Contents

Episodes

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Cover

Panoramic view of the Zumaya section, Spain. The lithology consists of purple marls at the upper Maastrichtian on the right, dark grey clays at the K/Pg boundary and red marly limestones at the Danian on the left. The section is very well known because of its superb exposure along the cliff just north of the Zumaya village. It was considered a suitable candidate to define the K/Pg boundary and in the vote process resulted second in position after the El Kef section (for details: see article by Molina et al. in this volume).

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The Global Stratotype Section and Point for the base of the Middle Ordovician Series and the Third Stage (Dapingian)

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The Huanghuachang section near Yichang, southern China was successively approved by ISOS, recognized by ICS and then officially ratified as being the Global Stratotype Section and point (GSSP) for the base of the Middle Ordovician Series and the Third Stage, named as Dapingian, of the Ordovician System. The conodont succession at the section is complete across the Lower to Middle Ordovician series boundary and several excellent phylogenetic lineages of Baltoniodus, Gothodus, Microzarkodina *and* Periodon *are represented. The base of the Middle Ordovician Series and the Daping Stage is defined at a point 10.57 m above the base of the Dawan Formation at the base of Bed SHod-16 of the Huanghuachang section, 22km NE of Yichang City, Hubei Province, South China. It coincides with the first appearance datum (FAD) of the conodont species* Baltoniodus triangularis *within the* Baltoniodus *lineage starting from* Baltoniodus *cf.* B. triangularis *to* Baltoniodus navis. *It is associated with the FAD of* Periodon *sp. A and followed closely by the FAD of* Microzarkodina flabellum, *which is taken as a reasonable proxy for the boundary. This level approximates the boundary between the lower and upper* Azygograptus suecicus *graptolite Biozone, and nearly coincides with the base of the* Belonechitina *cf.* henryi *chitinozoan Biozone. The same faunal succession is also recorded from the Chenjiahe section, near Daping village, 5 km to the north of the Huanghuachang section.*

The proposed boundary level, which has long been used in other important Ordovician successions worldwide, can be easily recognized and correlated globally with high precision in both relatively shallow-water carbonate facies as well as in deep-water graptolite facies. Its geographic coordinates are: latitude 30°51'37.8"N; Longitude 110°22'26.5" E of Greenwich.

Introduction

Since 1989, the Subcommission on Ordovician Stratigraphy (ISOS) of the International Commission on Stratigraphy (ICS) has been involved in an extensive project with the goal of establishing globally applicable stage and series subdivisions for the Ordovician System (Webby, 1994). The goal is now completed with the ratification of the last Global Stratotype Sections and Points (GSSPs) of the Ordovician System for the base of the Middle Ordovician Series and the Third Stag named Dapingian at the Huanghuachang section. The new Ordovician time-scale is composed of Lower, Middle and Upper Ordovician Series and seven stages – Tremadocian, Floian, Dapingian, Darriwilian, Sandbian, Katian and Hirnantian (Fig. 1).

The GSSPs for the base of the Middle Ordovician and the Third Stage of the Ordovician System have been sought and discussed for more than 12 years (Webby, 1994, 1995). In the early 90s of last century two biozone levels that appeared to have potential for reliable global correlation were proposed as definitions of the base of the Middle Ordovician Series and the Third Stage: (1) the base of the *Tripodus leavis* conodont Biozone, considered correlative with the base of the *Isograptus v. lunatus* graptolite Biozone, and (2) the base of the *Baltoniodus triangularis* conodont Biozone. The former was thought to coincide with the base of the North American Whiterock Series (Ross and Ethington, 1992; Ross et al., 1997), and the base of *B. triangularis* Biozone with the base of the Baltoscandian Volkhov Stage (Webby, 1994, 1995). After long discussions and a set of ballots and questionnaire circulated to the Voting Membership a formal Ordovician Subcommission postal ballot was held during October—December 1995 together with the ballot on the tripartite division of the Ordovician. The base of *T. laevis* Biozone was finally adopted by majority (82%) of voting members and then approved by the ISOS as the biohorizon on which to define the base of the Middle Ordovician Series (Webby, 1997, 1998). Afterwards, the Whiterock Narrows section in the Monitor Range, Nevada was recommended as the

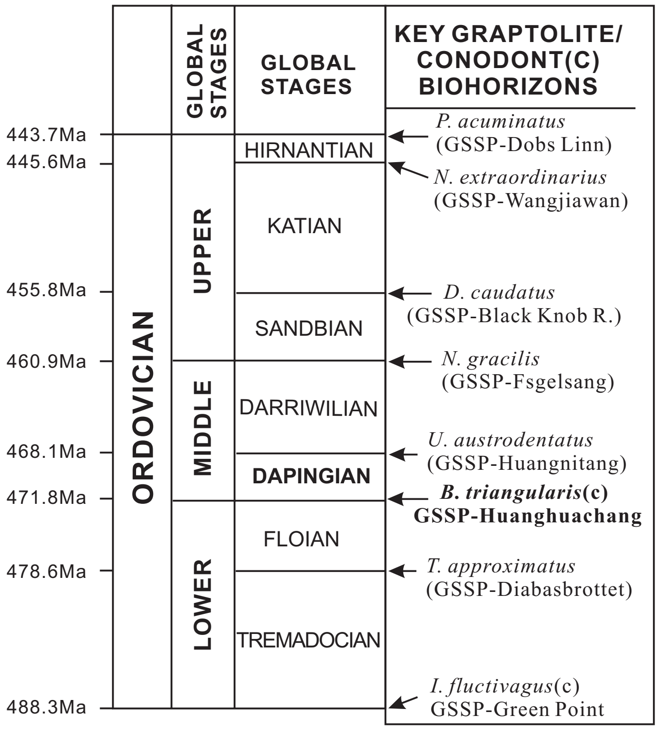

Figure 1. Ordovician choronostratigraphic chart showing global Series and Stages with their GSSPs (modified from Finney, 2005).

stratotype section for the base of the global Middle Ordovician Series with the boundary placed 3 m below the top of the Ninemile Formation at the FAD of *Tripodus laevis* (Finney and Ethington, 2000, 2001). With further study, however, the proposed boundary in the Whiterock Narrows section was shown to correlate with a higher level in the graptolite zonation than expected (Mitchell, 2001), which suggested also that the first appearance of *T. laevis* was diachronous. A subsequent search for potential stratotype sections in western Newfoundland, where the graptolites *Isograptus v. lunatus* and *I. (v.) victoriae* occur with conodonts was unsuccessful. Thus, the Subcommission was forced to consider alternative biohorizons. Albanesi and Carrera (2001, 2003) proposed the Niquivil section, Argentina as the global stratotype for the base of the Middle Ordovician with the FAD of the conodont *Protoprioniodus aranda* (= *Cooperignathus aranda* sensu Zhen et al., 2003) as an alternative index species for the boundary level, and Wang et al. (2002, 2003a) recommended the Huanghuachang section, China with the FAD of the conodont *Baltoniodus triangularis* as the boundary bio-marker.

The two GSSP proposals (Wang et al., 2004, 2005; Albanesi et al., 2006), were discussed and debated at length on the Ordovician Subcommission website. A postal ballot completed in October 2006, 75% of the votes favored the Huanghuachang proposal over the Niquivil proposal, and 94% of the voting members then approved the Huanghuachang GSSP in a ballot completed in December 2006. And then the International Subcommission of Ordovician System (November, 2006) and International Commission on Stratigraphy (ICS) of the IUGS (April, 2007) recognized and the International Union of Geological Sciences (IUGS) (March, 2009) officially ratified the Huanghuachang section, as being the global boundary stratotype and point (GSSP) for the base of Middle Ordovician Series and Third stage, named as the Dapingian Stage (Wang et al., 2007). The principal reasons for the positive votes are as follows: (1) The proposed level with the FAD of *Baltoniodus triangularis* at the Huanghuachang section is a speciation event, where the marker species evolved from its immediate ancestor, *B.* cf. *B. triangularis* and the horizon nearly coincides or is close to speciation events within several other conodont lineages – those of *Gothodus*, *Microzarkodina, Periodon* and *Paroistodus*. The level with FAD of *C. aranda* at the Niquivil section is not controlled by a speciation event in this section, and it is possible that the first appearance in the Niquivil section is not the true FAD of this species (Bergström, 2006). (2) The presence of graptolite and chitinozoan zones gives the Huanghuachang section significantly higher potential for global correlation. The associated graptolite fauna indicates that the base of the *B. triangularis* Biozone is very close to, if not coeval with, the base of the *Isograptus v. victoriae* Graptolite Zone (Maletz 2005). Graptolites have not been found at the Niquivil section, probably because of deposition in too shallow water or low preservation potential. (3) The level with the FAD of *Baltoniodus triangularis* correlates with major stratigraphic boundaries elsewhere, and the taxon has been used in other important Ordovician successions worldwide for a long time, e.g., the horizon lies at or very close to the base of the Whiterock Series in North America and the Volkhov Stage in Baltoscandia (Bergström, 1995; Finney, 2006). In contrast, the lower boundary of the Middle Ordovician Series, if it is defined on the basis of the level with the first occurrence of *C. aranda* in the Niquivil section, cannot be correlated with any precision into graptolite successions of either the Atlantic or Pacific province.

The Huanghuachang GSSP has excellent and well-known conodont, chitinozoan, graptolite, acritarch and shelly fossil records in a stratigraphically continuous succession (Figs. 2, 3). The Lower and Middle Ordovician boundary coinciding by the FAD of *B. triangularis* and followed by the FAD of *Microzarkodina flabellum* can be easily recognized and correlated globally with high precision in both relatively shallow-water carbonate facies as well as in deep-water graptolite facies.

Geographical location, access and geologic setting

The Huanghuachang GSSP is located along the major road from Yichang City to Xinshan County, 22 km NE of Yichang City, Hubei Province, China (Figs. 2, 3), and it can easily be accessed by car. The section is well exposed at the center of the Ordovician Geopark, which is part of the National Geopark of the Yangtze Gorges. Yichang City is the largest hydroelectric city and one of the most well-known tourist cities in China. It can be reached by major highway, train, and regular direct flights from Beijing, Shanghai, Guangzhou, Shenzhen and Hong Kong.

Geographically this area lies on the east limb of the Huangling Arch, and geologically belongs to the north-central Yangtze carbonate platform. The Ordovician rocks, together with the underlying Cambrian and overlying Silurian deposits, are widely distributed around the Huangling Arch (Fig.2). The Huanghuachang section is structurally undeformed and the strata dip at 11^{o} to the east. The Ordovician section at Huanghuachang and the GSSP for the Hirnantian Stage with the Ordovician-Silurian boundary section at Wangjiawan, 22 km NE of the Huanghuachang, are attracting attention to stratigraphic subdivision and correlation on a worldwide scale.

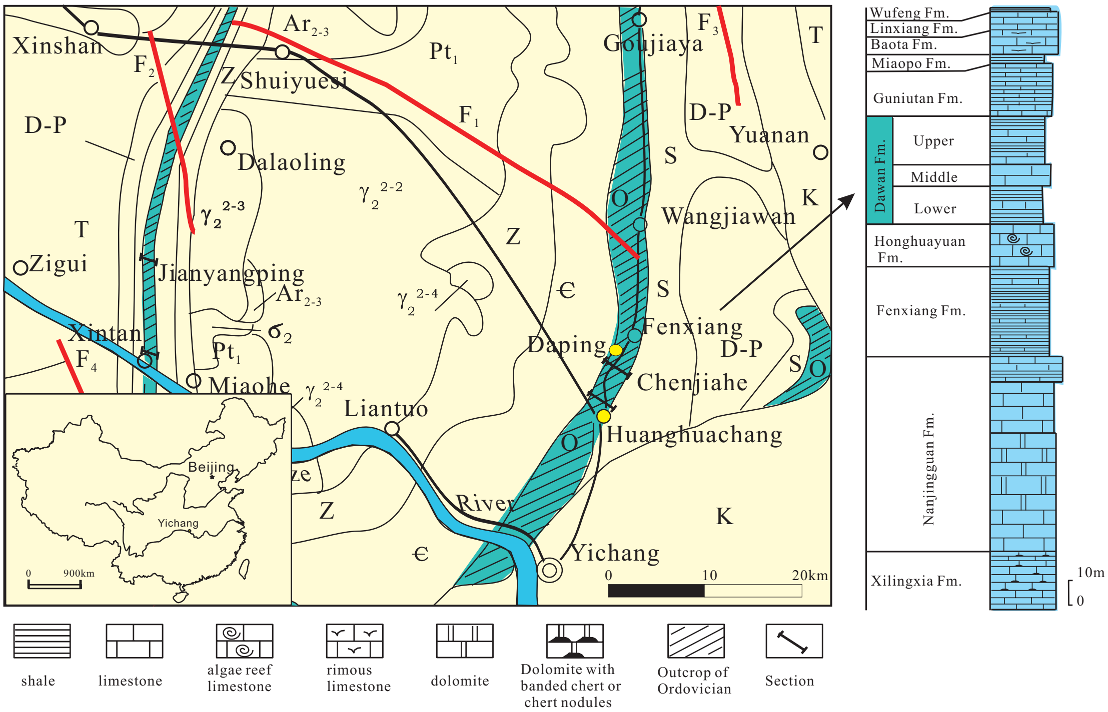

Figure 2. Geological map of the Yichang Area, Hubei, China. The localities of the Huanghuachang and adjacent Chenjiahe sections, and the Ordovician succession of this area are shown.

