalis* Zone. The upper part of this zone is correlated with the upper part of the *Paroistodus originalis* Zone of Löfgren (1994, 1995) and the *Microzarkodina parva* interval Zone of Bagnoli & Stouge (1997).

EXPLANATION OF PLATE 1

- Figs. 1, 2 - *Cornuodus longibasis* (Lindström). Lateral view, AFA 203/130367, x 57, x 50, respectively.
 Figs. 3, 4 - *Microzarkodina flabellum* (Lindström). Lateral view of S elements, AFA215/130368, AFA208/130369, x 50, x 60, respectively.
 Figs. 5-11, 14 - *Baltoniodus norrlandicus* (Löfgren).
 5) Lateral view of Sb element, AFA189/130370, x 80.
 6) Lateral view of Pb element, AFA210/130371, x 50.
 7) Postero-lateral view of Sa element, AFA213/130372, x 60.
 8) Posterior view of Sa element, AFA213/130373, x 80.
 9) Postero-lateral view of Sd element, AFA189/130374, x 100.
 10) Lateral view of Sc element, AFA213/130375, x 80.
 11) Lateral view of Pb element, AFA213/130376, x 60.
 14) Lateral view of Pa element, AFA189/130379, x 80.
 Fig. 15 - *Tripodus? brevibasis* (Sergeeva). Lateral view, AFA203/130380, x 80.
 Figs. 12, 13, 16-19 - *Baltoniodus navis* (Lindström).
 12) Lateral view of Pa element, AFA4/130377, x 80.
 13) Postero-lateral view of Sc element, AFA1/130378, x 100.
 16-19) Lateral views of P elements, AFA210/130381, AFA204/130382, AFA1/130383, AFA3/130384, x 80, x 80, x 60, x 80, respectively.
 Figs. 20-22 - *Oistodus lanceolatus* Pander.
 20) Lateral view of P element, AFA201/130385, x 50.
 21) Posterior view of Sa element, AFA200/130386, x 60.
 22) Lateral view of M element, AFA200/130387, x 50.
 Fig. 23 - *Oistodus meseaus* An. Lateral view of P element, AFA201/130388, x 67.



