

湖北宜昌大坪奥陶纪阿伦尼克期三叶虫生态组合*

S. T. 图凡伊

(牛津大学地球科学系, 牛津, 英国)

周志毅

(中国科学院南京地质古生物研究所, 南京 210008)

提要 首次对扬子区奥陶纪大湾组的三叶虫相作了初步分析。在详细研究了湖北宜昌大坪大湾组 30 种三叶虫的地层和岩相分布的基础上, 划分出 3 个生态组合, 即: Asaphid-*Pseudocalymene* 组合, Asaphid-Raphiophorid 组合和 Trinucleid 组合, 它们依次指示由浅而深的浅外陆棚环境。研究表明这 3 个组合在大湾组的交替出现应与阿伦尼克期海平面变化密切相关。

关键词 三叶虫 生态组合 奥陶纪 阿伦尼克期 大湾组 湖北 宜昌

ARENIG TRILOBITE ASSOCIATIONS OF DAPING , YICHANG , HUBEI , SOUTH CHINA

Samuel T. Turvey¹⁾ and ZHOU Zhi-Yi²⁾

1) Department of Earth Sciences , Oxford University , Parks Road , Oxford OX1 3PR , United Kingdom . E-mail : sam_turvey@hotmail.com

2) Nanjing Institute of Geology and Palaeontology , the Chinese Academy of Sciences , Nanjing 210008 , China .

E-mail : zyizhou@jlonline.com

Abstract Stratigraphical ranges of 30 trilobite species are recorded from the Ordovician Dawan Formation (Arenig) at Daping , Yichang , Hubei Province , China . Three trilobite associations are differentiated with respect to palaeobathymetrical and sedimentological gradients : the Asaphid-*Pseudocalymene* Association , the Asaphid-Raphiophorid Association and the Trinucleid Association . Stratigraphical occurrence of these associations within the formation reflects transgressive and regressive phases within the Arenig Series . This provides the first information on trilobite biofacies relationships across the Dawan Formation in the Yangtze Block .

Key words Trilobite association , Ordovician , Arenig , Dawan Formation , Hubei , South China

1 INTRODUCTION

The Yangtze Gorges area of western Hubei Province , China , is the geologically best-known part of the Yangtze Block . Palaeogeographically , the area was covered by an epeiric sea throughout the Ordovician (Wang , 1985). It contains extensive exposures

of Ordovician deposits around the Huangling Anticline , and has been considered as a type area for classification and correlation of the Ordovician in China (Wang *et al.* , 1987).

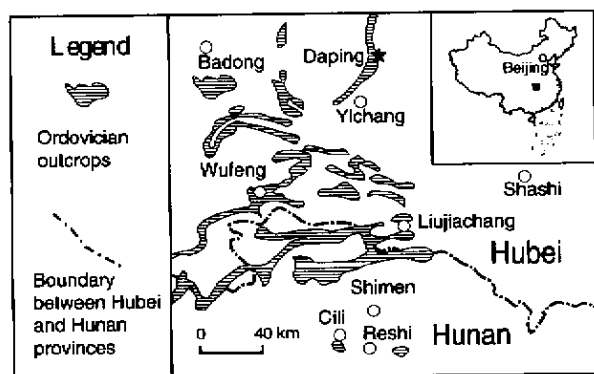
The Dawan Formation , consisting of carbonate and shaly rocks , is one of the best-developed stratigraphical units in the Yangtze Block . Some or all of the formation was once thought to be of Llanvirn age

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(Lu, 1975; Lu *et al.*, 1976), but graptolite evidence (Mu, 1974) suggests that it was deposited entirely within the Arenig. Shelly fossils and graptolites are both abundant in the formation. Trilobites of the Dawan Formation in western Hubei have been studied fairly extensively by previous authors from a taxonomic standpoint (e. g. Lu, 1975; Zhou *et al.*, 1977; Xia, 1978; Sun, 1984; Wang *et al.*, 1987). However, facies relationships, as for many other Yangtze Block faunas, remain poorly understood (Chen *et al.*, 1995). Although analyses of trilobite biofacies for Tremadoc and Caradoc formations in the Yangtze Gorges area have recently been conducted (Zhou *et al.*, 1999; Yuan *et al.*, 2000), only brief approximations have previously been provided for the Dawan Formation (Lu *et al.*, 1976).