Description of the Huanghuachang section

The Huanghuachang section has been studied in great detail and for almost 50 years (Zhang et al., 1957; Mu et al., 1979; Wang, 1980; Zeng et al., 1983; Wang et al., 1987, 1992a, b, 1995; An, 1987; Chen et al., 1995, 2003). It is in the type area for the subdivision of the Ordovician System in China, and it can be correlated confidently with other sections in the region. The section is characterized by a continuous series of strata across the Lower/Middle Ordovician boundary. The succession is mainly composed of carbonate rocks intercalated with some clastic sedimentary rocks bearing limestone lenses and yielding various fossils (Zeng et al., 1983; Wang et al., 1987). Many Ordovician specialists from China and abroad have visited the section since 1978 (Fig.4).

Figure 3. The Huanghuachang GSSP showing the monument of the GSSP on the left side, the model of Baltoniodus triangularis on the right side and the Lower and Middle Ordovician boundary, i.e the base of the Dapingian, defined by the FAD of B. triangulates at the base of Shod-16 and indicated by a red line with a small memorial table, 0.6 m above the characterietic grayish purple medium limestone of 0.9 m , or 10.57 m above the base of the Dawan Formation

The Ordovician stratigraphic succession of the Yangtze Gorges area is subdivided into 10 formations shown in Fig.2. The Huanghuachang section with the Lower/Middle Ordovician boundary interval begins in the Honghuayuan Formation, which is a highstand deposit composed of thick-bedded limestone with *Archaeocyphia* and *Calathium*. Conodonts of the *Serratognathus diversus* Biozone and the *Oepikodus communis* Biozone separately occur in the lower-middle parts and the uppermost part (Fig. 5). The *Oepikodus communis* Biozone ranges into the overlying Dawan Formation.

Lithostratigraphic subdivision of Dawan Formation

The Dawan Formation was defined by Zhang (1962) on the basis of the Dawan Bed (Zhang et al., 1957) and the *Yangtzeella* Bed established by Lee (1924). Zeng et al. (1983) subdivided the Dawan Formation at the Huanghuachang section into three lithological units: the Lower Member, the Middle Member and the Upper Member i.e.

Figure 4. More than 80 Ordovician and Silurian workers participated in the post-excursion of the 10th International Ordovician, 3rd Silurian and IGCP Project 508 Conference held in Nanjing in July 6, 2007, and visited the Huanghuachang section.

the Lower, Middle and Upper Dawan Formation, or Lower, Middle and Upper Units (Figs. 2, 5) (Wang et al., 1987, 1995, 2005).

The Lower Member is 12.97 m thick. It consists of gray, thin-bedded and minor medium-bedded limestone, bioclastic limestone and glauconitic limestone with yellow-green shale interbeds (Fig.5). The strata yield abundant conodonts with graptolites, chitinozoans, acritarchs, brachiopods, trilobites and cepholopods, representing a mixed biota of cool-water with warm-water biota (Wang, 1980; Wang and Chen, 1999). Three conodont biozones, the *Oepikodus communis* Biozone, *Oepikodus evae* Biozone (*sensu* Lindström, 1971, Bergström, 1995) and *Baltoniodus triangularis* Biozone, can be recognized in the Member (Wang et al., 2005). The GSSP is located in the upper part of the Lower Member.

The Middle Member of the Dawan Formation is 13 m thick. It is composed of purple medium-bedded micrite with yellow-green mudstone and shale interbeds. The strata yield abundant cephalopods of the *Protocycloceras* Biozone and brachiopods including *Yangtzeella poloi*. Recent studies show that the conodonts are characterisic for the *Baltoniodus navis* Biozone in the middle–upper parts and upper *Baltoniodus triangularis* Biozone in the lower part (Wang *et al.*, 2005).

The Upper Member of the Dawan Formation of 28 m thick, it consists of yellow-green shale intercalated with thin-bedded nodular limestone and mudstone at Huanghuachang section. The Upper Member correlates with the upper part of the Third Stage and the lower Darriwilian Stage based on the occurrence of graptolites of the *Undulograptus sinodentatus* Biozone at the base and representatives of the *U. austrodentatus* Biozone at the top, together with trilobites of the *Hanchugolithus* Biozone, brachiopods of the *Euorthisina* Biozone and conodonts of the *Baltoniodus norrlandicus* and *Lenodus antivariabilis* Biozones (An 1987; Wang et al., 1987; Stouge, *in prep*, Chen et al., 2003).

Detailed description of the succession across the proposed boundary horizon

The Lower Member and the lower part of the Middle Member of the Dawan Formation, composing most of the Huanghuachang section, have been described by Wang et al. (2005). The symbols Hod and SHod, used in the text, and figures, refer to beds or thin stratigraphic intervals sampled for fossils. If the sampling interval (Hod or SHod) possesses similar or identical lithological rock characters with a slightly bigger thickness it is subdivided into several secondary sampling intervals (i.e. SHod-17A, SHod-17B…) as shown in the section description (Figs. 3,5).

The Lower Member is subdivided informally into lower, middle, and upper parts (Wang et al., 2005), which are terms used in the following description and shown on the figures. The lower part of 5.45 m (Hod-29–Hod-4) comprises gray thick-bedded glauconitic limestone, 0.93 m thick (Hod-29–Hod-27), overlain by thin-bedded glauconitic limestone and nodular limestone with yellow green shale interbeds. The middle 5.52 m of the Lower Member (Hod-3–SHod-11) is composed of gray thin-bedded limestone and bioclastic limestone with yellow-green shale interbeds overlain by 0.9 m of the light purple-gray medium-bedded dolomitic micritic limestone at its top (SHod–9-11). The upper part of the Lower Member, which includes the GSSP, is 3m thick and composed of light purple thin-bedded nodular limestone and medium-bedded limestone interbedded with yellow-green shale with limestone lenses (SHod-12–24).

The proposed boundary biohorizon of the Middle Ordovician Series, i.e. defined by the FAD of *Baltoniodus triangularis*, and its under- and over-lying beds are described in detail as follows in descending order:

Lower Member of Dawan Formation (or Lower Dawan Formation): 12.97m

Upper part: 3m

SHod-24–22 Grayish-green shale with nodular limestone 0.80 m

SHod-24 (0.4 m) - conodonts: *Drepanoistodus forceps*, *Scolopodus princeps*, *Baltoniodus triangularis*, *Periodon* sp.A, *Microzarkodina flabellum*, *Paroistodus* cf. *proteus*; trilobites: *Rhombampyx yii* and brachiopods: *Pseudoporambonites yichangensis*, *Euorthisina orthiformis*, *E. kobayashii, Leptella grandis*, *Sinorthis typical*, *Nereidella sinuate* and *Yangtzeella yichangensis*.

SHod-23 (0.2 m) - conodonts: *Baltoniodus triangularis*, *Microzarkodina flabellum*, *Periodon* sp. A, *Protopanderodus flouridus*, *Drepanoistodus forceps*, *Scolopodus princeps*, *Oistodus lanceolatus*, *Gothodus* cf. *costulatus*; graptolites: *Expansograptus* cf. *suecicus*, *Phyllograptus* sp., *Tetragraptus reclinatus reclinatus*; chitinozoans: *Belonechitina* cf. *henryi*, *Conochitina decipiens, C.* cf. *parvulgata*, *C.* sp. aff. *langei*; trilobites: *Carolinites genacinaca*, *Rhombampyx yii*, *Liomegalaspides similis*, *Agerina elongata*, *Ningkianolithus* sp. and brachiopods: same as in SHod-24.

SHod-22 (A, B) (0.2 m): conodonts: *Baltoniodus triangularis*, *Microzarkodina flabellum*, *Periodon* sp. A, *Drepanoistodus*

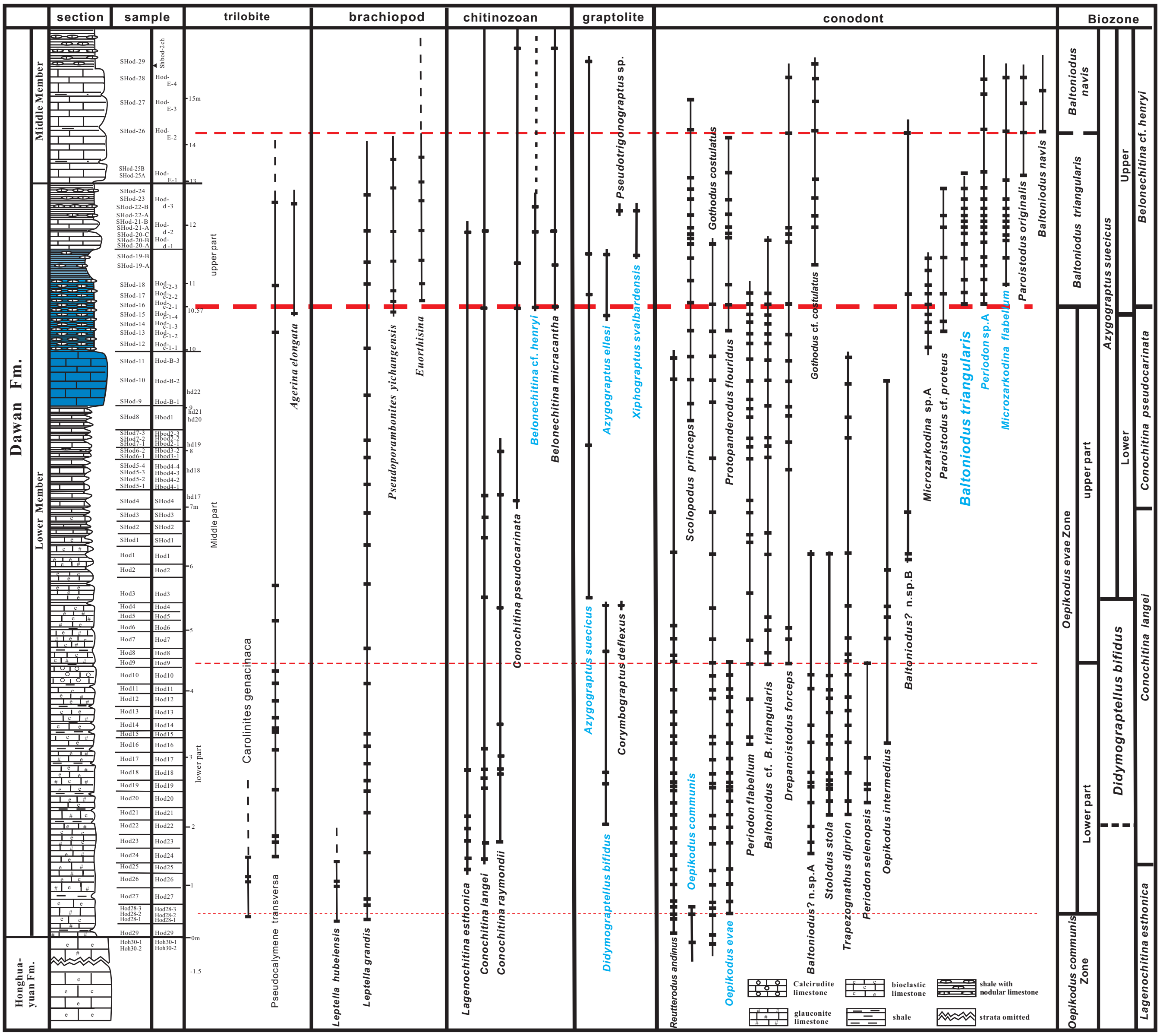

Figure 5. Stratigraphical ranges of principal conodonts, graptolites, chitinozoans, brachiopods, trilobites through the Lower Dawan Formation at the Huanghuachang section.

forceps, *Scolopodus princeps*, *Paroistodus* cf. *proteus, Oistodus lanceolatus*, *Protopanderodus flouridus*, *Gothodus* cf. *costulatus*; graptolites: *Xiphograptus svalbardensis*, *Pseudotrigonograptus* sp.; trilobites: *Phorocephala genalata*, *Ningkianolithus* sp., *Liomegalaspides similes*, *Geragnostus* sp., *Agerina elongata* and brachiopods: *Pseudoporambonites yichangensis*, *Euorthisina orthiformis*, *E. kobayashii*.