CONODONT ZONES IN THE STUDY SECTIONS

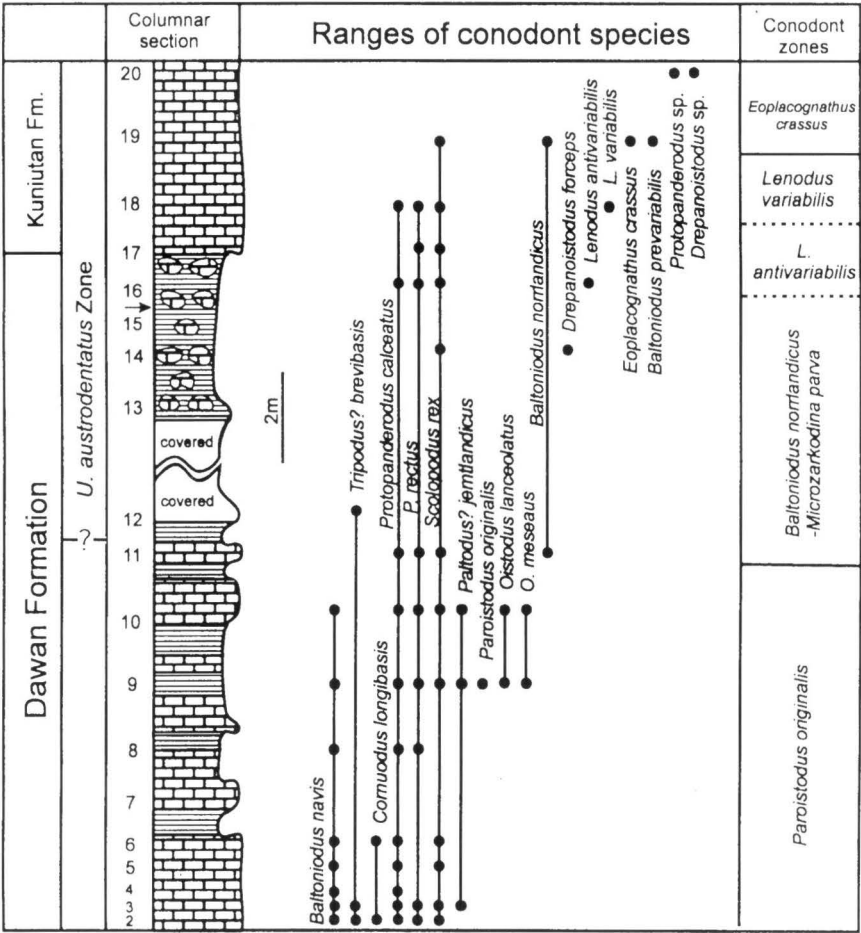
The Huanghuachang section

Specimens of *Baltoniodus norrlandicus* appear in Sample 11 (Text-fig. 3), which is located about 7 m below the top of the Dawan Formation and this level is taken as the base of the *Baltoniodus norrlandicus*-*Microzarkodina parva* Zone. This zone is overlain by a thin development of the *Lenodus antivariabilis* Zone that extends into the lowermost meter of the Kuniutan Formation. Unfortunately, the conodont faunal diversity is low in the shaly interval with the *Undulograptus austrodentatus* Zone graptolite fauna, and a substantial portion of that interval is not available for study any more, being covered by a building. However, based on a comparison with the section at Chenjiahe (Daping) described by Lindström, Chen & Zhang (1991), which is located only 4 km north of

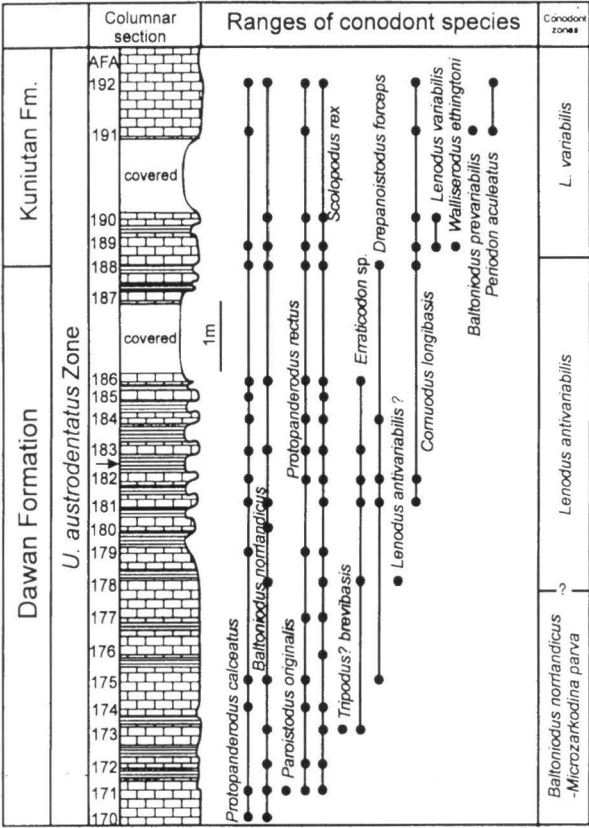
Huanghuachang, the appearance of this graptolite fauna is taken to be at about 7 m below the top of the Dawan Formation, hence nearly the same level as the base of the *Baltoniodus norrlandicus*-*Microzarkodina parva* Zone.

The Chenjiahe (Daping) section

The lowermost part of the investigated succession is referred to the *Baltoniodus norrlandicus* - *Microzarkodina parva* Zone that probably extends below the sampled interval. The interval with *U. austrodentatus*, the base of which is about 7 m below the top of the Dawan Formation according to Lindström, Chen & Zhang (1991), is virtually barren of platform index conodonts. If a fragmentary and specifically indeterminate platform specimen found at about 4.7 m below the top of the Dawan Formation represents *Lenodus antivariabilis*, this would indicate



Text-fig. 3 - Vertical ranges of conodont species and conodont zones in the Huanghuachang section. The interval of the principal occurrence of the *Undulograptus austrodentatus* Zone graptolites is indicated by an arrow. The level of the base of this graptolite zone is currently poorly constrained but appears to be close to the base of the *Baltoniodus norrlandicus* - *Microzarkodina parva* Zone.

