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SPECIAL OBSERVATIONS CONCERNING THE SINIAN-CAMBRIAN TRANSITION AND ITS STRATIGRAPHIC IMPLICATIONS ON THE CENTRAL AND SW YANGTZE PLATFORM, CHINA

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INTRODUCTION

The Yangtze Platform also referred to as "South China Plate" or "Yangtze Plate" was a discrete medium-sized partially cratonized metastable plate during the Neoproterozoic to Early Paleozoic interval (Chen and Rong, 1992). This plate is since Late Triassic bounded in the north by the Qinling-Dabieshan Suture against the much earlier consolidated Sino-Korean Plate (Maruyama, Liou and Seno, 1989). The western margin is usually taken along the Longmenshan and Erlangshan Mts. in Sichuan ("Songpan-Garze Fold System") and the southwestern margin against the Shan-Thai and Sibumasu terranes along the Ma River Fault System ("Song Ma") of NW Vietnam, probably including the northern (?) and central regions of Hainan Island. In the east the South China Plate is cut off by a complex fault system of the Tanlu and Shaoxing Faults. A contemporary extension of the Yangtze Plate into the south of the Korean Peninsula cannot be confirmed (Chough *et al.*, 2000). Between southern Yunnan across northern Vietnam (Cam Duong and Sapa Groups) to Hainan the Yangtze Plate margin was affected by an Early Paleozoic deformational event because the lithologies in Vietnam suffered thermal metamorphism up to tremolite facies. Most problematic is the nature and exact location of the southern and south-eastern margin of the Yangtze Platform because the Cathaysian Arc may have absorbed parts of a Precambrian consolidated southern basement ("Cathaysian Oldland": Chen *et al.*, 1991). Within this extensive territory (which includes from east to west and north to south the provinces of Jiangsu, Zhejiang, southern Anhui, Jiangxi, southern Shaanxi, Hubei, Hunan, eastern and southern Sichuan, Guizhou, Guangxi, eastern Yunnan, northern Vietnam, east of the Ma River Fault zone, and possibly Fujian, Hainan, Guangdong, and Taiwan) Sinian and Lower Cambrian deposits are widespread and reflect various depositional facies, volcanism and structural regimes and movements (see Fig. 1). Virtually everywhere on the South China Plate the terminal Neoproterozoic-Cambrian deposits are underlain by Varangeran glaciogenic diamictites, which themselves are usually (but not conformably) deposited on Paleo-, Meso- and/or Neoproterozoic (Banxi Supergroup) supracrustal rocks.

The Sinian-Cambrian record reflects various depositional facies types which could be best described by A) Yangtze Platform and B) Zhujiang Basin types with various intermediate and transitional developments. A definitive "slope facies" ("Jiangnan Facies") cannot be established along a linear zone during the Sinian and earliest Cambrian, although the strong local to regional derivation of large clasts within the non-marine tillites points to individual island sources ("Jiangnan Islands": Chen *et al.*, 1991) during glaciation (e. g. at Tongpengai, W. Hunan), however, a more regionally persistent slope seems to have formed during Middle and Late Cambrian. On the other hand, a linear "belt" extends from easternmost Yunnan across Guizhou, NW Hunan to southern Anhui which is characterised by syngenetic active faults and submarine-hydrothermal discharge during the Early Cambrian (Steiner *et al.*, 2001). In general, it may be stated that the northern, northwestern and western parts (as well as small areas of western Zhejiang) of the South China Plate belong to shallow-water shelf basins, whereas black siliceous or phosphatic shales predominate in the Zhujiang "restricted basinal" facies both for the postglacial Sinian and Early Cambrian depositional regimes. Within the somewhat narrower belt of the eastern part of the South China Plate there appears to be a south-north gradient from platformal (Tongying, also spelled as Dengying) facies to basinal (Liuchapo or Piyuanchun) facies, whereas west of Jiangxi Province the gradient is reversed from shallow in the northwest to deeper in the southeast (see Fig. 1).