To outline the replacement of trilobite associations across the Dawan Formation, large numbers of trilobites, comprising 30 species in 17 families, were collected during October–November 1998 and September 1999 at Daping, 27 kilometres north of the city of Yichang and 4 kilometres north of the well-known Ordovician section at Huanghuachang (Text-Figure 1). The relative abundance of different invertebrate groups across much of the formation, and the extremely thorough graphical representation of Ordovician lithostratigraphy recorded by Lindström *et al.* (1991) for Daping, facilitated the present high-resolution bed-by-bed analysis of trilobite biofacies at this locality.



Text-Figure 1 Maps showing location of Daping and Ordovician outcrops in western Hubei, China

2 STRATIGRAPHICAL SUMMARY

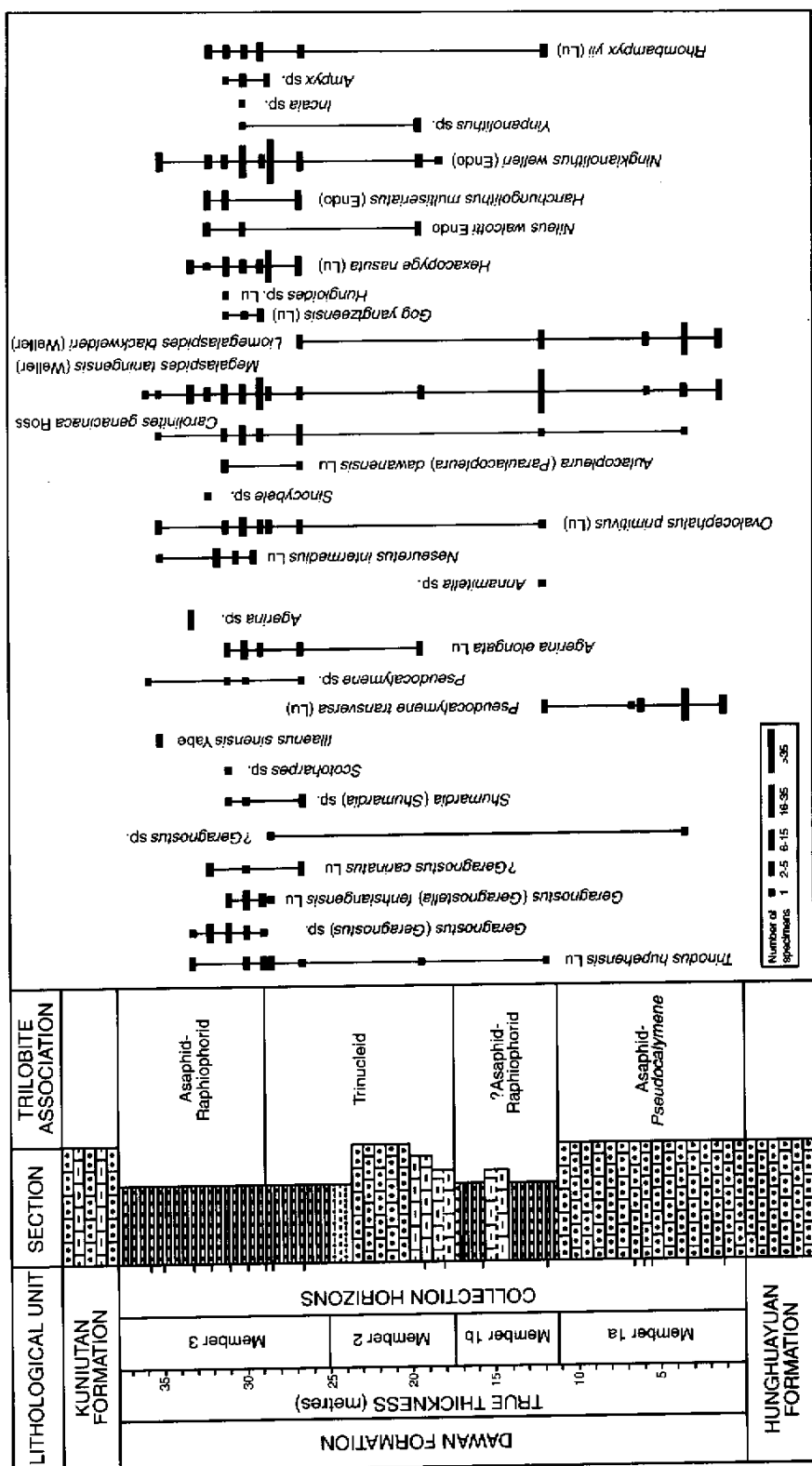
The Dawan Formation at Daping is underlain conformably by grey biocalcarenite and *Calathium-*