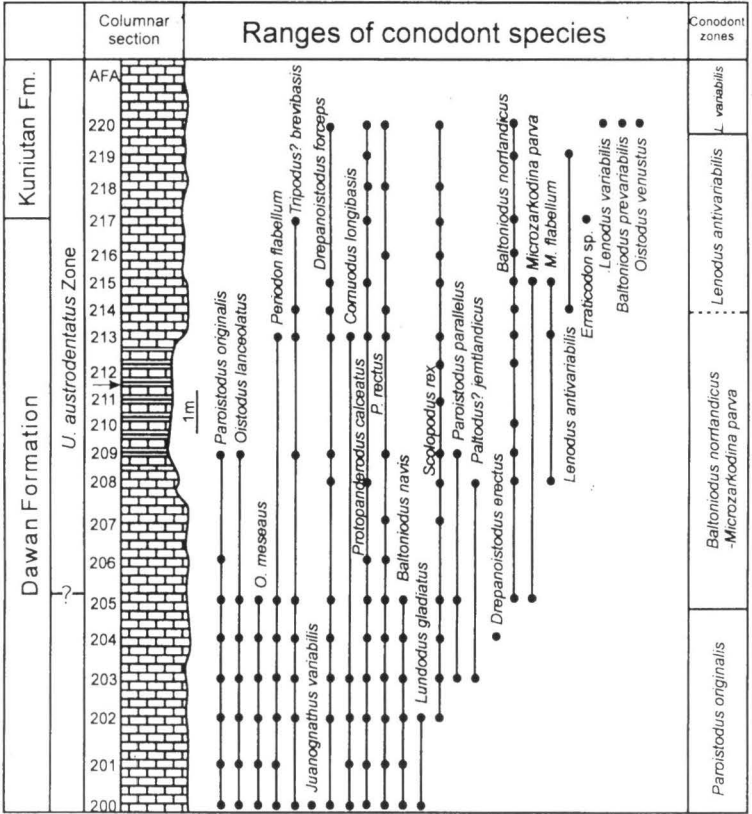


Text-fig. 4 - Vertical distribution of conodont species and conodont zones in the Chenjiahe (Daping) section. The interval of the principal occurrence of *Undulograptus austrodentatus* Zone graptolites is indicated by an arrow.

the *L. antivariabilis* Zone (Text-fig. 4). Based on specimens identified as *Lenodus variabilis*, the base of the *Lenodus variabilis* Zone is located in the lowermost part of the Kuniutan Formation. The thickness of the latter zone appears to be greater than in the Huanghuachang section a few km away. The stratigraphic position of this zone in relation to the Dawan/Kuniutan Formation boundary is slightly different than at the nearby Huanghuachang section, suggesting that this formation boundary is diachronous. This is in agreement with Zhang (1998) who showed that the top of the Dawan Formation is diachronous regionally.

The Jianyangping section

The conodont succession in this section (Text-fig. 5), which is located about 50 km northwest of Huanghuachang, is similar to that of the Huanghuachang section in that the *Baltoniodus norlandicus* - *Microzarkodina parva* Zone in the upper member of the Dawan Formation is about 6 m thick, and in that the *Lenodus antivariabilis* Zone, which is about four times as thick as at Huanghuachang, straddles the base of the Kuniutan Formation. *Baltoniodus norlandicus* first appears in Sample 205 from about 9 m below the top of the Dawan Formation, and this is provisionally taken as the base of the



Text-fig. 5 - Vertical distribution of conodont species and conodont zones in the Jianyangping section. The interval of the principal occurrence of *Undulograptus austrodentatus* Zone graptolites is indicated by an arrow. The level of the base of the *Undulograptus austrodentatus* Zone is poorly constrained by graptolite evidence in this section.

Baltoniodus norrlandicus - *Microzarkodina parva* Zone. Specimens of *Lenodus antivariabilis* were found in Sample 214 from about 2 m below the top of the Dawan Formation and this level is taken as the base of the *Lenodus antivariabilis* Zone that extends about 2 m into the overlying Kuniutan Formation. This is in close agreement with the vertical range of the latter zone in the Fenxiang section (Zhang, 1998, Text-fig. 14), which is located about 7 km north-east of the Huanghuachang section.

In Text-fig. 6 we summarize our conodont biostratigraphic classification of the Yangtze Platform sections and compare it with some previous classifications.