The critical and much disputed stratigraphic interval between Neoproterozoic and Lowermost Cambrian on the South China Platform concerns deposits which are referred to the Jinningian and the Meishucunian Stages of the newly proposed Diandongian Series (Peng, 2000; Geyer and Shergold, 2000), i. e. the Zhujiaping (formerly Meishucun) Formation of central Yunnan (Zhu, M.Y. personal communication). Based on the IUGS Precambrian-Cambrian boundary decision (FAD of the trace fossil *Trichophycus pedum*, formerly assigned to *Phycodes* and alternatively to *Treptichnus*: see Landing, 1994) and the "pre-trilobitic" Small Shelly Fossil (SSF) zonation, the Jinningian and Meishucunian deposits representing this interval can only be demonstrated in central and northern Yunnan, in south to northeast Sichuan and at special locations in south Shaanxi Province. Redeposited SSF may also occur in other platformal locations such as in the Tianzhushan Member of the Tongying Formation in the classical Three Gorges section of Yichang, Hubei and in northern Hunan as well as possibly in S. Anhui and adjacent W. Zhejiang (Diben and Xintangwu sections, see below). Practically all members of the Zhujiaping Fm. in Yunnan are separated by disconformable contacts which probably indicate major hiatus. The often conglomeratic and brecciated nature of the Zhujiaping beds and the usual washed-together mass occurrences of SSF point to frequent reworking of these sediments in quite shallow marine environments. Mainly for this reason the entire Zhujiaping Fm. (Zhu, personal communication, but "Meishucun Fm." *sensu* Zhang *et al.*, 1997) cannot be considered for GSSP deliberations for the PC/C boundary stratotype.

Far more complete depositional records across the disputed interval could be expected from basinal depotopes, i.e. from the Zhujiang facies region or respective sections. Many such