Receptaculites limestone of the Hunghuayuan Formation, and overlain by basal grey calcirudite (15 centimetres thick) and reddish-grey biocalculite and biocalcarenite of the Kuniutan Formation (Text-Figure 2). As at other localities in the Yangtze Gorges area, the formation is lithologically divided into three distinct members, in ascending order:

Member 1 The lower part (Member 1a), 11 metres thick, consists mainly of light-grey to grey, thin- to medium-bedded biocalcarenite, nodular biocalcarenite and marl; the basal 4.8 metres of biocalcarenite is rich in glauconite and secondary sparite calcite. Biostratigraphically, the basal beds are assigned to the conodont *Oepikodus evae* Zone (Lindström *et al.*, 1991). The upper part (Member 1b), 6.4 metres thick, falls within the graptolite *Azygograptus suecicus* Zone (Lindström *et al.*, 1991), and is composed of greyish-green shale and intercalations of grey biocalculite, nodular biocalculite and biocalcarenite.

Member 2 Chiefly purplish-red thin to medium-bedded biocalculite, intercalated with nodular biocalculite and biocalcarenite, 7.6 metres thick. It belongs to the cephalopod *Protocycloceras deprati* Zone or the conodont *Paroistodus originalis* Zone (Lindström *et al.*, 1991).

Member 3 Previously called the *Yangtzeella* Beds in the Yangtze Gorges area (Chang, 1962; Lu, 1975), after the abundance of the brachiopod *Y. poloi* (Martelli) in this member. It is 12.6 metres thick at Daping, containing dirty yellow-green or grey-green marly shale intercalated with marl, thin-bedded biocalculite and nodular biocalculite, with 3 metres of biocalcarenite at the top of the section. Two conodont zones recently established for this member at the section by Wang and Bergström (1999, p. 327, figure 2, as the Chenjiahe section) are the *Baltoniodus norrlandicus-Microzakodina parva* Zone (lower 7.9 metres) and the *Lenodus antivariabilis* Zone (upper 4.7 metres). According to the graptolite biostratigraphy of Lindström *et al.* (1991), the shales of the lower 6 metre interval represent the *Undulograptus sinodontatus* Zone, and horizons upsection of this the *U. austrodentatus* Zone.



Text-figure 2. Columnar section of the Dawan Formation at Daping, showing vertical ranges of identified trilobite species and trilobite associations

3 TRILOBITE ASSOCIATIONS

The overall pattern of stratigraphical ranges shown by the different species (Text-Figure 2) represents three different trilobite associations occurring at different horizons within the formation. Representative trilobites of each association are figured in Plate I. Following Jaanusson (1984), the term 'association' is used here to refer to a consistent co-occurrence of taxa, and 'assemblage' to refer to faunal remains in a sample from a given horizon.

3.1 Asaphid-*Pseudocalymene* Association

The trilobite fauna of Member 1a is dominated (> 95% faunal composition) by three species, the asaphids *Liomegalaspides blackwelderi* (Weller) and *Megalaspides taningensis* (Weller) and the leiostegiid *Pseudocalymene transversa* (Lu). Rare material representing two additional genera, *Carolinites* and *Geragnostus*, was also collected. *M. taningensis* occurs throughout most of the Dawan Formation at Daping, and *Liomegalaspides* and *Pseudocalymene* are widespread in both clastic and carbonate beds over the majority of the Yangtze Block, and the geographically proximal Indo-China Terrane and Tarim Block, during the Arenig and Llanvirn (Sheng, 1958; Lu and Chang, 1974; Lu, 1975; Zhou *et al.*, 1977; Yin and Lee, 1978; Xia, 1978; Zhou *et al.*, 1982; Chang and Jell, 1983; Qiu *et al.*, 1983; Zhou *et al.*, 1992, 1998a, b, c).

Trilobite material from Member 1a is disarticulated and partly fragmentary, with some local concentration, suggesting a high-energy depositional environment. Tempestite layers and lenses, as noted by Lindström *et al.* (1991), occur repeatedly throughout the 11 metre carbonate sequence, indicating a depositional depth above the storm wave base. The major lithological change between the underlying Hunghuayuan Formation and the Dawan Formation, with the disappearance of *Calathium-Receptaculites* limestone and the sudden appearance of glauconite, has been interpreted as indicating a depositional shift from platform margin facies (Yuan *et al.*, 2000) to outer-shelf margin or platform fore-slope facies (Xue Yaosong and Zhang Junming, personal communication).