CONODONT - GRAPTOLITE ZONE RELATIONS

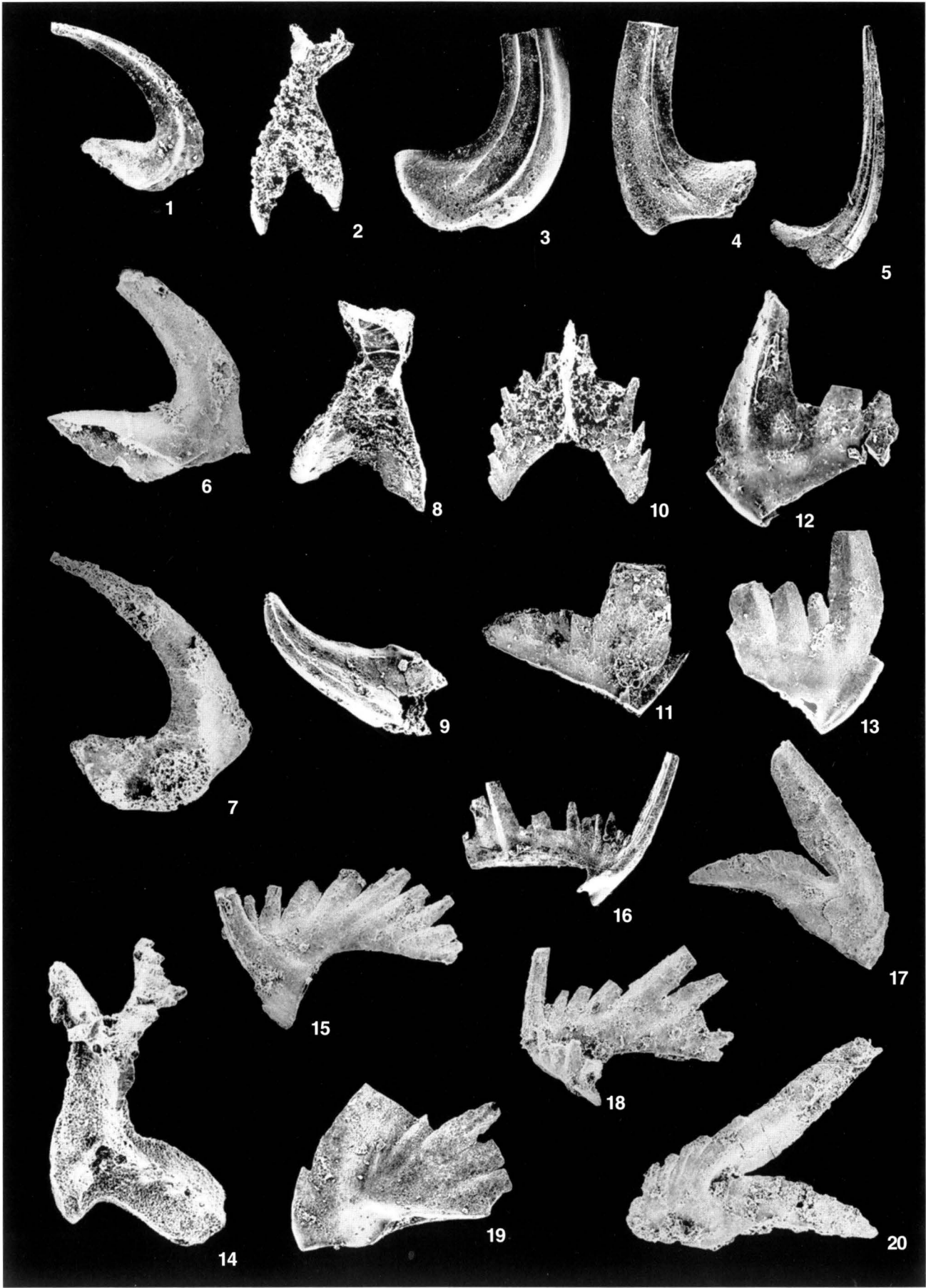
THE YANGTZE PLATFORM

The occurrence of biostratigraphically diagnostic graptolites is restricted to narrow, rather widely spaced, stratigraphic intervals in the upper member of the Dawan Formation which makes the establishment of the precise level of the base of the *Undulograptus austrodentatus* Zone, that is, the base of the Darriwilian Stage, a challenging, if not impossible, task. A low-diversity graptolite fauna, which includes *Undulograptus austrodentatus*, has long been known to occur in the upper member of Dawan Formation (see, e.g. Mu *et al.*, 1979). According to Chen, Zhang & Mitchell (1995; oral communication, 1998) this fauna represents a high level in the *Undulograptus*