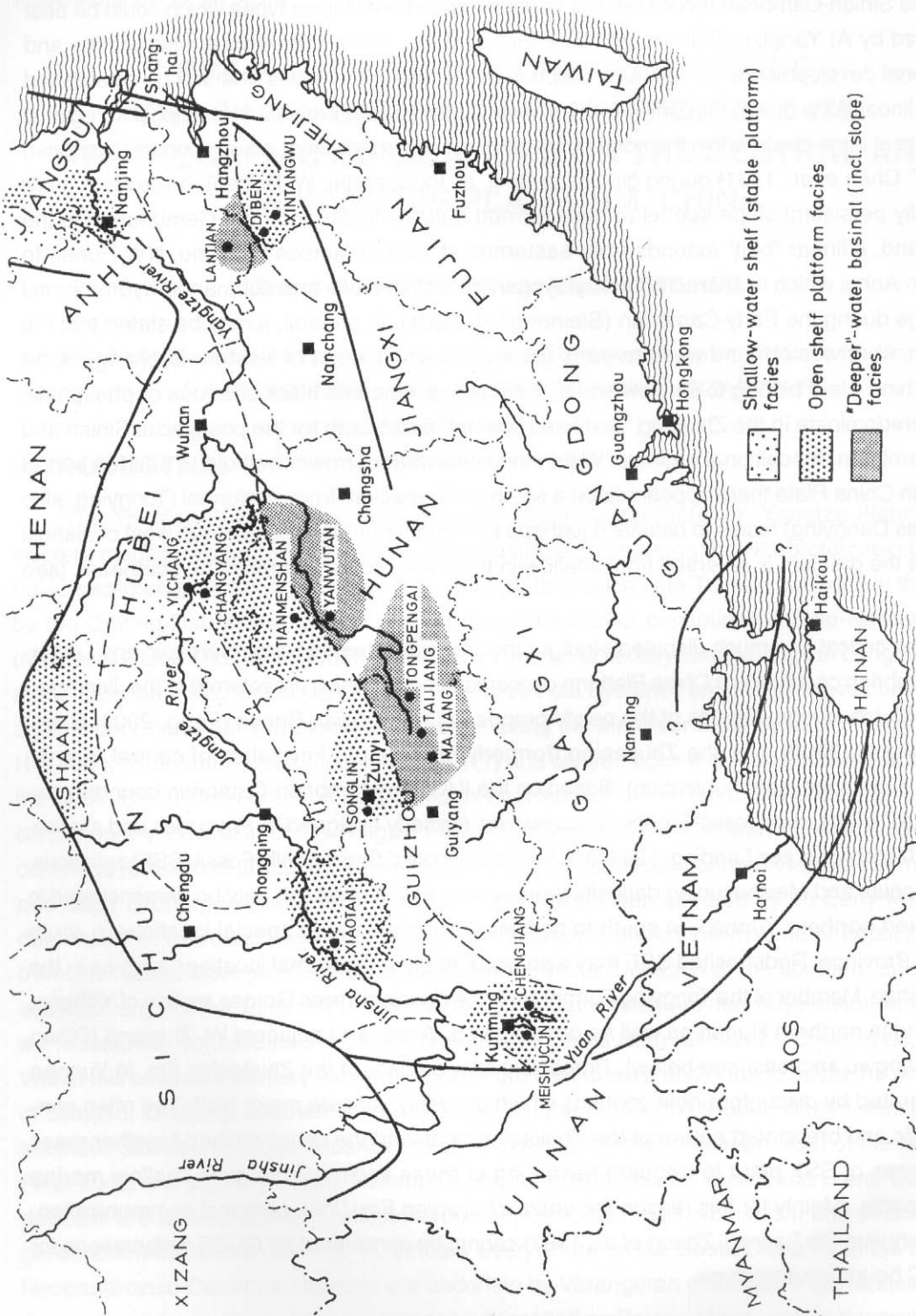


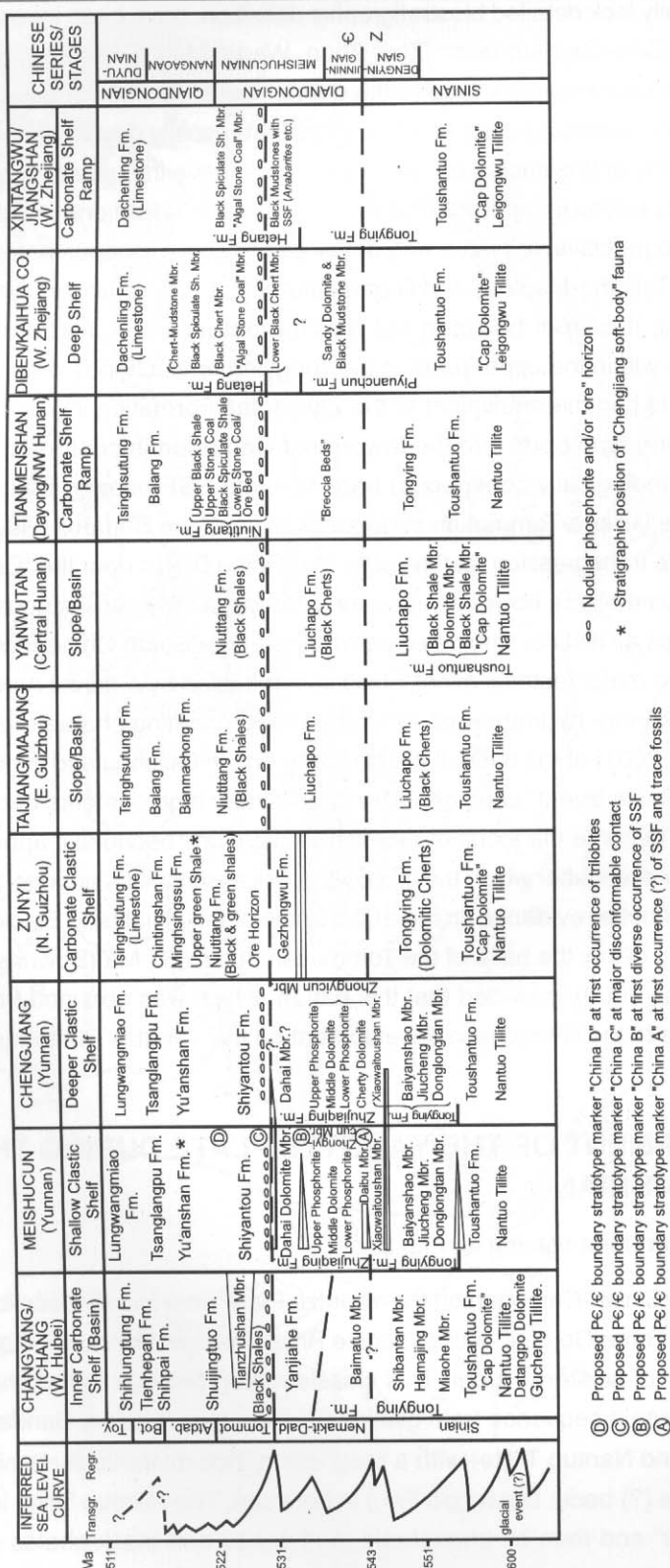
Fig. 1. General map of today's extent of the Yangtze Platform including distribution of generalized lithofacies regions and location of representative sections (full circles, capital letters). Indication is also given for the regions which show evidence of medium- to high-grade metamorphism and potential incorporation of platform-derived terranes (especially along the northern and southwestern margins: oblique stripping). The Sinian-Cambrian development in SE China is not yet known (white regions).