3.2 Asaphid-Raphiophorid Association

The yellow shales of the upper *Undulograptus sinodontatus* Zone and lower *U. austrodonatus* Zone in Member 3 contain a diverse benthic trilobite association. This is characterised by genera such as *Geragnostus*, *Agerina*, *Ovalocephalus*, *Ningkianolithus* and *Rhombampyx*, as well as containing abundant specimens of *Megalaspides taningensis*; rarer genera include *Hungioides*, *Gog*, *Nileus* and *Shumardia*. The globally widespread epipelagic trilobite *Carolinites genacinaca* Ross (see McCormick and Fortey, 1999) is also fairly common in these beds.

Hungioides, *Ullaenus* and *Neseuretus* are characteristic of shallow-water environments on other plates (see Fortey, 1975; Fortey and Morris, 1982; Fortey and Shergold, 1984; Nielsen, 1995). However, all three are very uncommon in this association, and the only material of *Ullaenus* from Daping was collected from a fossil-poor horizon towards the top of Member 3. *Neseuretus intermedius*, the species present at Daping, is not morphologically characteristic of *Neseuretus* and may represent a different genus; Wang *et al.* (1987) recorded this species (as *N. xiadongensis*) in a similar trilobite association at Huanghuachang.

Other trilobite genera, such as *Nileus*, *Ampyx*, *Rhombampyx*, *Gog* and *Ovalocephalus*, are typical of deeper-water facies (see Zhou and Dean, 1986; Zhou *et al.*, 1992, 1998b, 1999; Fortey, 1975, 1997). Raphiophorids, a group relatively abundant in this association, were noted by Fortey and Owens (1978) as characteristic of clastic shelf-slope facies. Although mostly disarticulated, trilobites are randomly distributed on the bedding surface without sorting or reworking, suggesting an almost undisturbed depositional environment below storm wave base. It is appropriate to refer to this association as the Asaphid-Raphiophorid Association, after the abundance of *M. taningensis* and the ecological significance of raphiophorids. Contemporaneous assemblages similarly characterised by *Geragnostus* and *Rhombampyx*, but with few asaphids, were recorded by Nielsen (1995) from the Baltican Komstad Limestone, occurring in water intermediate in depth between isotelid and nileid assemblages.

Lithologically similar shales occurring in the

older *Azygograptus suecicus* Zone in Member 1b contain a somewhat less diverse assemblage, consisting of several similar trilobite taxa (agnostids, raphiophorids, *Ovalocephalus*, *M. taningensis*). Contemporaneous shales at Huanghuachang reported by Wang *et al.* (1987) also contain additional taxa characteristic of Member 3, such as *Ningkianolithus* and *Hungioides*. Although the presence of rare material attributable to *Annamitella* and *Pseudocalymene transversa* makes the Daping Member 1b assemblage different slightly from the faunal composition of the Asaphid-Rapxtension of this association. Faunal differences between the two members at Daping may reflect slight differences in water depth or substrate conditions, or temporal constraints, with some but not all trilobite taxa characteristic of Member 3 having evolved or migrated to the region during the time of deposition of Member 1b. Trilobites from the *A. suecicus* Zone at Daping were not well collected due to poor exposure, and occur relatively infrequently in Member 1b across western Hubei. Stochastic variation in assemblage composition within an association means that further sampling of the *A. suecicus* Zone is required before it is possible to determine whether the Member 1b assemblage represents a separate association, or just a variant of the Asaphid-Raphiophorid Association. As in Member 1b at Huanghuachang and the Asaphid-Raphiophorid Association in Member 3 at Daping, trilobites in Member 1b at Daping are mostly disarticulated, although graptolite rhabdosomes are locally distributed subparallel with each other on bedding planes, indicating weak storm wave influence (Chen and Qiu, 1986).