SHod-21–20 Gray medium-bedded limestone with grayish-green shale interbeds, dominated by conodonts brachiopods in limestone (SHod-21A-E -SHod-20A-C) and a few graptolites, chitinozoans and trilobites in shale 0.60 m

SHod-21 (A–B) (0.23 m) - conodonts: *Baltoniodus triangularis*, *Microzarkodina flabellum*, *Periodon* sp. A., *Drepanoistodus forceps*, *Gothodus* cf. *costulatus*, *Scolopodus princeps*, *Paroistodus* cf. *proteus, Protopanderodus flouridus*, *Oistodus lanceolatus*; graptolites: *Tetragraptus reclinatus reclinatus*; chitinozoans: *Belonechitina* cf. *henryi*, *B. micracantha*, *Conochitina kryos*, *Conochitina decipiens*, *C.* cf. *parvulgata*, *C.* sp. aff. *langei*, *C. longei*, *Loganochitina esthonica*, trilobites *Pseudocalymene transversa*; trilobites: *Carolinites* sp. and brachiopods: *Pseudoporambonites yichangensis*, *Euorthisina* sp.

SHod-20A–C (0.37 m) - trilobites: *Carolinites* sp.; brachiopods: *Pseudoporambonites* sp. and conodonts: same as below.

SHod-20C (0.11 m)-conodonts: *Drepanoistodus forceps*, *Periodon* sp. A, *Scolopodus princeps*, *Protopanderodus flouridus*, *Baltoniodus triangularis*, *Gothodus costulatus.*

SHod-20B (0.11 m): *Baltoniodus triangularis*, *Microzarkodina flabellum, Drepanoistodus forceps*, *Periodon* sp. A, *Oistodus lanceolatus*, *Protopanderodus flouridus.*

SHod-20A (0.15m): *Microzarkodina flabellum*, *Periodon* sp., A, *Drepanoistodus forceps*, *Oistodus lanceolatus*, *Scolopodus princeps.*

SHod-19A–B Grayish-green shale with a few nodular limestone, containing conodonts, the trilobites *Liomegalaspides similes*, *Rhombampyx yii* and brachiopods *Pseudoporambonites yichangensis*, *Euorthisina kobayashi*, *Sinorthis typical*;

graptolites, chitinozoans, and brachiopods are present in the lower part, 0.50 m

SHod-19B (0.2 m) - conodonts: *Microzarkodina flabellum*, *Microzarkodina* sp. A, *Drepanoistodus forceps*, *Scolopodus princeps*. *Periodon* sp. A., *Gothodus* cf. *costulatus*.

SHod-19A (0.3m) - conodonts: *Periodon* sp. A.; graptolites: *Azygograptus suecicus*, *A.ellesi, Xiphograptus svalbardensis*; chitinozoans: *Belonechitina micracantha*, *Conochitina brevis*, *C. pseudocarinata, C. decipiens,*

SHod-18–12 Gray thin-bedded limestone intercalated with gray-greenish shale with limestone lenses, bearing conodonts, graptolites, chitinozoans and acritarchs. 1.10 m

SHod-18 (0.3 m) - conodonts: *Baltoniodus triangularis*, *Microzarkodina flabellum* (FAD), *Microzarkodina* sp. A., *Periodon* sp. A., *Drepanoistodus forceps*, *Protopanderodus flouridus*, *Scolopodus princeps*, *Oistodus lanceolatus*; trilobites: *Liomegalaspides similes*, *Pseudocalymene transversa*, *Hungioides* sp. *Aulacopleura* (*Paraaulacopleura*) *dawanensis* and brachiopods: *Pseudoporambonites yichangensis*, *Euorthisina orthiformis*, *E. kobayashii, Leptella grandis*, *Sinorthis typica*.

SHod-17 (0.1 m) - conodonts: *Baltoniodus triangularis*, *Baltoniodus* cf. *B. triangularis, Microzarkodina* sp. A, *Periodon* sp. A, *P. flabellum*, *Drepanoistodus forceps*, *Paroistodus* cf. *proteus, Scolopodus princeps*; graptolites: *Azygograptus suecicus*; trilobites: *Amphyx yii* and brachiopods: *Pseudoporambonites yichangensis*, *Euorthisina orthiformis*, *Leptella grandis*, *Sinorthis typica*.

SHod-16 (0.1 m) - conodonts: *Baltoniodus triangularis* (FAD), *Baltoniodus* cf. *B. triangularis, Microzarkodina* sp. A. *Periodon* sp. A (FAD), *P. flabellum*, *Baltoniodus*? n. sp. B., *Nasusgnathus dolonus, Drepanoistodus forceps*, *Scolopodus princeps*, *Oistodus lanceolatus*, *Gothodus costulatus*; chitinozoans: *Belonechitina* cf. *henryi*, *B. micracantha*, *Conochitina pseudocarinata*, *C.* cf. *parvulgata*, *C. longei*, *C. decipiens*; trilobites: *Liomegalaspides similis* and brachiopods: *Pseudoporambonites yichangensi, Euorthisina* sp.

SHod-15 (0.10 m) - conodonts: *Microzarkodina* sp. A, *Baltoniodus* cf. *B. triangularis*, *Periodon flabellum*, *Drepanoistodus forceps*, *Scolopodus princeps*; graptolites: *Azygograptus ellesi*; trilobites: *Agerina elongata* and brachiopods: *Pseudoporambonites yichangensi*.

SHod-14 (0.15 m) - conodonts: *Microzarkodina* sp. A, *Periodon flabellum*, *Baltoniodus* cf. *B. triangularis*, *Protopanderodus flouridus*, *Scolopodus princeps*, *Gothodus costulatus*; and brachiopods: *Leptella* sp.*, Sinorthis tipica, Pseudomimella formosa.*

SHod-13 (0.2 m) - *Microzarkodina* sp. A, *Periodon flabellum*, *Baltoniodus* cf. *B. triangularis*, *Drepanoistodus forceps*, *Scolopodus princeps, Oistodus lanceolatus*, *Gothodus costulatus*.

SHod-12 (0.15 m)- conodonts: *Microzarkodina* sp. A, *Baltoniodus* cf. *B. triangularis*, *Periodon flabellum*, *Paroistodus* cf. *proteus*, *Scolopodus princeps*, *Gothodus costulatus*, *Drepanoistodus forceps*; trilobites: *Liomegalaspides similes;* and brachiopods: *Sinorthis tipica*.

Underlying beds: uppermost middle part of the Lower Dawan Formation with 4.52 m

SHod-11–9 gray purplish medium-bedded dolomitic limestone, containing conodonts 0.9 m

SHod-11 (0.3 m) - conodonts: *Baltoniodus* cf. *B. triangularis*, *Periodon flabellum*, *Paroistodus* cf. *proteus*, *Reutterodus andinus*, *Drepanoistodus forceps*, *D.* spp., *Scolopodus princeps*, *Gothodus costulatus.*

SHod-10 (0.3 m) - conodonts: *Periodon flabellum*, *Baltoniodus* cf. *B. triangularis*, *Oepikodus intermedius*, *Reutterodus andinus*, *Scolopodus princeps*, *Gothodus costulatus*, *Oistodus lanceolatus*, *Drepanoistodus forceps*, *Trapezognathus diprion*, *Proto-prioniodus yapu, Nasusgnathus dolonus*.

SHod-9 (0.3 m) - conodonts: *Periodon flabellum*, *Baltoniodus* cf. *B. triangularis*, *Drepanoistodus forceps*, *Reutterodus andinus*, *Scolopodus princeps*, *Gothodus costulatus*, *Oistodus lanceolatus*.

The proposed Lower/Middle Ordovician boundary is defined at the base of SHod-16 with the FAD of *Baltoniodus triangularis*. This level is 0.6 m above the top of the distinctive 0.9 m-thick, medium-bedded dolomitic micritic limestone at the uppermost middle part (SHod– 9–11) (Fig.3), 10.57 m above the base of the Dawan Formation and 2.4 m below the base of the Middle Member of the Dawan Formation (Figs.3,5). This level nearly coincides with the first appearance of *Periodon* sp. A (*sensu* Bagnoli and Stouge, 1997) in SHod-16 and is 0.2 m below the FAD of *Microzarkodina flabellum* (i.e. SHod-18; Fig. 5).

Biostratigraphy

The Dawan Formation is widely distributed on the Yangtze Platform. In the Yichang area there are at least two other relevant sections that have been studied, the Chenjiahe section (Fig. 6) and the Jianyangping section. They are exposed, respectively, in the eastern and western limbs of the Huangling Arch, and correlation with the Huanghuachang section is straightforward. The Chenjiahe section is located 5 km to the north of the Huanghuachang section. It is well exposed along a country roadside. The Jianyangping section is well exposed in main roadside, close to a small town named Jianyangping in the Xinshan County. The conodonts of the Chenjiahe section have been studied in detail by Stouge (2002, *in prep.*). The conodont, graptolite, and chitinozoan biostratigraphic successions and their relationship across the Lower and Middle Ordovician boundary

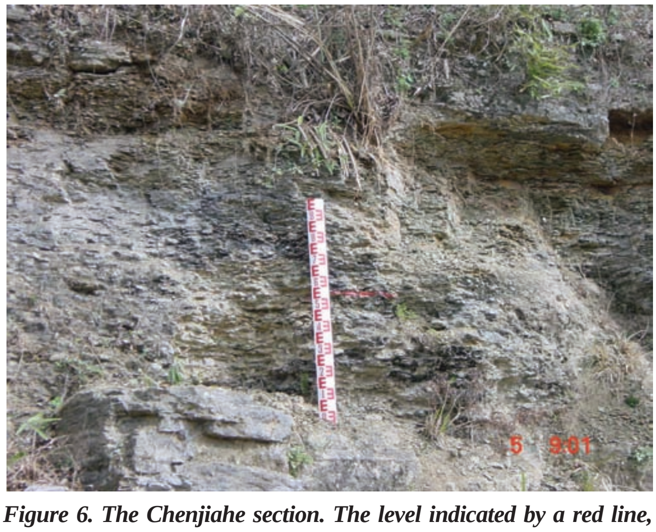

Figure 6. The Chenjiahe section. The level indicated by a red line, with FAD of* B.? triangulates *is 0.6m above the grayish purple medium limestone of 0.9 m thick, same as the Huanghuachang section.

interval at the Huanghuachang section are also documented in the Chenjiahe and Jianyangping sections (Fig. 6).

Conodonts

The conodonts from the Lower Member of the Dawan Formation have been studied in detail by several specialists (Zeng et al., 1983; An, 1987; Ni in Wang et al., 1987; Wang Z. et al., 1995; Wang and Bergström, 1998, Chen X. et al., 1995, Stouge, 2002 *in prep.*). The conodont species association and succession from the Lower Member of the Dawan Formation mark a prominent change from the underlying fauna of the Honghuayuan Formation, which includes taxa of the *Serratognathus diversus* and *Oepikodus communis* Biozones (An, 1987). The *Oepikodus communis* Biozone continues into the lowest Dawan Formation where the *Oepikodus evae* Biozone (*sensu* Lindström, 1971, Bergström, 1995) and *Baltoniodus triangularis* Biozone are present in the Lower Member (Wang et al., 2004, 2005) (Figs. 3, 5).

Subdivision of conodont biozone in the Lower Dawan Formation

Oepikodus communis Biozone. - The base of the *Oepikodus communis* Biozone is defined by the interval from the FAD of the nominate species to the first appearance of the early type of *Oepikodus evae* (Hod 28-3). The *Oepikodus communis* Biozone spans about 1.73 m in the uppermost Honghuayuan Formation (Hoh31–Hod 30) and the thick-bedded glauconitic bioclastic limestone of 0.93 m thickness (Hod 29–28) at the base of the Dawan Formation**.** Two new conodonts species reported by Zhen et al. (2006) from the Honghuayuan Formation of Guizhou probably appear in the *Serratognathus diversus* Biozone in the lower-middle parts of the Honghuayuan Formation here.

Oepikodus evae Biozone. - The *Oepikodus evae* Biozone is defined by the FAD of the early *Oepikodus evae* to the FAD of *Baltoniodus triangularis*. The biozone can be subdivided into two parts, where *Oepikodus evae* is represented first by an early type succeeded by *Oepikodus intermedius* at base of Hod 16 and together with *Periodon flabellum* (3.03 m above the base of the Dawan Formation) (Figs. 5,7B). Advanced *O. evae* specimens typical for the Baltic region and described by Lindström (1971) follow and represent the lower *O. evae* Biozone *sensu* (Lindström, 1971). Associated important conodont species in the zone include *Bergstroemognathus extensus, Gothodus costulatus*, *Juanognathus variabilis, Lundodus gladiatus*, *Periodon* spp., *Reutterodus andinus, Tropodus* spp., *Baltoniodus*? n. sp. A and *Baltoniodus*? n. sp. B. *Reutterodus andinus* is present throughout the biozone.

The biozone comprises most of the Lower Member of the Dawan Formation (Fig. 2). *O. evae* first appears within the thick-bedded glauconitic bioclastic limestone (Hod 28-3), 0.6 m above the base of the Dawan Formation, and ranges upwards to the base of Hod 9, 4.35 m above the base of the Dawan Formation.