sections which, however, usually lack detailed biostratigraphic definition, have been investigated since 1991 by a collaborative Sino-German team (Zhu, Zhao, Wang, Mao, Erdtmann, Steiner, Siegmund, Wallis: DFG unpublished reports). Due to the deeper water (usually anoxic) conditions these basinal depocenters (including deep shelf locations) are usually devoid of both SSF and trace fossils, but because the entire lithofacies, both below and above the usually sharp PC/C contact is of deep-water type (without apparent erosional or paleosol indications of subaerial exposure) it is surmised that no perceivable hiatus was developed at these "deeper-water" locations (see e. g. at Yanwutan, Taijiang-Majiang and Diben columns in Fig. 2) across the PC/C boundary. On the other hand, it cannot be ruled out that the actual PC/C boundary (in a chronostratigraphic sense) lies within the upper parts of the Tongying or Liuchapo Formations, if one considers these top beds to be time-equivalent to the Zhujiaping Formation in Yunnan and Sichuan. The range of Tongying type beds into the lowermost Cambrian is confirmed by the tubular cloudinids and their (lithologically continuous) transition into SSF-bearing beds which characterize the latest Tongyingian-pre-Tommotian sequences of southern Shaanxi (Hua *et al.*, 2000). The renewed black shale transgression starting after the "China B" - or near the "China C" marker (i.e. possible base of Tommotian), however, appears to denote a very conspicuous short-term event deposit which onlaps all distinct lithologies across the entire South China Plate (see Fig. 2). This is underscored by a major tectonic event which is manifested by a dense network of syngenetic faults, related submarine- hydrothermal exhalations and resulting characteristic Fe-Ni-Mo ore layers (Steiner *et al.*, 2001) at the base of the Niutitang Fm. in Guizhou and in northern Hunan. This "Niutitang Black Shale Event" coupled with extraordinary high contents of organic matter ("algal stone coal") has become the focus of recent investigations because it appears to reflect a "spontaneous" turnover event after which the first body fossil associations appear (Steiner *et al.*, 1993). For current lack of better evidence timing of the onset of this "Niutitang Black Shale Event" has been dated at or just below the base of the Tommotian at ca. 531 Ma (Bowring *et al.*, 1993; McKerrow and Van Staal, 2000), provided that this datum, which was obtained from the Siberian Platform, is correlative to the lithogenetic development on the Yangtze Platform.

LITHOFACIES DEVELOPMENT OF THE YANGTZE PLATE DURING THE SINIAN-LOWER CAMBRIAN

1. The "Three Gorges" region (First column in Fig. 2)

The type sections for the Sinian-Cambrian on the Yangtze Plate were initially described by Lee and Chao (1924) from the "Three Gorges" of the Yangtze River between Yichang and around the "Huangling Granite Dome" of western Hubei. This classic region belongs to the shallow-water carbonate facies, displaying a sequence from glacio-fluvial arkoses (Liantuo Sandstone), two tillite horizons (Gucheng and Nantuo Tillite) with a magnesium-rich rhythmically laminated mudstone (possible glacial lake (?) beds: Datangpo Fm.) in between. The Nantuo Tillite is covered by a basal "cap-dolomite" and then by phosphatic mudstones and black shales of the



Toushantuo Fm. The Toushantuo Fm. is in turn in some areas (Miaohe) covered by an organic-rich black shale horizon which initiates a transgressive cycle of Tongying Fm. carbonates. Above the top of the Tongying Fm., at the base of the Shuijingtuo Fm. in the Three Gorges region there are at least two hiati, into which the (redeposited) small-shelly-bearing Tianzhushan Mbr. is sandwiched, i.e. however, only in those areas where the Yanjiahe Fm. is absent. On the other hand, where the Yanjiahe Fm. is developed, the SSF contained in the Tianzhushan Mbr. are not redeposited. According to modern definition the Tianzhushan Mbr. belongs to the pre-trilobitic Lower Cambrian and the disconformably overlying *Tsunyiidiscus*- and *Hupeidiscus*-bearing black shales of the Shuijingtuo Fm. would indicate the local advance of the first trilobitic (Atdabanian) transgressive cycle. Only ca. 50 km to the south, however, within the Changyang Anticline (at Heziao), black organic shales of the Yanjiahe Fm. containing both *Vendotaenia* and small shelly fossils as well as hyolithids overly Tongying carbonates with a very slight disconformity, lacking the phosphatic carbonates of the Tianzhushan Mbr. Therefore, it is presumed that the Early Cambrian black shale transgression (Yanjiahe) proceeds diachronously from SE to NW, although a detailed biostratigraphic analysis is as yet outstanding. Except for the strongly bioturbated (*Planolites*, *Psammichnites*, etc.) fine-clastic (top Atdabanian to basal Botoman) Shipai Fm. the superjacent Cambrian succession is dominated by carbonates, especially by dolomites (Wang, Erdtmann and Mao, 1996), which contain archaeocyathids near the base (Shipai Fm.), but due to the dolomitization fossils are rare within the partially evaporitic Cambrian succession.