austrodentatus Zone, presumably the *Undulograptus sinicus* Subzone of Chen *et al.* (1995). This graptolite fauna occurs in different sections at somewhat different levels in the uppermost few m of the formation. Another graptolite species association, which includes *Undulograptus sinodentatus*, *Exigraptus clavus*, *Tetragraptus* (*T.*) *bigsbyi*, and *T. (T.) reclinatus*, is present in stratigraphically lower strata in the upper member of the Dawan Formation (Wang *et al.*, 1987; Chen, Zhang & Mitchell, 1995; Lindström, Chen & Zhang, 1991). Its zonal assignment is somewhat uncertain but it represents either the lowermost part of the *Undulograptus austrodentatus* Zone or, more likely, the *Exigraptus clavus* Zone. Chen, Zhang & Mitchell (1995, text-fig. 22) referred this fauna to the *Undulograptus sinodentatus* Zone and correlated this zone with the *E. clavus* Zone of the JCY area. The stratigraphic occurrences of this fauna in relation to the top of the Dawan Formation vary a great deal; hence Lindström, Chen & Zhang (1991) recorded it from about 7 m below the top of the formation at Chenjiahe (Daping) whereas Wang *et al.* (1987) and Chen, Zhang & Mitchell (1995) reported it from 27 m below the same level at Huanghuachang. Doubtless, the sporadic occurrences of these graptolite faunas were controlled by local environmental conditions. The base of the *Undulograptus austrodentatus* Zone most likely corresponds to a level between the intervals of these two graptolite faunas, and it is herein somewhat arbitrarily taken to be at 7.5 m below the top of the Dawan Formation at Huanghuachang (Text-fig. 3) based on comparison with the nearby Chenjiahe (Daping) section described by Lindström, Chen & Zhang (1991). If this is approximately correct, the base

EXPLANATION OF PLATE 2

- Fig. 1 - *Paroistodus parallelus* (Pander). Lateral view of drepanodontiform element, AFA201/130389, x 80.
 Fig. 2 - *Lenodus variabilis* (Sergeeva). Upper view of P element, AFA189/130390, x 60.
 Figs. 3, 5 - *Protopanderodus calceatus* Bagnoli & Stouge. Lateral views, AFA203/130391, AFA203/130392, x 80, x 50, respectively.
 Fig. 4 - *Protopanderodus rectus* (Lindström). Lateral view, AFA189/130393, x 100.
 Figs. 6, 7 - *Paroistodus originalis* (Sergeeva). Lateral views of drepanodontiform elements, AEP210/130394, AEP210/130395, x 120 (From the Ningkuo Formation, Huangnitang section, JCY area; for sample location, see Wang & Bergström, 1995, text-fig. 35.)
 Figs. 8, 9 - *Lenodus antivariabilis* (An).
 8) Upper view of P element, AFA178/130396, x 80.
 9) Lateral view of S element, AFA213/130397, x 80.
 Figs. 10-13 - *Microzarkodina parva* Lindström.
 10) Posterior view of Sa element, AFA205/130398, x 100.
 11-13) Lateral views of P elements, AFA205/130399-130401, x 120, x 120, x 100, respectively.
 Fig. 14 - *Eoplacognathus crassus* Chen & Zhang. Upper view of P element, AEP250/130402, x 120 (From the Hulo Formation, Huangnitang section, JCY area; for sample location, see Wang & Bergström, 1995, Text-fig. 35).
 Figs. 15-19 - *Periodon flabellum* (Lindström).
 15, 18) Lateral views of S elements, AEP151A1/130403, AEP156A/130405, both x 100 (From the Chenjiawu and Huangnitang sections, for sample location, see Zhang & Winston, 1995, text-figs. 16, 13).
 17) Lateral view of M element, AEP156A1/130407, x 120 (same JCY area section as Figs. 15 and 18).
 16, 19) Lateral views of Sc and P elements, AFA213/130404 and AFA200/406, x 50 and x 80, respectively.
 Fig. 20 - *Periodon aculeatus* Hadding. Lateral view of M element, AEP4-3/130408, x 80 (From the JCY area, for sample location, see Zhang & Winston, 1995, text-fig. 11).