The upper part of the *O. evae* Biozone is the interval where the nominated species is rare to absent. The biozone is recorded in the interval from Hod 9 to SHod-15 and is characterized by *Trapezognathus diprion*, *Periodon flabellum*, *Gothodus costulatus*, *Tropodus* spp., *Drepanoistodus forceps*, *Oepikodus intermedius*, *Periodon selenopsis*, *Baltoniodus* cf. *B. triangularis*, *Tripodus* cf. *leavis* (=*Tripodus leavis*, sensu Wang et al., 2003a, b; Chen X.H. et al., 2003; Li et al., 2004), *Gothodus costulatus*, *Protoprioniodus yapu* and *Microzarkodina* sp. A. The last species occurs in the uppermost part of the biozone. The conodont assemblage and succession in the upper *O. evae* Biozone (Figs.5, 7) are similar to those of the *Gothodus crassulus* (= *G. costatus*), *Trapezognathus diprion* and *Microzarkodina* sp. A zones reported from Sweden (Löfgren 1993; Stouge et al., 1995; Bagnoli and Stouge, 1997). The base of the upper *O. evae* Biozone herein is also indicated by the first apperance of *Drepanoistodus forceps*, *Baltoniodus* cf. *B. triangularis* and *Tripodus* cf. *leavis* at the base of Hod 9 (Fig. 5). The former is a very common species reported from the *O. evae* to *B. navis* Zone in the Baltoscandic region (Lindström 1971; Löfgren 1978; Rasmussen 2001) and NW Russia (Tolmacheva and Federov, 2001). *Baltoniodus* cf. *B. triangularis* (Fig.8), which was named *Baltoniodus*? cf. *B.*? *triangularis* by Wang et al. (2005) and identified as *Baltoniodus triangularis* by Wang et al. (2002, 2003a, b), Chen X.H. *et al*. (2002, 2003) and Li et al. (2004). It is similar to B. *triangularis* (Lindström) from the Baltic region in most aspects, but the main difference is the lack of confluent denticles on the anterior process of the Pb element. It is the ancestor of *B. triangularis* within the *Baltoniodus* lineage (Fig.9).

The *O. evae* Biozone in the Cow Head Group, W. Newfoundland (Johnston and Barnes, 1999) is equivalent to the *O. evae* Biozone of the Baltic region or the lower *O. evae* Biozone of the Huanghuachang section. The

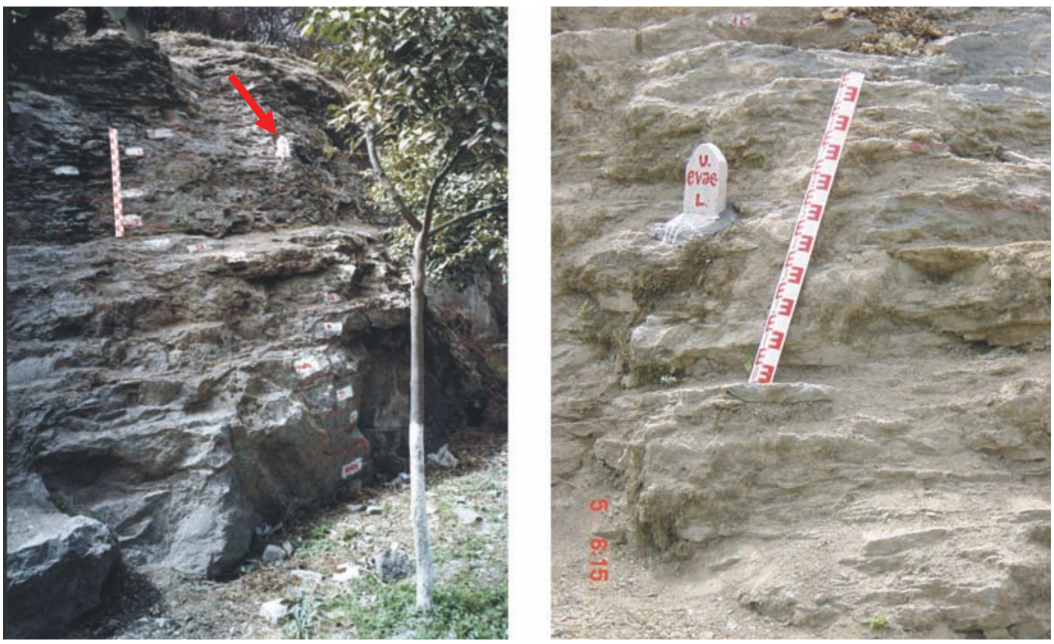

Figure 7. (A) Indicating the level with FAD of* O. intermedius *at the Huanghuachang. (B) Showing the boundary between the Upper and Lower* Oepikodus evae *Biozone.

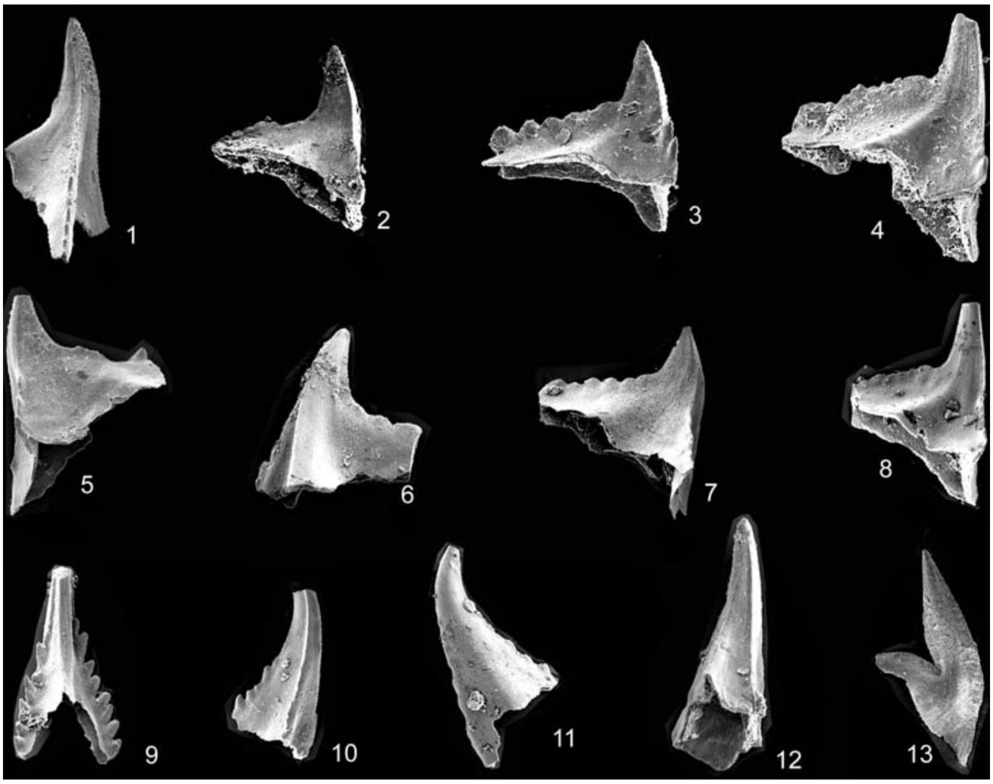

Figure 8. **Baltoniodus** ***cf.*** **B. triangularis** ***(Lindström). 1. Pa element, lateral view, ×150, sample, Hod-9-0/6092, Hod-9; 2. Pb element, lateral view, ×150, sample, Hod-9-0/6078, Hod-9; 3. Pb element, lateral view, ×180, sample, Hod-9/1486, Hod-9; 4. Pb element, lateral view, ×150, sample, Hod-9-2/1340, Hod-9-2; 5. Pb element, lateral view, ×150, sample, Hod-9-1/1378, Hod-9-1; 6. Pb element, inter-lateral view, ×100, sample, Hod-c-2/6006, SHod-16; 7. Pb element, lateral view, ×180, sample, Hod-9-0/6090, Hod-9; 8. Pb element, lateral view, ×120, sample, Hod-9-0/6080, Hod-9; 9. Sa element, posterior view, ×150, sample, Hod-8/6088, Hod-8; 10. Sb element, lateral view, ×100, sample, Hod-c-1/5995, SHod-12; 11. Sc element, lateral view, ×180, sample, Hod-c-1/5992, SHod-12; 12. Sd element, posterior-lateral view, ×150, sample, Hod-c-1/5994, SHod-12; 13 M element, lateral view, ×120, sample, Hod-8/2287, Hod-8.***

succeeding *T. leavis* Biozone in the Cow Head Group is likely to be equivalent to the lower part of the upper *O. evae* Biozone from the Huanghuachang section based on the co-occurrence of *Oepikodus evae*, *O. intermedius* and *Tripodus* cf. *leavis*. In the Niquivil section near San Juan, Argentina the FAD of *Cooperignathus aranda* basically coincides with the boundary between the *O. evae* and *O. intermedius* Biozones as these biozones have been defined by Albanesi et al. (2006). This level should be a little below the top of the lower *O. evae* Biozone in the Huanghuachang section (Wang et al. 2005).

Baltoniodus triangularis Biozone. - The *Baltoniodus triangularis* Biozone is defined by the FAD of *B. triangularis* (Figs. 3, 5, 9) together with first appearance of *Periodon* sp. A (*sensu* Bagnoli & Stouge, 1997) and extends upwards to the FAD of *Baltoniodus navis* at the base of SHod-26. The *Baltoniodus triangularis* Biozone is same as the *Baltoniodus*? *triangularis - Microzarkodina flabellum* Biozone (*sensu* Wang et al., 2005). *Microzarkodina flabellum* (Wang et al. 2005, p.108, Fig. 5) first appears at SHod-18, 0.2 m above the base of the biozone. The important newcomers across the boundary interval are first *Microzarkodina* sp. A (*sensu* Bagnoli and Stouge, 1997) followed by *Baltonionus triangularis* and *Periodon* sp. A, and then *Microzarkodina flabellum.* This faunal succession suggests the correlation of present biozone with the *B. triangularis* Biozone (*sensu* Lindström, 1971) of the Baltic region, the *B. triangularis* to *M. flabellum* interval zone of Öland, south Sweden (Bagnoli and Stouge, 1997), and the *T. leavis- M. flabellum* interval in the Ibex, Utah section of North America (Ethington and Clark, 1982, Ross et al., 1997).

Baltoniodus navis Biozone. The *Baltoniodus navis* Biozone is defined by the first appearance of *Baltoniodus navis*. The base is at SHod-26, 1.5 m above the base of the Middle Member of the Dawan Formation. The following faunal succession is mainly composed of *Oistodus*, *Periodon* and *Paroistodus* and characteristic associated species includes *Periodon* sp. A, *Oistodus lanceolatus,* and *Paroistodus originalis*. The same faunal association continues into the upper part of the Middle Member of the Dawan Formation.

Evolutionary conodont lineages in the Huanghuachang section

Significant speciation events occur in the *Baltoniodus, Gothodus*, *Microzarkodina* and *Periodon* lineages across the Lower and Middle Ordovician Series boundary, where species of the taxa other than *Baltoniodus triangularis* are good proxies for the defined boundary level (Fig. 10). In addition, species within the *Paroistodus* and *Trapezognathus* lineages change across the series boundary.

The *Baltoniodus* lineage is the most significant lineage and the FAD of *Baltoniodus triangularis* is proposed as the boundary biomarker for the base of the Middle Ordovician. Based on Baltoscandian material the lineage was considered to begin with *Baltoniodus triangularis* and followed by *Baltoniodus navis* (Lindström, 1971; Löfgren, 1978; Dzik 1976, 1994). Bagnoli and Stouge (1997) were cautious because some specimens of *Baltoniodus triangularis* in their collection resemble *Trapezognathus* elements and there were no known taxa that could be assigned as the obvious ancestor to *Baltoniodus triangularis.* Bagnoli and Stouge (1997) therefore tentatively assigned the *triangularis* elements to the genus *Baltoniodus* with a question mark. The discovery of the species *Baltoniodus* cf. *triangularis* in the South China sections solved the problem, because this species is the obvious ancestor to *Baltoniodus triangularis* (Figs.8-9). The *Baltoniodus* lineage continues with the more advanced successor *Baltoniodus navis* via the transitional forms referred to *Baltoniodus* cf. *navis* by Bagnoli and Stouge (1997).