2. The Dianchi Lake region South of Kunming, Yunnan (2nd and 3rd columns in Fig. 2)

The hills around the Dianchi and Fuxian Lakes of central Yunnan are a second classical region for post (Nantuo-) glacial Sinian and Lower Cambrian outcrops of the Yangtze Platform. The counties of Kunming in the north, Jinning in the west, Jiangchuan in the southeast, Chengjiang and Huaning in the east and Chenggong and Yiliang in the northeast offer several hundred artificial and natural outcrops of Sinian and Lower Cambrian sediments yielding probably the best insight into critical litho- and biostratigraphy and facies relations across this latest Neoproterozoic to Cambrian interval. The famous Meishucun Precambrian/Cambrian boundary stratotype candidate section of the Xiaowaitoushan Mtn. is located in Jinning County as well as the Haikou fossil site (Jinning County; Luo *et al.*, 1997) and, of course, the Maotianshan and Ma'anshan fossil sites for the unique "Chengjiang fauna" (Zhang and Hou, 1985), which are located in Chengjiang County. The general lithostratigraphy has been subject to several revisions since Lu (1941) and Lu and Zhu (1981) established a lithostratigraphically based stage system for SW China in the Kunming region (but see Peng, 2000).

The complexity of the Sinian-Lower Cambrian lithostratigraphy in the Dianchi Lake region is largely due to locally heterogenic facies developments as a result of basically very shallow marine environments. At the Wangjiawan locality in the south of Jinning County the rather thin (7.70 m) continental Nantuo Tillite is succeeded by cherty laminarites of the Toushantuo Fm. which is overlain by a thick dolomitic Donglongtan Mbr., a rough equivalent of the Hamajing Mbr. of the Tongying Fm. in the Three Gorges region. The Jiucheng Mbr. (probable correlative of the Shibantan

Mbr. of the Three Gorges region) contains a great diversity of *Chuarina*, *Vendotaenia*, *Tyrasotaenia*, and other mega-algal fossils. Similar assemblages were also observed from the Jiucheng Mbr. along the inclining road between Meiyie and Dapotou villages near the Maotianshan in Chengjiang County. The 360 m thick Baiyanshao Mbr. consists of mostly calcareous siltstones and mudstones.

The PC/C boundary is usually drawn at the contact between the Xiaowaitoushan Mbr. of the Tongying Fm. and the Zhongyicun Phosphorite Mbr. of the Zhujiqing Fm. (see above), although the contact relations are being debated (Zhang *et al.*, 1997) as to their time-conformable transition. Zhang *et al.* (1997) argue that a far more complete and conformable sequence can be observed at Xiaotan, Yongshan County in northern Yunnan, where the Xiaowaitoushan Mbr. is replaced or succeeded by the Daibu Mbr., a much thicker black to grey cherty siltstone containing small shelly fossils displaying, however, a disconformable contact with the underlying Baiyanshao Mbr., too. Zhu, M.Y. (based upon $\delta^{13}\text{C}$ -isotope stratigraphy, personal communication, 2001) strongly argues to place the PC/C boundary within the Daibu Mbr. of the Zhujiqing Fm. based on the stratigraphically more complete Xiaotan section.

The Zhongyicun Mbr. of the Zhujiqing Fm. consists of ubiquitously mined phosphorites, rich in Assemblage 1 and 2 SSF and in trace fossils, containing a so-called "white middle member" of metabentonites, thinly bedded dolomite and mudstones. These economically and stratigraphically significant phosphorites may represent a relatively short time interval, but probably also record the beginning of an active volcanic phase as part of the "Sancha Disturbance".

In the Dianchi Lake region both the lower and upper contacts of the Zhongyicun Phosphorites and of the superincumbent dolomitic siltstones of the Dahai Mbr. are disconformable, especially the top contact of the latter is sharp against the black heavily bioturbated (*Psammichnites*, *Planolites*, etc.) Shiyantou Fm. According to a more recent single-zircon dating (taken from Siberia: Bowring *et al.*, 1993; McKerrow and Van Staal, 2000) the stratigraphic interval between the Xiaowaitoushan deposition and the base of the Shiyantou (the range of the Nemakit-Daldyn Stage in Siberia or the lower Diandongian Stage of China) would entail at least ca. 13 million years (based on radiometry from Siberia) which most certainly were not fully represented by the rather coarse-grained or brecciated phosphorites of the Zhongyicun Mbr. At many locations the basal horizon of the Shiyantou Fm. contains small phosphoritic nodules and several beds near the top of the Shiyantou Fm. displaying "flow rolls" as well as layers of metabentonite (Zhang *et al.*, 1997) which may further underscore the presence of tectonism and volcanic activity at this level. It should be pointed out that the phosphoritic nodular layer at the base of the Shiyantou Fm. (old "China B"-marker) is here taken to indicate a quasi-synchronous event slightly above the base of the Tommotian, which appears across the entire Yangtze Plate regardless of different lithofacies environments (see Fig. 2). At present time it is not possible to apply bio- or chronostratigraphic methods to discern a potentially diachronous black shale onlap on the Yangtze Platform as previously claimed (Steiner *et al.*, 1993).