An <i>et al.</i> , 1981		An, 1987	Wang & Bergström, 1995 Bergström & Wang, 1998	Zhang, 1998	This paper
Kuniutan Formation (part)	<i>Amorphognathus variabilis</i>	<i>A. variabilis</i>	<i>E. crassus</i>	<i>Y. crassus</i>	<i>E. crassus</i>
	– <i>A. antivariabilis</i>	<i>A. antivariabilis</i>	<i>A. variabilis</i>	<i>L. variabilis</i>	<i>L. variabilis</i>
			-----	<i>L. antivariabilis</i>	<i>L. antivariabilis</i>
Dawan Formation (part)	unnamed zone	<i>Baltoniodus aff.navis</i>	<i>Microzarkodina parva</i>		<i>B. norrlandicus</i> – <i>M. parva</i>
	<i>Paroistodus originalis</i>	<i>P. originalis</i>	<i>P. originalis</i>		<i>P. originalis</i>

Text-fig. 6 - Comparison between some conodont zone classifications of the upper Dawan Formation and lower Kuniutan Formation in the Yichang region of the Yangtze Platform. The base of the Darriwilian appears to correspond with a level in the lowermost *Baltoniodus norrlandicus* - *Microzarkodina parva* Zone.

of the *Undulograptus austrodentatus* Zone at Huanghuachang would be near the base of the *Baltoniodus norrlandicus*-*Microzarkodina parva* Zone. The corresponding level in the Chenjiahe (Daping) section (Text-fig. 4) would be about 1 m above the base of the sampled section, and most of the portion of the Dawan Formation having *Undulograptus austrodentatus* would represent the *Lenodus antivariabilis* Zone. In the Jianyangping section (Text-fig. 5) the base of the *Undulograptus austrodentatus* Zone, and the base of the Darriwilian Stage, is tentatively taken to be at about 6-7 m below the top of the Dawan Formation and near the base of the *Baltoniodus norrlandicus*-*Microzarkodina parva* Zone.

COMPARISON WITH THE JCY AREA

The ratified global stratotype of the base of the Darriwilian Stage is in the Huangnitang section in the JCY area where 'the golden spike' is at the the base of Bed AEP 184 of the Ningkuo Formation (Mitchell *et al.*, 1997, Text-fig. 5). This level does not coincide with any marked change in the conodont fauna, which is of low diversity in the boundary interval (Wang & Bergström, 1995, Text-fig. 35). The absence of biostratigraphically diagnostic taxa makes it difficult to classify the *Undulograptus austrodentatus* Zone in terms of conodont zones in the JCY area but based on the admittedly incomplete data at hand, Wang &

Bergström (1995) suggested that the base of the latter graptolite zone is very close to the base of the *Microzarkodina parva* (now *Baltoniodus norrlandicus*-*Microzarkodina parva*) Zone. Although we have no additional data from the JCY area, the new information from the Yangtze Platform gained during the course of the present study appears to be consistent with this correlation.

CONCLUDING REMARKS

It is obviously important that global stage and series boundaries are defined in such a way that they can be identified with confidence in a variety of facies using more than one fossil group. The base of the Darriwilian Stage is fundamentally defined on graptolites but compared to other fossil groups, conodonts appear to offer the best prospects to serve as secondary index fossils to locate this level, especially in the dominantly calcareous successions on many continental platforms in which zonal graptolites are rare or absent. The present study supports the idea that this level is in the lowermost part of the *Baltoniodus norrlandicus* - *Microzarkodina parva* Zone of the Atlantic conodont zone scheme. Furthermore, Bergström & Wang (1995) showed that this level is likely to be close to the base of the *Histiodella sinuosa* Zone of the North American Midcontinent conodont zone scheme (Sweet, 1984). Hence, it is possible to recognize the approximate

position of this important horizon using conodonts in several key regions in both Europe, Asia, and North America. Furthermore, recent work on the conodonts in the San Juan Limestone in the Precordillera of Argentina (Lehnert, 1995; Albanesi, Hünicken & Barnes, 1998) suggests that the base of the Darriwilian, although not yet located precisely, is in the upper portion of that formation.

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