The *Gothodus* lineage begins with *Gothodus* sp., which is recorded in the sections from South China. It is succeeded by *Gothodus costulatus* in the Lower Ordovician *Oepikodus evae* Biozone and is followed by *Gothodus* cf. *costulatus* in the *Baltoniodus*

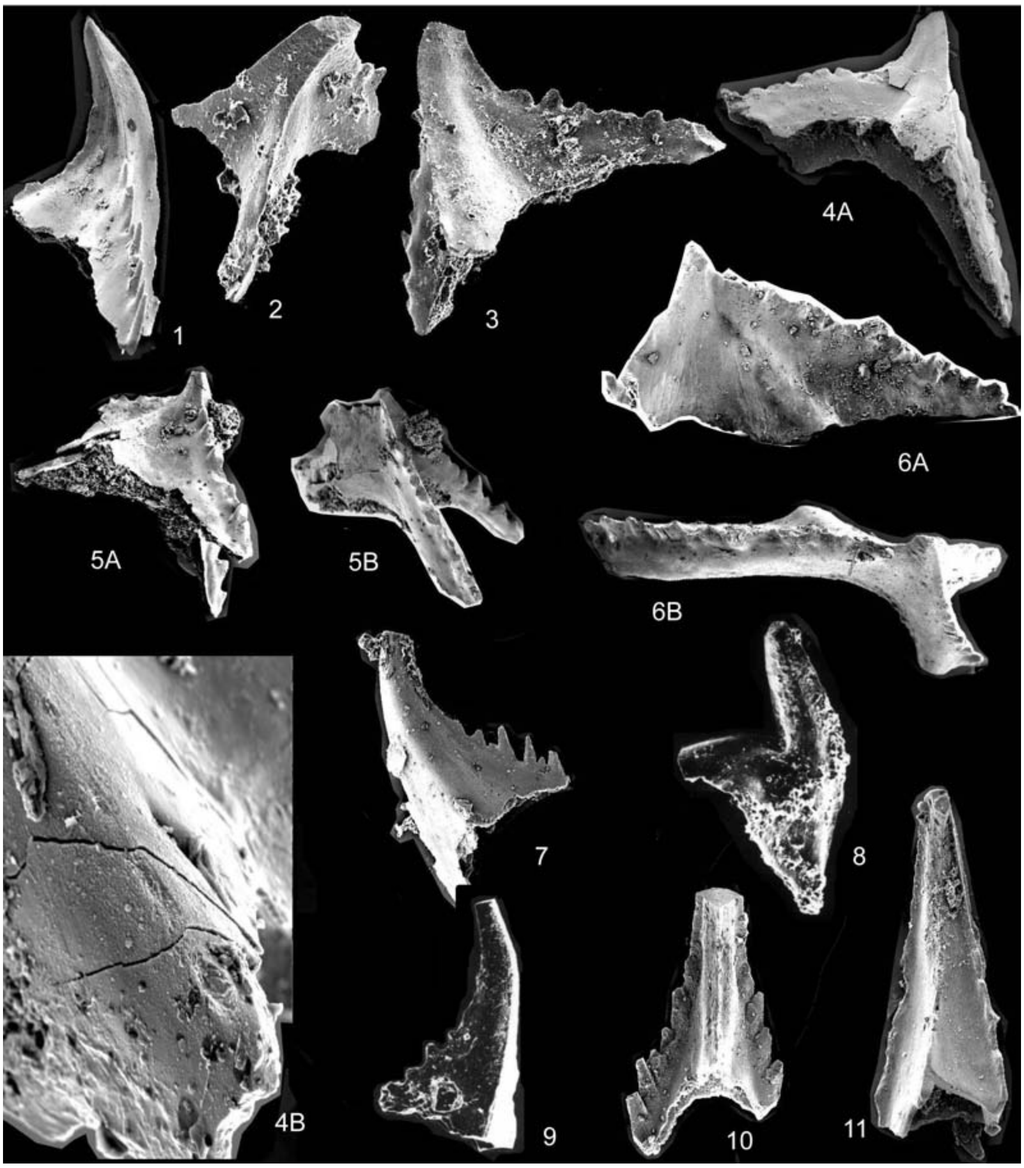

Figure 9. **Baltoniodus triangularis** *(Lindström). 1. Pa element, lateral view, ×150, sample, Hod-c-2/6009, SHod-16; 2. Pa element, oral view, ×200, sample, SHod-16/1464, SHod-16; 3. Pb element, lateral view, ×120, sample, SHod-16/1469, SHod-16; 4A. Pb element, lateral view, ×120, sample, Hod-c-2/6007, SHod-17; 4B. Pb element, lateral view, characteristics of the denticles in the anterior process, ×800, sample, Hod-c-2/6008, SHod-17; 5A. Pb element, lateral view, ×90, sample, Jod-23/6053; 5B. Pb element, anterior view, ×90, Jod-23/6054; 6A. Pb element, lateral view, ×90, Jod-23/6049; 6B. Pb element, oral view, ×90, Jod-23/6048; 7. Sc element, lateral view, ×180, sample, Hod-c-2/6000, SHod-17; 8. M element, lateral view, ×120, sample, SHod-16/1467, SHod-16; 9. Sb element, lateral view, ×120, sample, SHod-16/1468, SHod-16; 10. Sa element, posterior view, ×180, sample, Hod-c-2/5999, SHod-16; 11. Sd element, posterior view, ×180, sample, SHod-2/6012, SHod-2.*

triangularis Biozone i.e. in the basal Middle Ordovician. Younger species exist but are not yet formalized. The *Gothodus* lineage probably is the ancestor to the *Phragmodus* lineage, which appeared in the Middle Ordovician (Dzik, 1994; Stouge and Bagnoli, 1999).

The *Microzarkodina* lineage is well displayed in the sections in China and Baltoscandia. The oldest known representative of the genus is *Microzarkodina* sp. A from the top of the Lower Ordovician and *Microzarkodina flabellum* is the immediate successor (Bagnoli and Stouge, 1997, Wang et al., 2005). *M. flabellum* appears slightly above the base of the Middle Ordovician. Younger forms of the lineage include *M. corpulenta*, *M. parva*, *M. bella*, *M. hagetiana* and *M. ozarkodella*.

The *Periodon* lineage has been outlined by Dzik (1976), Löfgren (1978), Stouge and Bagnoli (1988), Bagnoli and Stouge (1997), Johnson and Barnes (1999) and Rasmussen (2001). The oldest known species is *Periodon primus* followed by *Periodon selenopsis*, *Periodon flabellum* and *Periodon* sp. A. *Periodon* sp. A appears just at the base of the *Baltoniodus triangularis* Biozone of the Middle Ordovician and ranges into *Baltoniodus navis* Biozone. Further species of the lineage in the Middle Ordovician have most recently been revised and outlined by Rasmussen (2001). Younger species includes *Periodon aculeatus* and *P. grandis* from the Upper Ordovician.

The *Trapezognathus* lineage was described by Bagnoli & Stouge (1997) and the present study confirms the status of the lineage. In the Huanghuachang section *T. diprion* appears in the upper *Opikodus evae* Biozone of the Lower Ordovician and is succeeded by *T. quadranculum* in the *Baltoniodus navis* Biozone of the Middle Ordovician. The precise shift of species has not yet been observed or recorded as the two species are separated by a stratigraphical interval without representatives of the taxon both in South China and Baltoscandia.

Lindström (1971) established the *Paroistodus* lineage, and he (Lindström, 1971) used species of the genus as zonal index species. In the Huanghuachang section, *Paroistodus proteus* is present in the lower part of the succession and is succeeded by *Paroistodus* cf. *proteus* in the upper part of the Lower Ordovician (Wang et al., 2005). *Paroistodus originalis* is present in *Baltoniodus navis* Biozone of the Middle Ordovician, where it can be abundant. *Paroistodus originalis* has been used as a zonal index species in South China (Wang and Bergström, 1995) and in Baltoscandia (Lindström, 1971). The *P. originalis* Biozone is an acme zone and the zones bearing the same name from respectively China and Baltoscandia are not isochronous. In South China the zone corresponds to the *Baltoniodus navis* Biozone and in Baltoscandia the *P. originalis* Biozone is younger and succeeds the *B. navis* Biozone (Lindström, 1971). A younger

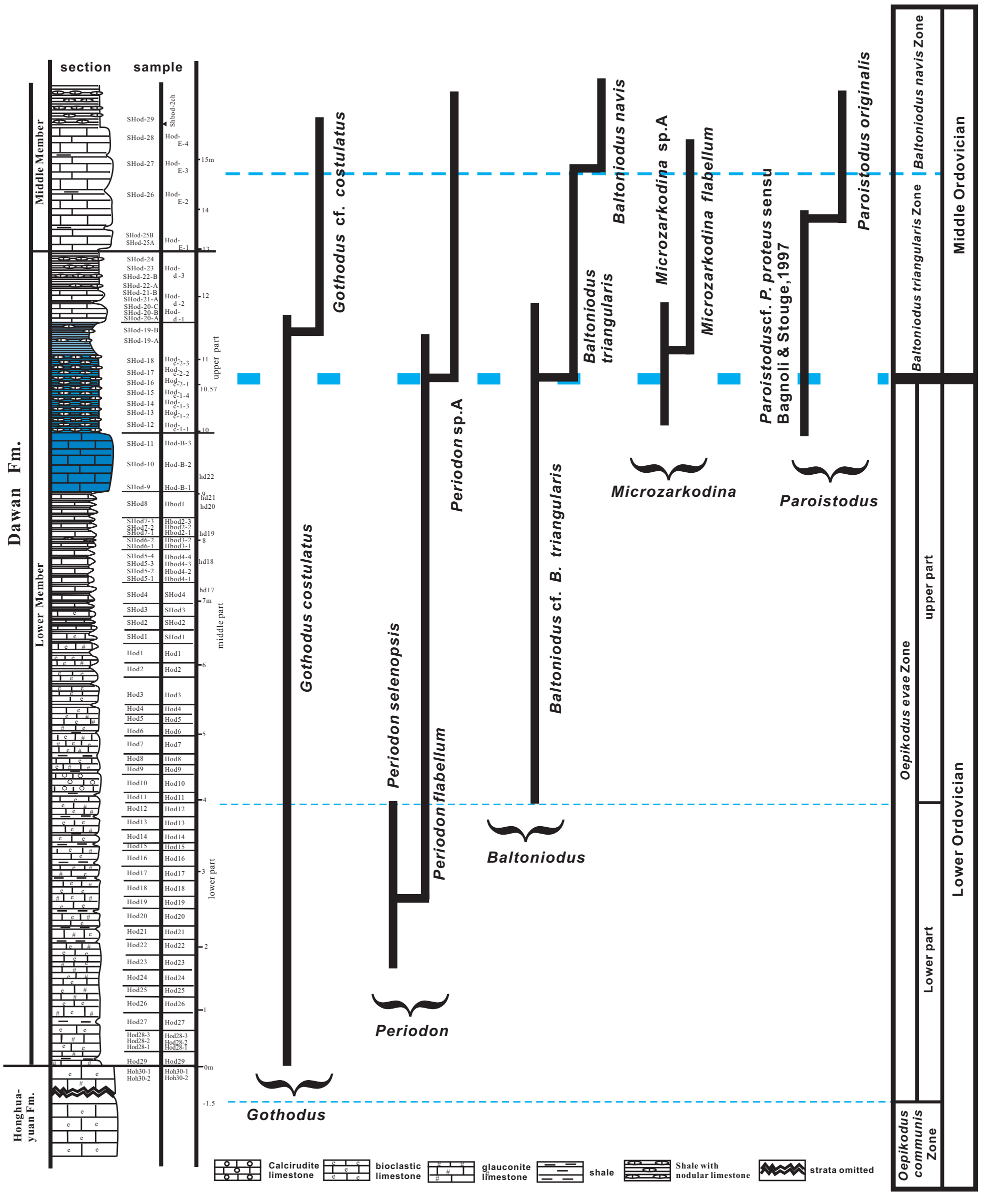

Figure 10. Evolutionary conodont lineages across the Lower / Middle Ordovician boundary in the Huanghuachang section (modified from Wang et al. 2005).

with *C. deflexus*, *Tetragraptus bigsbyi*, *Acrograptus kurki*, and directly underlie the bed (Hod3) with the first appearance of *Azygograptus suecicus*. The conodonts from the underlying and overlying limestones indicate that the boundary between the *D. bifidus* and *A. suecicus* Biozones is within the lower part of the upper *O. evae* Biozone (Fig. 4).

The *Azygograptus suecicus* Biozone here is defined by the first appearance of the index fossil at the base of Hod3, 5.45 m above the base of the Dawan Formation, and it ranges upwards to the lower part of the Middle Member of the Dawan Formation. It may be subdivided into two intervals based on the species association of *Azygograptus*. The lower interval, located between the Hod3 and SHod-14, yields *Azygograptus suecicus*, *A. eivionicus,* and *Phyllograptus anna*, and the upper interval (SHod-15–29) *Azygograptus ellesi*, *A. suecicus*, horizontal *Xiphograptus svalbardensis*, *Pseudotrigonograptus* sp. and *Tetragraptus* sp. Associated conodonts in the section indicate correlation of the lower *A. suecicus* Biozone with the major part of the upper *O. evae* conodont Biozone and the upper *A. suecicus* Biozone (SHod-15–29) occurs in the uppermost Lower Member to the lower Middle Member of the Dawan Formation and roughly corresponds to the *B. triangularis* to the lower *Baltoniodus navis* Biozones.

The graptolite succession documented in the Lower Member of the Dawan Formation and its relationship with relevant conodont and graptolite biozones of the world have been discussed in detail by Wang et al. (2005, Table 1). The *Didymograptellus bifidus* Biozone herein is suggested to correspond to the *D.* "*protobifidus*" and the *C. deflexus* Biozones in the Jiangnan slope, South China (Zhang and Chen, 2003), the Australian *protobifidus* and *I. primulus* Biozones (Webby and Nicoll, 1989; Cooper and Lindholm, 1990), and the North American *bifidus* Biozone (Berry, 1960, Finney and Ethington, 1992). It is correlated with the upper *varicosus* to lower *simulans* Biozones of Britain (Cooper et al. 1995) and the upper *balticus* to *densus* Biozones of Baltoscandia on the basis of the presence of *D. bifidus* and *C. deflexus*. The overlying *Azygograptus suecicus* Biozone is widely recorded in the interval between the *D. bifidus* and lower *E. hirundo* Biozones in the Yangtze platform and between the *deflexus* and *I. cauduceus imitatus* Biozones in the Jiangnan slope of South China plate (Chen et al. 2003; Zhang and Chen, 2003). *Azygograptus* is considered to be diagnostic of the *Isograptus-Azygograptus* radiation (Chen and Bergström, 1995) and one of the most

species is *Paroistodus horridus,* which appears to be the youngest representative of the genus.