The FAD of trilobites in Yunnan is generally seen near the base of the Yuanshan Fm. In

contrast to deeper water facies in Zunyi, Guizhou (4th column in Fig. 2), however, among tiny eodiscids, such as *Tsunyiidiscus*, also the redlichiid genus, *Parabadiella* is found, which according to Luo, Jiang and Tang (1994) would be the oldest trilobite on the Yangtze Platform (Atdabanian marker "China D") - if not worldwide. Chengjiang-type fossils cooccur with trilobites into the 57-67 m level of the Yuanshan Fm. (at the Dapotou ravine near Chengjiang), where the well-known soft-bodied richly diverse soft-bodied "Chengjiang Fauna" appears at many localities on both east and west sides of Dianchi Lake (2nd and 3rd columns in Fig. 2).

3. The Zunyi section (4th column in Fig. 2)

Ca. 20 kms to the west of the northern Guizhou city of Zunyi, around a small town of Songlin, a ca. 12 km diameter structural "dome" exposes the entire Sinian succession from the Nantuo Tillite upsection into the Lower Cambrian. Along the periphery of the Sinian outcrop, especially of the top Tongying outcrop margin, several contacts with the Lower Cambrian black Niutitang Shales are well exposed. At the Heishapo Hill, ca. 6 km SW of Songlin, the Sino-German team discovered a new fossiliferous section in April 1998 displaying at its base a partially reworked 27 cm thick phosphorites belonging to the Gezhongwu Fm. (which increases significantly in thickness to the SW) upon a conformable contact with Tongying silicified dolostones. Upon this contact a ca. 1 m thick "ore horizon" (black shale hosted ore debris and layers, containing massive pyrite and other Ni-, As-, Sb- sulfides) occurs which is overlain by ca. 45 m of grey and black pyritic mudstones replete with hexactinellid sponge spicules, root tufts and entirely preserved sponge bodies, with *Byronia* spp., bivalved arthropods of *Perspicaris* sp.(-type) and undetermined bradoriids, and near the top tiny triangular tubes referred to tunicates (Zhao *et al.*, 1999). Even more prolific appears to be a greenish mudstone bed at the middle part of the Niutitang Shales at Heishapo which yields similar soft-bodied biota as found in the probably coeval middle Yuanshan Fm. of Chengjiang and around Dianchi Lake in Yunnan, such as *Tsunyiidiscus*, *Naraoia*, *Scenella*, and others. A more thorough investigation of this section is expected to produce a continuous fossil record from the upper Tommotian to Atdabanian "Niutitang Black Shale Event" into the upper Atdabanian (Yuanshan Fm.) strata containing the Chengjiang fauna.

4. The Taijiang County sections in eastern Guizhou (5th column in Fig. 2)

In the vicinity of the east-central Guizhou city of Kaili, especially near the village of Yangtiao in Majiang County and along the Qingshui River near Gedong town in Taijiang County, are several good natural exposures documenting the most important segments of the stratigraphic interval under discussion. The Qingshui River section displays a very condensed Sinian part of the sequence in which the combined thickness between Nantuo Tillites and the Niutitang (formerly "Jiumenchong") Black Shales measures no more than ca. 100 m. This condensation of the Touthantuo and common deeper-water black cherts of the Liuchapo Fm. (formerly Laobao Fm. in central and western Hunan) has also been observed at Tongpengai right on the border between Guizhou and Hunan in Xinhuang County, where the entire Sinian succession with all

formations being present only measures 27 m in total thickness. Tightly folded slumps are common, especially in the primarily mud-supported strata, i.e. in the Toushantuo, Liuchapo and basal Cambrian Niutitang Fms., which indicate that the Liuchapo cherts were originally deposited as black clays and muds and their silicification is due to a later basal Cambrian(?) diagenetic process probably controlled by exhalative vents nearby (Steiner *et al.*, 2001).

At Yangtiao village the basal Cambrian Niutitang Black Shales start with phosphoritic nodules on top of grey cherts (which are probably "Meishucunian" in age) and extend at least for 25 m upsection. The contact between the chertified Tongying-"Liuchapo" beds and the Niutitang Fm. appear to be sharp but conformable. It is possible, although as yet lacking fossil dating, that the Liuchapo Fm. reaches into the early Meishucunian Stage of the earliest Cambrian. Except for very rare hexactinellid sponge spicules the lower 15 m of the Niutitang Fm. seem to be devoid of macrofossils. Above the 15 m level, for at least 10 m, *Perspica*-like arthropods are found. This succession displays a potential phylogenetic or at least morphogenetic series of form variation of the bivalved arthropods which provisionally are placed into *Perspica*. Further upsection trilobites belonging to *Hupeiidiscus* were also found.