3.3 Trinucleid Association

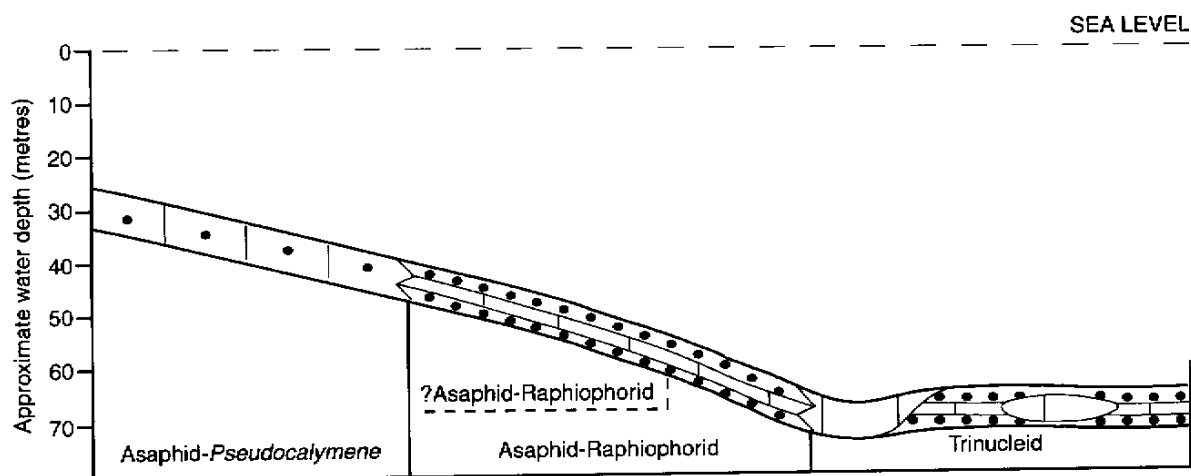
The grey calcareous shale beds in the 3.5 metre interval at the base of the *U. sinodentatus* Zone in Member 3 contain assemblages consisting of similar trilobite genera to those present in the Asaphid-Raphiophorid Association, but dominated by hanchungolithine trinucleids (over 50% of total trilobite composition). The majority of identifiable trinucleid material represents *Ningkianolithus welleri* (Endo). The remopleuridid *Hexacopyge nasuta* (Lu) also occurs more frequently in these assemblages than in the Asaphid-Raphiophorid Association. The

term Trinucleid Association, modified from the Trinucleid Biofacies of Zhou *et al.* (1992), is adopted to describe this fauna. The Trinucleid Association at Daping is similar to that reported from the neighbouring Indo-China Terrane by Zhou *et al.* (1998a); both are characterised by hanchungolithines and *Hexacopyge*, which suggests similar environmental conditions and faunal admixture between these regions. Taphonomy is similar to that in the Asaphid-Raphiophorid Association.

The reddish biocalcilutite interval (Member 2) in the middle part of the formation comprises almost no terrigenous clastics, but shows several layers of hematitic stromatolites and discontinuity surfaces, indicating a starving and quiet depositional environment. This interval contains relatively few fossils, and so association assignment of the scarce trilobite material from these beds is not straightforward. The collection of several specimens of *Nileus*, a genus absent from Member 1 and occurring only rarely in Member 3 at Daping, suggests that Member 2 may represent a deep-water Nileid Association. Similar associations were first proposed from Spitsbergen by Fortey (1975), and have also been recorded from the North China (Zhou *et al.*, 1989) and Tarim (Zhou *et al.*, 1992, 1998b) blocks. However, other identifiable trilobite material from Member 2 represents *Trinodus*, *Agerina*, *Yinpanolithus*, *Ningkianolithus* and *Megalaspides*, all of which also occur in shallower-water associations at Daping. Trinucleids are relatively abundant in Member 2, and so, in the absence of more extensive trilobite material from the interval, these assemblages are also interpreted as representing the Trinucleid Association.

4 ENVIRONMENTAL IMPLICATIONS

Three trilobite associations are identified from the Dawan Formation at Daping, with the assemblages occurring in the Member 1b shales and Member 2 biocalcilutites possibly also distinct. The different associations are believed to have occurred in different water depths during the Arenig (Text-figure 3).