In the Chenjiahe section the same conodont assemblages and lineages mentioned above are found across the suggested boundary (Wang et al. 2005).

Graptolites

The graptolites of the Dawan Formation of the Huanghuachang section have been studied by Wang et al. (1987, 1992a, 1995). The revised two graptolite biozones, *Didymograptellus bifidus* and *Azygograptus suecicus* Biozones, can be recognized in the Lower to lower Middle Members of the Dawan Formation (Figs.2-4) (Wang et al. 2004, 2005). The index fossil of *Didymograptellus bifidus* Biozone is present in four interbeds of yellow-green shale (Hod22, Hod18, Hod8 and Hod4) between thin-bedded limestones bearing conodonts in the lower part to lower middle part of the Lower Member. The uppermost shale interbeds (Hod4) of 0.17m thick have *D. bifidus*

Table 1. Correlation of the graptolite biozones across the Lower/Middle Ordovician boundary of the Huanghuachang section (modified from Wang et al. 2005)

Series	South China: Huanghuachang section — Fm	Unit	graptolite (Wang et al. 2005; this paper)		conodont (Wang et al. 2005; this paper)		Jiangnan Slope (Chen et al.2003; Zhang &Chen,2003)	Northwest Europe: Baltoscandia (Cooper et al. , 1995; Maletz, 2005)	Britain	W. Newfound-land, Canada (William & Stevens, 1988)	N. America (Berry, 1960;Finney & Ethington,1992)	Australasia (Webby & Nicoll, 1989)
Middle Ordovician	Dawan Formation	Middle Mb.			*Baltoniodus navis*		*Isograptus caduceus imitatus*	*Isograptus* sp.n.2 & *Maeandrogr. schmalenseei*	*Isograptus gibberelus*	*Isograptus v. maximus*	*Isograptus v. maximus*	Ca3 *Isograptus v. maximus*
Middle Ordovician	Dawan Formation	Lower Member	*Azygograptus suecicus*	Upper	*Baltoniodus trangularis*		*Isograptus caduceus imitatus*	*Isograptus v. victoriae*	*Isograptus v. victoriae*	*Isograptus v. victoriae*	*Isograptus v.victoriae*	Ca2 *Isograptus v. victoriae*
Lower Ordovician	Dawan Formation	Lower Member	*Azygograptus suecicus*	Lower	*Oepikodus evae*	Upper	*Azygograptus s uecicus*	*Pseudophyllogr. angustifolius elongatus*	*D.*(s.l.) *simulans*	*Isograptus v. lunatus*	*Isograptus v.lunatus*	Ca1 *Isograptus v. lunatus*
Lower Ordovician	Dawan Formation	Lower Member	*Didymogr. bifidus*		*Oepikodus evae*	Upper	*C. deflexus*	*Pseudophyllogr densus*	*D.*(s.l.) *simulans*	*Didymogr. bifidus*	*Didymogr. bifidus*	Ch2 *I. primulus*
Lower Ordovician	Dawan Formation	Lower Member	*Didymogr. bifidus*		*Oepikodus evae*	Lower	*D. "protobifidus"*	*Pseudophyllogr densus* / *D.*(s.l.) *balticus*	*D.* (s.l.) *varicosus*	*Didymogr. bifidus*	*Didymogr. bifidus*	Ch1 *D.* ¡*protobifidus*¡
Lower Ordovician	Dawan Formation	Lower Member	No graptolite		*Oepikodus evae*	Lower	*P. fruticosus*	*D.*(s.l.) *balticus*	?	*P. fruticosus*	*P. fruticosus*	Be1-4 *P. fruticosus*
Lower Ordovician			No graptolite		*Oepikodus communis*		*P. fruticosus*	*D.*(s.l.) *balticus*	?	*T. akzharensis*	*T.akzharensis*	Be1-4 *P. fruticosus*
Lower Ordovician	Honghua-yuan Fm.		No graptolite		*Oepikodus communis*		*approximatus*	*Phyllograptoides*	*Phyllograp-toides*	*T. approximatus*	*T. approximatus*	La3 *T.approximatus*

characteristic genera of the Atlantic Province during the "Arenig" (Beckly and Maletz, 1991). It is widely reported from Britain, Scandinavia, Bohemia, northern Spain, Gorny Altai, southern Bolivia and South China (Beckly and Maletz, 1991; Cooper and Lindholm, 1990). The *A. suecicus* Biozone of the Huanghuachang section lies directly above the *D. bifidus* Biozone and about 9 m below the *U. sinodentatus* Biozone at the base of the Upper Dawan Formation. This suggests the *A. suecicus* Biozone here is coeval with the *lunatus* to *victoriae* Biozones of Australia (Webby and Nicoll, 1989), North America (Berry, 1960) and Canada (Williams and Stevens, 1988), and approximately equivalent to the Scandinavian *elongatus* to lowest *hirundo* (or *victoriae*) Zones, and the British upper *simulans* Zone to the lower *gibberulus* Biozone or *victoriae* Biozone (Cooper et al. 1995; Maletz, 2005). The upper Middle Member of the Dawan Formation, located between the *A. suecicus* and *U. sinodentatus* Biozones in the Huanghuachang section, should correspond to Ca 3–Ca 4 of the Australian standard. It is important to note that the base of upper *A. suecicus* interval, characterized by the occurrence of *Azygograptus ellesi*, is close to, or only 0.1m below the level with FAD of *B. triangularis* (SHod-16) in the Huanghuachang section. The succeeding graptolites, including the horizontal and declined *Xiphograptus svalbardensis*, *Expansograptus* sp., *Pseudotrigonograptus* sp. found in its lowest part (SHod-15–22) are very common in the lower *E. hirundo* Biozone of Baltoscandia (Cooper et al., 1995) and the base of latter is considered very close to, if not coeval with, the base of the *I. v. victoriae* Biozone (Maletz, 1992, 2005). These indicate that the boundary between the *lunatus* and *victoriae* Biozones in these localities mentioned above is nearly coincident with the boundary between the lower and upper *A. suecicus* Biozone and close to the base of the *Baltoniodus triangularis* Biozone (SHod-16) in the Huanghuachang section (Table 1). This correlation is also suggested by the graphic correlation of conodonts and graptolites in the boundary inteval from several sections worldwide (Stouge et al., 2005, 2006).

Chitinozoans and acritarchs

The chitinozoans in the Dawan Formation were reported by Chen X.H. et al. (1996, 2002, 2003). Further sampling has shown that four chitinozoan biozones can be recognized in the Lower and lower Middle Members of the Dawan Formation (Wang et al., 2005).

The *Lagenochitina esthonica* Biozone is defined by the incoming of the index fossil in lowest *O. evae* Biozone (Fig.5). This species, however, is widely recorded from the lowest Dawan Formation and correlative strata throughout the Yangtze platform with *Conochitina raymondii*, *C. ordinaria*, and these represent the primary radiation of the chitinozoan fauna during the Early Ordovician (Wang and Chen, 2003). Based on the co-occurrence of nominated species below the first appearance of *Conochitina langei* the *L. esthonica* Biozone herein is suggested to correlate with the *L. esthonica-Conochitina raymondii* Zone reported from Quebec and western Newfoundland, Canada (Achab, 1989)

The overlying *Conochitina langei* Biozone is defined by the FAD of the index fossil at bed Hod 24 and extends upwards to the FAD of *Conochitina pseudocarinata* at the bed of SHod-4. The chitinozoan biozone in the Lower Dawan Formation covers the interval of the *D. bifidus* to the lower part of the *A. suecicus* Biozones or the lower to lower upper *O. evae* conodont Biozone (Fig.5). The principal chitinozoans include *Lagenochitina esthonica*, *Conochitina brevis*, *C. decipiens, C. poumoti*, *C. ordinaria*, *C. langei*, *Tanuchitina* sp. aff. *achabae* and *Eremochitina baculata*. Although the last species is considered as a diagnostic for northern Gondwana (Paris, 1990), the chitinozoan assemblage is similar to that of the *C. langei / C. brevis* Biozone reported from the Lévis Formation, Canada (Achab, 1986, 1989). The *C. langei* Biozone at Huanghuachang is correlative only with the lower part of the *C. langei / C. brevis* Biozone based on associated graptolites and conodonts.

The *Conochitina pseudocarinata* Biozone is defined by the FAD of the nominate fossil at the bed of SHod–4. Most of the associated chitinozoans range into the Biozone from below, except *Sagenachititina oblonga* and *Cyathochitina*? sp. *C. pseudocarinata* and *S. oblonga*, which first appear in the biozone, are considered to be representative of the *D. ornensis* Biozone in north Gondwana (Paris, 1990, 1996). The *C. pseudocarinata* Biozone at Huanghuachang, therefore, is correlated with the *D. ornensis* Biozone in north Gondwana. The upper limit of the *C. pseudocarinata* Biozone is defined by the first appearance of *Belonechitina* cf. *henryi* at the bed of SHod-16.

The *B.* cf. *henryi* Biozone is characterized by the first appearance and development of the nominated fossil together with *B. micracantha* and *Conochitina kryos*. This chitinozoan association indicates that the *B.* cf. *henryi* Biozone of the section is equivalent to the *Belonechitina henryi* Biozone in north Gondwana (Paris, 1990, 1996). In the Huanghuachang section the base of the *B.* cf. *henryi* Biozone is very close to or coincident with the base of *B. triangularis* conodont Biozone.

Well-preserved and diversified acritarchs have been reported from the Lower Dawan Formation by Tongiorgi et al. (1995), Brock and Li (1999), Yin et al. (1998) and Li et al. (2003). The latest study indicates the correlation of the *Arbusculidium filamentosum–Aureotesta clatirata* Assemblage Zone with *Didymograptellus bifidus* Biozone and the overlying *Ampullula–Barakella felix* Assemblage Zone (Li et al., 2003) with the *Azygograptus suecicus* Biozone (Wang et al., 2004, 2005).

The chitinozoan sequences recorded in the continuous Lower to lower Middle Dawan Formation and its relation with relevant conodont and graptolite biozones in the Huanghuachang section suggest that it is necessary to re-examine the time scales of the *C. langei / C. brevis* Biozone in North America and the *D. ornensis* and *B. henryi* Biozones in north Gondwana, and their correlation with relevant conodonts and graptolite Biozones (Webby et al., 2004, figures 2.1 and 2.2). In the Huanghuachang section the base of *B. triangularis* conodont Biozone approved for the base of the Middle Ordovician Series is close to the boundary between the lower and upper *A. suecicus* Biozone, nearly coincident with the base of the *Belonechitina* cf. *henryi* chitinozoan Biozone and within the *Ampullula-Barakella felix* acritarch Assemblage Zone.

Other fossils

Brachiopods are very common in the Lower Member of the Dawan Formation, and were studied in detail by Zeng *et al*. (1983, 1991). The common brachiopods include *Leptella, Sinorthis, Pseudomimella, Tritoechia*, *Noreidella*, *Pseudoporambonites*, *Euorthisina*, *Yangtzeella*, *Martellia* and *Lepidorthis* (Wang et al., 2005; Zhen and Harper, 2006). Restudy further confirms that two biozones, the *Leptella* Biozone and *Euorthisina* Biozone, are present in the Lower Member (Fig.5). The *Leptella* Biozone is characterized by the appearance of the index fossil at the base of the Dawan Formation. Its upper limit is defined by the appearance of *Euorthisina,* although *Leptella* itself may extend upwards to the uppermost part of the Lower Dawan Formation. The *Euorthisina* Biozone is indicated by the incoming of the zonal fossil with *Pseudoporambonites* in the upper part of the Lower Dawan Formation, close to the base of the (SHod-16) of *B. triangularis* Biozone. Associated graptolites indicate the correlation of *Leptella* Biozone with the *D. bifidus* Biozone to the lower interval of the *A. suecicus* Biozone. The overlying *Euorthisina* Biozone corresponds to the upper interval of the *A. suecicus* Biozone and extends upwards to the *U. austrodentatus* Biozone.