5. The Yanwutan section near Yuanling in west-central Hunan (6th column in Fig. 2)

The Yanwutan section is a natural river gorge exposure very close to a hydroelectric power dam on a tributary of the Yuan River. Similar to the Taijiang-Majiang sections described above this section is apparently complete for the Sinian part but very much reduced in thickness. There are at least 3 "segments" two of which are individually intensely slump-folded which probably indicates influence of gravity-induced instabilities. The distinct slumps were triggered at the termination of sedimentary cycles right after the deposition of carbonate members (Toushantuo III Mbr. and carbonate beds in the lower part of the Liuchapo Fm.). The only undeformed gradual contact within this multiple-deformed succession is across the Liuchapo-Niutitang transition, i. e. "somewhere" across the PC/C boundary.

Below the concrete dam several tens of meters of Nantuo Tillite are exposed which contain pyrite rimmed angular clasts and unusually many euhedric pyrite concretions indicating reduction of sulfates during deposition of bedded marine tillites. The upper part of the tillite shows laminar bedding with dropstones, i.e. the development of a glacial-marine environment. A "cap dolomite" is also seen, but only ca. 50 cm thick. The Tausantuo Fm., characteristic for the basinal "uplift" sections ("Jiangnan Islands"?), is set up as 4 members (incl. the cap dolomite on top of the Nantuo Tillite), although the 4th member, an organic-rich black shale should be regarded as the initial transgressive unit of the Liuchapo Fm. carbonate beds are usually only less than 1 m thick and consist of "primary" (?) deep-water dolomites (Tucker, 1982; Kempe, 1990).

The Liuchapo Fm. is not consistently developed as bedded black chert, but it is interbedded with dolomites and breccias. There is no perceivable interruption nor disconformable contact between the Liuchapo Cherts and the cherty black shales of the Niutitang Fm. Over an interval of several meters widely dispersed phosphorite nodules may be observed and a distinct sharp

increase of carbon ("stone coal"?), below which the PC/C boundary was drawn during field work. Only a few cm above this "pitch-black" marker bed first very small sponge spicules are observed, whereas vendotaenids (which are usually associated with late Tongyingian laminarites, e.g. Shibantan Mbr. of the Three Gorges region) occur within the basal 10 m of the lowermost Cambrian Niutitang Fm. The latter black shale sequence is cyclically intercalated by reddish-weathering Fe-rich dolomitic mudstones.

The condensed nature and total absence of phosphoritic SSF-bearing beds makes a decision for the PC/C boundary in the Yanwutan section extremely difficult. Faint *Planolites*-type trace fossils are observed ca. 14 m downsection from the selected C-rich marker bed which, however, may best correspond to the late Meishucunian "Niutitang Black Shale Event" and not denote the internationally established PC/C boundary near the old "China A"-marker bed, near which horizon *Trichophycus pedum* had been observed according to Chen and Zhou (1997, p. 20).

6. The Tianmenshan sections, South of Zhangjiajie City (Dayong) in the Wuling Mts. of NW Hunan (7th column in Fig. 2)

In the central part of the Wulingshan South of the city of Zhangjiajie (former Dayong) numerous mine pits and adits were intermittently opened into the basal Niutitang (formerly locally called Muchang Fm.) because of resources of organic-rich "algal stone coals" which are burned in open pits by local farmers to produce lime from the overlying Tsingshutung carbonates. Especially near the road checkpoint Sansha and near the village of Daping numerous bedding parallel excavations (pits and adits) are observed, which have yielded sulfide ores and rare element associations (Fe-Ni-Mo-sulfid debris and layered horizons: SEDEX ores) immediately overlying a basal phosphorite nodule layer (Coveney and Chen, 1991; Coveney *et al.*, 1992; Steiner *et al.*, 2001). The basal beds of the Niutitang Fm. have also yielded mass occurrence horizons of *Perspicaris*, hexactinellid sponges and of tiny pyritized tubes which were originally interpreted as small shelly fossils (Erdtmann, field notes, 1987, 1991) and may represent tunicates. (see Zhao *et al.*, 1999, pl. 1, fig. 2). Detailed geochemical analysis of the Sansha ore beds gave evidence for syntectonic displacement of the underlying Tongying cherty dolomites ("brittled stockwork") and short-term existence of submarine-hydrothermal exhalations immediately overlying the Tongying-Niutitang boundary and the association of first organic-shelled *Perspicaris* and other metazoans having been associated with chemotrophic bacterial communities as possible nutrient source in this hypoxic environment (Steiner *et al.*, 2001). The Niutitang Black Shale sequence is more than 100 m thick in the Tianmenshan area, yielding large siliceous sponge spicules and excellent sponge bodies (Steiner *et al.*, 1993; Mehl and Erdtmann, 1994) being followed upsection by yellow-weathering green shales of the Balang Fm. which contains trilobites.

7. The Diben and Xintangwu sections in western Zhejiang (8th and 9th columns in Fig. 2)

Two sections should here represent numerous outcrops which are known to occur between the Huangshan (Yellow) Mts. in southern Anhui and Kaihua, Changshan and Jiangshan Counties in western Zhejiang in the west and Shaoxing County east of Hangzhou City in eastern

Zhejiang. In general, the Sinian formations, i.e. the basal tillites (here usually referred to as Leigongwu Fm.) and the Toudantuo Fm. display lithologically similar developments as in the Hunan to Yunnan sections. Furthermore, the carbonate facies of the Tongying Fm. is seen again in several sections between Kaihua and Jiangshan Counties and further east, but the northern sections (near Shishan and Lantian in southern Anhui) document black cherts similar to the Liuchapo Fm. (in this region called Piyuanchun Fm.), instead of Tongying-type carbonates. Therefore, it is interpreted that at least in the Huangshan County region deeper water facies prevailed through the Upper Sinian interval.

Based upon the occurrences of "concretionary" phosphates and massive pyrite and widely mined "algal stone coals" within black shales and black cherts, the lower boundary of the Lower Cambrian Hetang Fm. is usually defined in these sections. Both in the Diben and Xintangwu (and at several other) sections "algal stone coals" are intercalated at least at two horizons with black cherty shales containing mass occurrences (possible "mesh carpets" which may have covered parts of the seafloor) of hexactinellid sponge spicules. At the Diben and Xintangwu sections also *Anabarites*-type SSF are reported to occur in thin lenticular carbonate lenses at the top of the Tongying Fm. Except for these possibly reworked occurrences the presence of distinctly Jinningian and Meishucunian sediments (e.g. phosphorites or coeval deposits) cannot be directly observed in the same lithofacies at virtually all eastern Yangtze Platform sections.

LITHOFACIES DEVELOPMENTS AND CHRONOSTRATIGRAPHIC CORRELATIONS ACROSS THE YANGTZE PLATFORM

As described above for the most representative lithological successions on the Yangtze Platform there are those formations and ore horizons which allow a reasonable long-distance correlation and there are other stratigraphic segments which are difficult to interpret and to date with a certain degree of precision. Considering paleoclimatological controls, the Nantuo-Leigongwu Tillites and their "Cap Dolomites" are most positively correlative. Also, the rather monotypic development of the Toudantuo Fm. does not present major correlation problems (except for the "top black shale member" which may be best included as the transgressive part of the Tongying Fm.). The Tongying and Liuchapo Fms. represent different facies depending on carbonate platform to deeper-water location and environment (Wang *et al.*, 1998). The lower boundary of these distinct lithological units may be better correlative than the tops which probably encompass the time interval of the Jinningian and of the Meishucunian Stages at all regions outside Yunnan. The Zhongyicun Phosphorites and the Dahai Dolostones best represent pre-trilobitic Cambrian strata in South China, but the typical and best fossiliferous sections, especially in the Dianchi Lake region of Yunnan, represent only a fraction of the earliest Cambrian (Nemakit-Daldynian) time because of extensive hiatus. The onset of the Shiyantou-Niutitang "black shale event" with its concretionary phosphorite layer and/or sedex-type ore beds is proposed to represent the best "geological instant" on an interregional scale to mark a quasi-synchronous "event" indicating a

possibly climatically or hydrothermally induced basin-wide watermass overturn. Such a watermass overturn and subsequent anoxic black shale onlaps virtually all underlying facies across the entire Yangtze Platform. Sedimentological and geochemical indicators strongly support a short-time watermass turnover event to be the cause of the onset of this remarkable "Niutitang Black Shale Event". It appears rather implausible to argue for a geologically definable longer-term diachronous onlap (except possibly around the Huangling Dome in western Hubei: Yanjiahe to Shuijingtuo Fms.) of this organic-rich black shale which is also an indicator for extreme high organic productivity and conducive burial conditions over a considerable time interval. By correlation with Siberian Platform and other coeval occurrences on a global scale it could be assumed that this event took place at or near to the base of the Tommotian Stage, but not at or near the PC/C boundary as currently defined (FAD of trace fossils: Landing, 1994).

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