The trilobites from the Lower Member of the Dawan Formation have been reported by Zhou (*in* Wang et al., 1987), Turvey and Zhou (2002) and Turvey (2005). Re-study suggests the principal trilobites include *Pseudocalymene*, *Carolinites*, *Agerina*, *Phorocephala*, *Ningkianolithus*, *Megalaspides, Liomegalaspides*, *Ovalocephalus*, *Taihuangshania*, *Aulacopleura* (*Paraaulacopleura*) and *Rhombampyx*. Most of them have a long range, except of *Agerina*, which is mainly found in upper part of the Lower Member (Fig. 5). Among these trilobites *Carolinites genacenaca*, which has been reported from the *Reutterodus andinus* Biozone in North American (Ross et al., 1997), is found in the Lower and Upper Members of the Dawan Formation, respectively (Turvey and Zhou, 2002). *Agerina elongata* first appears in the bed of SHod-15 at the Huanghuachang section. This level is basically coincident with the boundary between the Lower and Upper *A. suecicus* Biozone and 0.1m below the base (SHod-16) of *B. triangularis* Biozone, so that this species, together with the index fossil and *Pseudoporambonites* of the *Euorthisina* brachiopod Biozone, seem to be also considered as an auxiliary biomark indicating the ratified Lower and Middle Ordovician boundary.

Sequence- and eco-stratigraphy

The study of sequence and ecostratigraphy facilitate a subdivision the Lower Member of the Dawan Formation into three transgressive to regressive cycles or sequences and related two brachiopod communities, namely, the *Leptella (L.) - Sinorthis* Community and *Pseudoporambonites-Euorthisina* Community (Zeng, 1991, 2006 *in prep.*). The first and second cycles, showing a generally transgressive trend and deepening upwards (Wang et al., 2005), occupy the lower-middle parts of the Lower Member with the *Leptella (L.) - Sinorthis* Community, indicating Benthic Assemblages 1-2 (BA1 in lower part and BA2 in middle part) (Figs.5, 11). Main brachiopods include *Leptella*, *Sinorthis*, *Martellia*, *Pseudomimella*, *Yangtzeella*, *Nereidella*, *Tritoechia*, *Westonia* and *Nushbiella* etc. An obvious change in lithofacies, sequence and biological assemblage first appears between the glauconitic bioclastic limestone of 0.93 m with rich conodonts and brachiopods at the base of the Dawan Formation (Hod29–27) and the underlying thick-bedded dolomitic limestone (Hoh 30-31) with *Archaeocyphia*, *Calathium* at the top of the Honghuayuan Formation. This sequence turnover was associated with the replacement of warm water biota by the cool-water mixed with warm-water biota (Figs. 5, 11). The second cycle covered the middle part of the Lower Member, and contained brachiopods of BA2 community (Zeng, 2001, 2006 *in prep*). It starts at the base of yellow-green shale interbeds (Hod 5) with first appearance of *Azygograptus suecicus*. The underlying highstand regressive thin-bedded bioclastic limestone yields numerous brachiopods. The second cycle was characterized by a smaller sea-level rise succeeded by a gentle regression and terminated at the top of the 0.9 m-thick, highstand dolomitic limestone in the uppermost middle part of the Lower Dawan Formation (SHod-9–11). The lowstand deposit of the third sequence, marking the base of the upper part of the Lower Dawan Formation, is recognized as an important worldwide sea-level lowstand event in the Lower/Middle Ordovician boundary interval (Ross & Ross, 1992, Nielsen, 1992, 2004). In the Huanghuachang section this event is recognized by the sequence change that occurred between SHod-11 and SHod-12. The succeeding transgressive deposits, covering the interval from the uppermost *Oepikodus evae* Biozone to the lowest *Baltoniodus triangularis* Biozone (SHod-12–18), are characterized by thin-bedded nodular limestone with yellow-green shale interbeds. The fauna includes conodonts i.e. *Baltoniodus triangularis*, *Microzarkodina* sp. A and *Periodon* sp. A, graptolites *Azygograptus suecicus*, *A. ellesi*, some trilobites, and well-preserved brachiopods of the *Pseudoporambonites-Euorthisina* Community. The faunal associations indicate that a relatively deep and calm depositional environment prevailed upwards and equivalent to BA3. Among brachiopod community *Euorthisina* is a characteristic genus of the *Euorthisina* Community for Benthic Assemblages 3 to 5 (Havlícek, 1982, Zeng, 1991). The maximum flooding is here interpreted to correspond to yellow-green shale of 0.5 m (SHod-19) with graptolites in the lower part of the upper *Azygograptus suecicus* Biozone (Fig.11). A minor regression (SHod-20–21), in turn succeeded by a gentle sea-level rise, is interpreted for the upper part of the upper *A. suecicus* Biozone, and it extends up to the uppermost part of the Lower Member (SHod-22–24). The purple medium-bedded limestone of the Middle Member of the Dawan Formation represents the highstand regressive deposits. A smaller sea-level rise is coincident with the last appearance of *Azygograptus suecicus* in the 1.5 m thick of yellow green shale with limestone lens (SHod-29), 2.6 m above the base of the Middle Member. Following regression covered the middle–upper part of the Middle Member. The Upper Member of the Dawan Formation has a transgressive succession, deepening and fining upwards. A sequence change is recognized at a level between the Middle and Upper Members of the Dawan Formation and supported by a change in the brachiopod communities from BA 2 in the Middle Member to BA 3 in the Upper Member (Zeng, 1991, 2006 *in prep*).

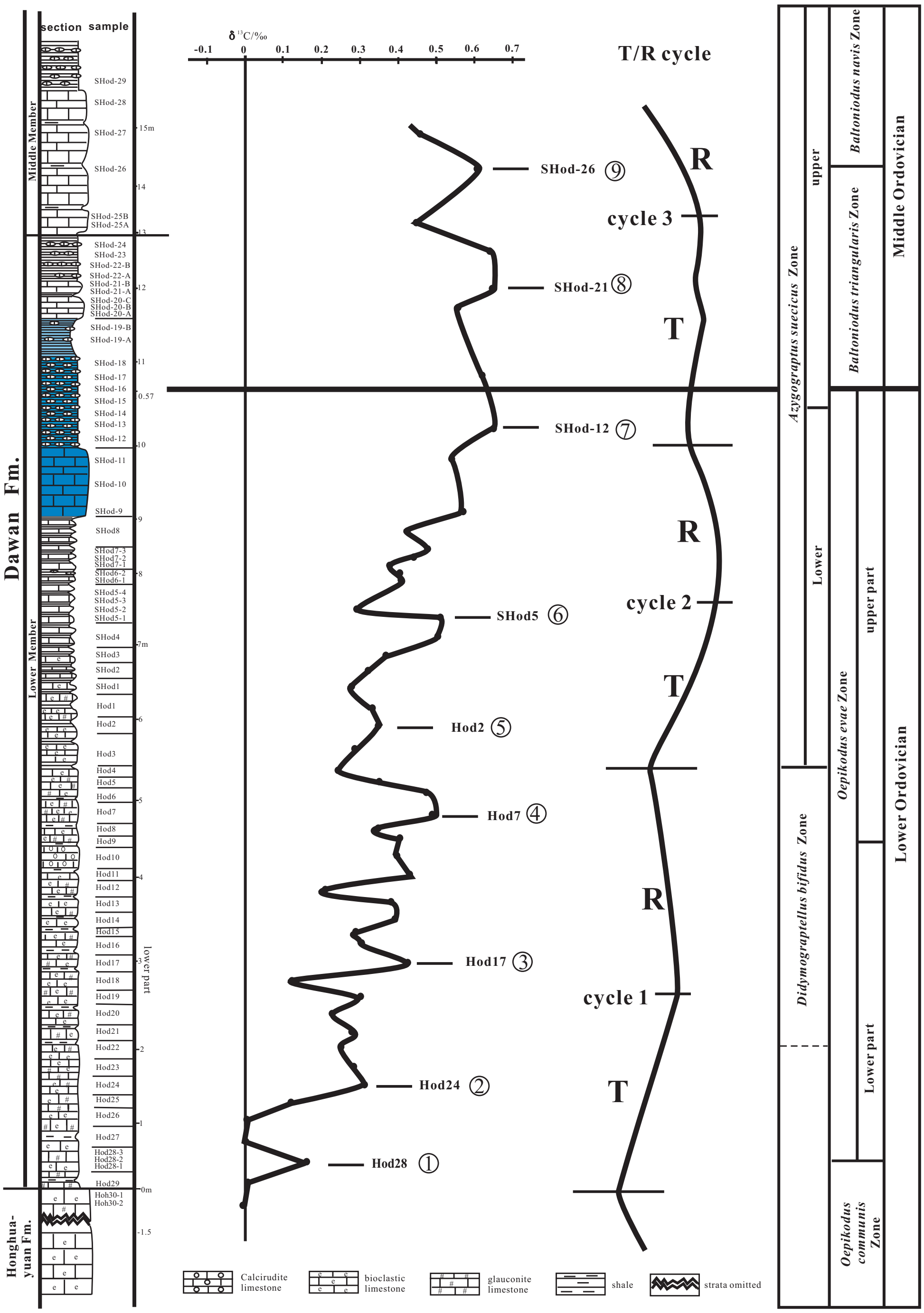

Figure 11. ***$\delta^{13}C$ data on the carbonates from the Lower Dawan Formation and their relation with sea-level changes in the Huanghuachang section.***

Stable isotopic record

During the Early–Middle Ordovician, the Yangtze platform was covered by an epicontinental sea dominated by temperate to cool water carbonate accumulation. The Huanghuachang section, located in the north-central shallow to middle-shelf area of the basin, has a continuous Lower to Middle Ordovician sequence dominated by carbonates with minor argillaceous deposits. The carbon isotopic data obtained from whole rock samples are analyzed bythe MAT 251 mass spectrometer in the Isotopic Geochemistry Laboratory of Yichang Institute Geology & Mineral Resources. The result shows in general a steady rising trend during most of the *O. evae* Biozone (Fig.11). The $\delta^{13}C$ curve begins with a low excursion of around 0‰ in the lowest Dawan Formation and then follows a steady rise of $\delta^{13}C$ values until the maximum value of +0.68 ‰ close to the boundary between the middle and upper parts of the Lower Member of the Dawan Formation. Higher in the section, the $\delta^{13}C$ values are constant, but define two small peaks in the upper part of the Lower Member to the lower part of the Middle Member. The isotopic composition of the Lower Member reveals a significant relation of positive isotopic shifts with biotic diversification and sea-level fluctuation. The lowest $\delta^{13}C$ value is found to be associated with the transgressive facies at the base of the Dawan Formation and the related biotic change (Fig.11, No.1). The warm water biota was replaced by a predominately cool-water biota. The two succeeding positive excursions (Fig.11, Nos.2–3) during the first transgressive to regressive cycle may reflect changes in carbonate sedimentation and organic productivity. A relatively higher $\delta^{13}C$ value (No. 4) is coincident with the sea-level fall preceding the FAD of *Azygograptus suecicus*.

An interesting change is the maximum carbon isotopic positive excursion (Fig.11, No.7), which is coincident with a sea-level lowstand and an accumulation of various organic-shelly fossils at the Huanghuachang section. This is interpreted to be related to the eustatic sea-level lowstand event found in the lowest Whiterockian of North America (Ross & Ross, 1992) and the lowest Volkhov of Baltoscandia (Nielsen, 1992, 2004). It is worth noting that this event in the continuous sedimentary succession of the Huanghuachang section was preceded by the speciation event represented by the FAD of *B. triangularis*. Further up section are two smaller positive isotopic excursions (Fig.11, Nos.8–9), which may be related to changes in carbonate sedimentation and produced by the smaller sea-level pulses.

Organic maturity

The organic maturity of the Huanghuachang section was studied using CAI, reflectance of graptolites and chitinozoans, and IR-studies (Wang et al., 1992b, 1993). The vitrinite reflectance equivalent is estimated 0.9–1.1% R_o, and the CAI is 2–3, indicating that the Huanghuachang section is suitable for the palaeomagnetic and geochemical study.

Identification of the Huanghuachang GSSP

The Huanghuachang GSSP has excellent and well-known conodont, chitinozoan, graptolite, acritarch, and trilobite, brachiopod fossil records in a stratigraphically continuous succession. Its conodont succession across the Lower and Middle Ordovician boundary interval is well developed with several evolving lineages (Figs.3,10). The stratigraphic level of the GSSP coincides with the FAD of *Baltoniodus triangularis*, where this species develops from its immediate ancestor, *B.* cf. *triangularis*. This datum is also coincident with the FAD of *Periodon* sp. A, and followed by the FAD of *Microzarkodina flabellum*, which all are very useful for global correlation of the boundary. The proposed boundary level in the Huanghuachang section approximates the boundary between the lower and upper intervals of the *Azygograptus suecicus* Biozone and is nearly coincident with the base of the *Belonechitina henryi* chitinozoan Biozone (Fig.5).

The Huanghuachang GSSP is located in a roadside exposure at the base of the bed SHod-16. The boundary level is 10.57m above the base of the Dawan Formation, and 0.6 m above the top of the distinctive 0.9 m-thick, highstand dolomitic limestone (SHod-9–11) with the maximum carbon isotopic excursion related with the worldwide lowstand event in the uppermost part of the Lower Member of the Dawan Formation. The boundary level falls within a transgressive succession characterized by thin-bedded nodular limestones with graptolite-bearing yellow green shale interbeds (Fig.3). Its geographic coordinates are: latitude 30°51'37.8"N; Longitude 110°22'26.5" E of Greenwich.

Global correlation of the GSSP

The base of the Middle Ordovician Series and the Dapingian Stage is within a stratigraphic interval that is characterized worldwide by a very high degree of biogeographic provincialism and palaeoecological differentiation (Ross & Ross, 1992; Webby 1998, 2004; Finney 2005). Conodonts and graptolites are the fossil groups most used for correlation of Ordovician strata, in large part because of their wide global distributions. Nevertheless, in the boundary interval North Atlantic and Midcontinent province conodont faunas and Atlantic and Pacific province graptolite faunas characterize stratigraphic successions of different paleoplates and paleoecological setting. The conodont and graptolite faunas in the Huanghuachang section are dominated by conodont species of the North Atlantic province and graptolite species of the Atlantic province. Nevertheless, the Huanghuachang GSSP can be correlated into the zonations of Midcontinent province conodonts and Pacific province graptolites with confidence and considerable precision.

The base of the *B. triangularis* Zone in the Baltoscandia (North Atlantic province) zonation was suggested to coincide with the base of *Tripodus laevis* Biozone in the North American (Midcontinent province) zonation based on considerable available evidence (Bergström, 1995). Both were proposed as the biohorizon for the definition of the base of the global Middle Ordovician Series (Webby, 1994). The conodont succession identified in the Lower Member of the Dawan Formation of the Huanghuachang section further demonstrates that the base of the *B. triangularis* Biozone can easily be recognized in both the North Atlantic Realm and the Mid-continent Realm (Table 2). The occurrence of *M. flabellum* in the Huanghuachang section demonstrates that the boundary coincides with the base of the *T. leavis* Biozone in type localities for the North American Whiterockian and the Ibexian sections (Ethington & Clark, 1982, Ross *et al.*, 1997). It also correlates with the base of the *T. leavis* Biozone in the upper San Juan Limestone of Precordillera, San Juan, Argentina (Albanesi et al., 2003, 2006) based on the presence of diagnostic fossils typical of the underlying *Oepikodus evae* Biozone, e.g. *Reutterodus andinus*, *Oepikodus intermedius* and *Microzarkodina* sp. A. The conodont succession across Lower–Middle Ordovician boundary at Huanghuachang section clearly shows that the base of the *B. triangularis* Biozone correlates with the base of *B. triangularis* Biozone at the base of the Volkhov Stage of the Baltoscandian region (Bagnoli and Stouge, 1997) and northwestern Russia (Tolmacheva et al., 2001, 2003, Dronov et al., 2003). The occurrence of *Azygograptus ellesi,* together with *Xiphograptus*

Table 2. The biostratigraphic correlation across the Lower / Middle Ordovician boundary between the recommended GSSP with the Jiangnan Slope, China, North Europe, North America, South America and Australia (Modified from Wang et al. 2005).

Ordovician Series	South China						Northeast Europe		North America		South America	Australasia
	Huanghuachang section					Jiangnan Slope	Baltoscandia	NW. Russia	Great Basin	W. Newfoundland	Argentina	
	Fm.	Unit	Conodont zones	Graptolite zones	Chitinozoan zones	Graptolite zones	Conodont zones	Conodont zones	Conodont zones	Conodont zones	Conodont zones	Graptolite zones
			(An 1987; Wang et al. 2005; this report)	(Wang et al. 2005; this report)	(Wang et al. 2005; this report)	(Chen X. et al.,2003; Zhang and Chen,2003)	(Lindström 1971; Löfgren 1995; Bagnoli & Stouge 1997)	(Viira et al. 2001; Tolmacheva 2001)	(Ross et al. 1997)	(Stouge & Bagnoli 1988; Johnston & Barnes 1999)	(Albanesi 1998; Albanesi et al. 2003)	(Webby & Nicoll, 1989)
Middle Ordovician	Dawan	Middle Member	*Baltoniodus navis*		*Belonechitina cf. henryi*	*Isograptus cadeus imitatus*	*Baltoniodus navis*	*Baltoniodus navis*	*Histiodella altifrons*	Not Zoned	*Baltoniodus navis*	Ca3 *Isograptus (v.). maximus*
Middle Ordovician	Dawan	Middle Member / Lower Member	*Baltoniodus triangularis*	*Azygograptus suecicus* (Upper)	*Belonechitina cf. henryi*	*Isograptus cadeus imitatus*	*Baltoniodus triangularis*	*Baltoniodus triangularis*	*Tripodus laevis*	*Tripodus laevis*	*Tripodus laevis*	Ca2 *Isograptus (v.). victoriae*
Lower Ordovician	Dawan	Lower Member	*Oepikodus evae* (Upper)	*Azygograptus suecicus* (Lower)	*Conochitina pseudocarinata*	*Azygograptus suecicus*	*Oepikodus evae*: *Microzar-kodina* sp. A	*Oepikodus evae*	*Reutterodus andinus*	*Tripodus laevis*	*Oepikodus intermedius*	Ca1 *Isograptus (V.) lunatus*
Lower Ordovician	Dawan	Lower Member	*Oepikodus evae* (Upper)	*Azygograptus suecicus* (Lower)	*Conochitina langei*	*Corymbograptus deflexus*	*Oepikodus evae*: *Trapezo-gnathus diprion*	*Oepikodus evae*	*Reutterodus andinus*	*Oepikodus evae*	*Oepikodus intermedius*	Ch2 *Isograptus primulus*
Lower Ordovician	Dawan	Lower Member	*Oepikodus evae* (Upper / Lower)	*Didymograp-tellus bifidus*	*Conochitina langei*	*Didymograp-tellus protobifidus*	*Oepikodus evae*: *Trapezo-gnathus diprion*	*Oepikodus evae*	*Reutterodus andinus*	*Oepikodus evae*	*Oepikodus evae*	Ch1 *Didymograptellus protobifidus*
Lower Ordovician	Dawan	Lower Member	*Oepikodus evae* (Lower)	No graptolite data	*Lagenochitina estonica*	*Pendeograptus fruticosus*	*Oepikodus evae*: *Oepikodus evae*	*Oepikodus evae*	*Reutterodus andinus*	*Oepikodus evae*	*Oepikodus evae*	Be1-4 *Pendeograptus fruticosus*
Lower Ordovician	Dawan	Lower Member	*Oepikodus communis*	No graptolite data	*Lagenochitina estonica*	*Tetragraptus approximatus*	*Prioniodus elegans*	*Prioniodus elegans*	*Oepikodus communis*	*Prioniodus elegans*	*Prioniodus elegans*	La3 *Tetragraptus approximatus*
Lower Ordovician	Hong-huayuan		*Serratognathus diversus*	No graptolite data	*Conochitina symmetrica*	*Tetragraptus approximatus*	*Paroistodus proteus*	*Paroistodus proteus*	*Acodus deltatus* - *Oneotodus costatus*	*Prioniodus adami* / *Prioniodus oepiki*	*Paroistodus proteus*	La3 *Tetragraptus approximatus*

svalbardensis, *Expansograptus* sp., *Pseudotrigonograptus* sp. in the upper *Azygograptus suecicus* Biozone, moreover, allows for the correlation of the base of *B. triangularis* Biozone at the Huanghuachang section with the level close to the base of *Isograptus v. victoriae* graptolite Biozone (Ca2) of the Australia standard (Webby and Nicoll, 1989; Wang et al., 2005).

The worldwide lowstand event preceding the FAD of the *B. triangularis* in the Huanghuachang section and the related carbon isotopic positive excursions are auxiliary physical and geochemical global markers.

Graphic correlation was carried out for conodont and graptolite data from 20 sections that represent a great range of biotic provinces and depositional environments for conodonts and both Atlantic and Pacific provinces for graptolites. The correlations resulting from the graphic correlation are consistent with those proposed by Cooper and Lindholm's (1990) for graptolites, and further confirm that the FAD of *Baltoniodus triangularis* in the Huanghuachang section correlates with a level close to the base of the *I. v. victoriae* graptolite Biozone (Fig.12). This permits the series boundary to be correlated with precision and confidence into graptolite successions with Pacific province faunas (Stouge et al., 2005, 2006).

It is concluded that the Huanghuachang GSSP has excellent and well-known conodont, chitinozoan, graptolite, acritarch and other shelly fossil records in a stratigraphically continuous succession. Its conodont succession across the proposed boundary interval is well developed with several evolving lineages (Figs.5, 10). The proposed boundary coincides with the FAD of *B. triangularis*, which has long been used in other important Ordovician successions worldwide. It can be directly correlated with zonal level precision into the graptolite succession in both Atlantic and Pacific provinces on the occurrence of graptolites in the Huanghuachang section (Finney, 2006), so that it can be recognizable worldwide in both shelly and shale facies.

Summary and Formal Proposal

The proposed Global Stratotype Section and Point for the base of the Middle Ordovician Series and the lower stage of the Middle Ordovician Series at the Huanghuachang section, near Yichang, Hubei, China fulfills all the basic requirements for a GSSP as follows:

1. The proposed GSSP is accessible and well protected. It is 22 km away from Yichang City and well exposed in the Ordovician Geopark near the main road. A stone marker indicating the base of the Dawan Formation was set up in 1978 and a new big protective marker erected on the upper Lower Dawan Formation for ensuring its protection in 2004.
2. The boundary interval is well exposed with adequate thickness. The structure is simple and the section is without serious structural disturbances.
3. The boundary is within a transgressive sequence and within an

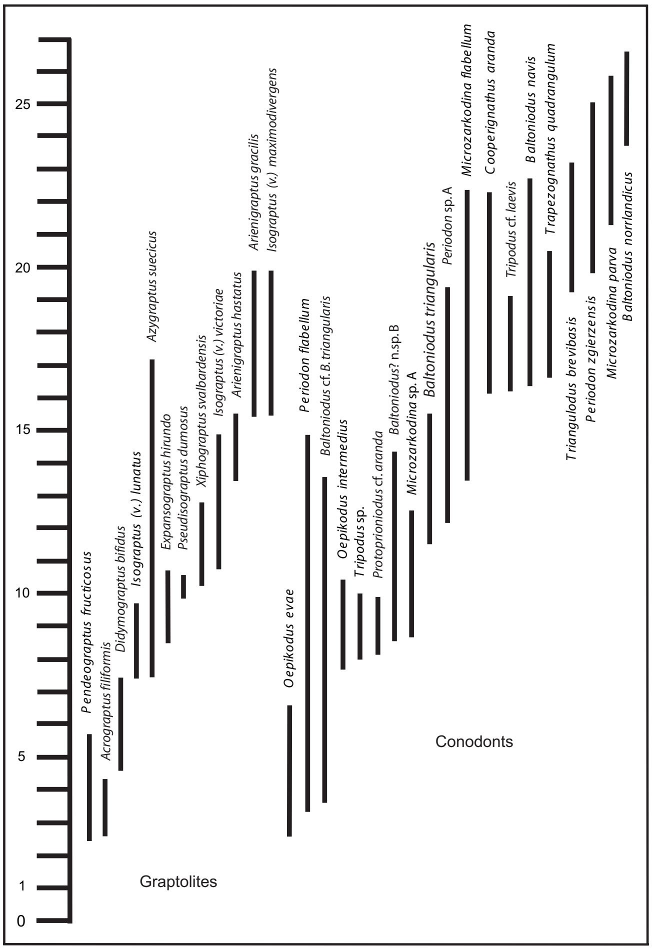

Figure 12. Ranges of selected species from the composite section achieved by means of graphic correlation between 20 Lower–Middle Ordovician Series boundary sections with the high palaeolatitude faunas or low palaeolatitudinal faunas, respectively

interval of uniform lithology, indicating continuous deposition in the boundary interval.

4. Various fossil groups, including conodonts, graptolites, chitinozoans, acritarchs, trilobites and brachiopods are well represented in the boundary interval and allow for correlation into both North Atlantic and Midcontinent conodont provinces, and Atlantic and Pacific graptolite provinces.
5. The conodonts are very abundant and diversified with several evolving lineages in the boundary interval. Associated graptolites plus well-preserved and abundant chitinozoans provide auxiliary markers for the recognition and correlation of the boundary biohorizon in both shelly and graptolite facies.
6. The continuation of several evolving conodont lineages and the range of many additional species of conodonts, graptolites and chitinozoans across the boundary indicate the absence of any significant hiatus at the boundary.
7. The CAI values and the reflectance of organic-walled fossils indicate that the section is suitable for palaeomagnetic and chemostratigraphic studies.
8. The base of the Middle Ordovician Series and the Third Stage named Dapingian Stage coincides with the first appearance of *B. triangularis* at the base of Shod16, 10.57m above the base of the Dawan Formation. This level is 0.2 m below the FAD of *Microzarkodina flabellum*, close to the boundary between the lower and upper *Azygograptus suecicus* Biozone and nearly coincident with the base of the *Belonechitina* cf. *henryi* chitinozoan Biozone. Thus, this biohorizon at the GSSP can be recognized and correlated globally with high precision on the basis of a number of speciation events.

The present paper, modified from the proposal to ISOS (Wang et al. 2005) and final report to ICS and IUGS in January, 2007, was submitted in August 2007 after the Huanghuachang section was approved as the GSSP.

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