Text-figure 3 Model showing relationship of trilobite associations of the Dawan Formation to substrate conditions and water depth

The interpretation by Chen and Qiu (1986) that the entire Dawan Formation in the Yichang area shows signs of storm wave disturbance suggests that all of these associations might have occurred in inner-shelf environments. Although these associations are generally characterised by deeper-water taxa indicative of largely subtidal depositional conditions, their presence at Daping is not incompatible with the palaeoenvironmental model of Chen and Qiu (1986); the Trinucleid Biofacies of the Indo-China Terrane is interpreted as having occupied a shallow outer-shelf environment (Zhou *et al.*, 1992, 1998a), and although *Nileus* typically occurred in shelf-slope environments, associations containing this genus could extend inshore into shallower conditions at or near wave base (Fortey, 1975, 1980; Zhou *et al.*, 1998b). Chen and Qiu (1986) estimated that the formation was deposited under a maximum water depth of 60 metres; depth of storm wave base is very variable on different shelves, averaging from 20–200 metres (Nichols, 1999). Trilobite taphonomic evidence suggests, however, that at least members 1b, 2 and 3 may have been deposited largely below storm wave base.

The end-Arenig regression culminated approximately at the Arenig-Llanvirn boundary, as indicated by the appearance of basal calcirudite in the overlying Kuniutan Formation. The time and scale of transgression and regression as evidenced by the replacement of Arenig-Llanvirn trilobite associations at Daping coincides approximately with global eustatic changes (Fortey, 1984; Ross and Ross, 1992). On

the basis of changes in brachiopod and graptolite faunal composition, Chen and Qiu (1986) and Zeng (1991) proposed that the majority of Member 3 represents the Arenig transgressive phase, with only the uppermost beds deposited in shallowing water conditions. If this conclusion is correct, it would suggest that changes in trilobite assemblage composition up-section through the Dawan Formation at Daping represent progressively deeper-water associations, although specimens of *Illaeus* recorded from the top of the formation may indicate regressive conditions.

If this is correct, then the assemblage recorded from the *A. suecicus* Zone of Member 1b cannot be referred to the Asaphid-Raphiophorid Association of Member 3, as the latter association occurs in significantly deeper-water facies. However, the Trinucleid Biofacies occurs in slightly deeper-water conditions than the biofacies characterised by *Liomegalaspides*, *Hungioides* and *Neseuretus* on the Indo-China Terrane (Zhou *et al.*, 1998a), and similar facies relationships are also suggested at Daping; *Ningkilithus* is less common in the Asaphid-Raphiophorid Association in Member 3, which is lithologically similar to the upper part of the Trinucleid Association but also contains some characteristically shallow-water trilobite genera, than in the Trinucleid Association of Member 2 and the lower part of Member 3.

Lindström *et al.* (1991), who regarded the Member 2 carbonates as homologous with the Baltoscandian 'Blodlågert' beds, considered that much of Member 3 represented a regressive depositional sequence. The occurrence of the Trinucleid Association

in both pure carbonate rocks and shale beds in the middle and upper parts of the formation respectively may then mark the climax of the Arenig transgression, with shales higher up in Member 3 having been deposited under shallower water conditions. This model coincides more closely with trilobite associational composition from these members. However, trilobite faunal composition and taphonomy suggest that the depositional environment of Member 3 may still have represented < 100 metre deep shallow outer-shelf.

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EXPLANATION OF PLATE I

The figured specimens are all from the Dawan Formation , Arenig Series , of Daping , Yichang , western Hubei , China. They are deposited in the Nanjing Institute of Geology and Palaeontology , the Chinese Academy of Sciences , and are prefixed with NIGP.

1. *Ningianolithus welleri* (Endo)

Internal mould of cephalon , x 15. Member 3 (Trinucleid Association). NIGP 133772.

2. *Carolinites genacinaca* Ross

Internal mould of cranidium , x 8. Member 3 (Asaphid-Raphiophorid Association). NIGP 133773.

3. *Agerina elongata* Lu

Internal mould of cranidium , x 15. Member 3 (Asaphid-Raphiophorid Association). NIGP 133774.

4. *Rhombampyx yui* (Lu)

Internal mould of cephalon , x 8. Member 1b (? Asaphid-Raphiophorid Association). NIGP 133775.

5. *Trinodus hupehensis* Lu

Internal mould of pygidium , x 10. Member 3 (Trinucleid Association). NIGP 133776.

6. *Neseuretus intermedius* Lu

Internal mould of cranidium , x 5. Member 3 (Asaphid-Raphiophorid Association). NIGP 133777.

7. *Megalaspides taningensis* (Weller)

Pygidium , x 5. Member 1a (Asaphid-Pseudocalymene Association). NIGP 133778.

8. *Ampyx* sp.

Silicone rubber cast of external mould of cranidium , x 10. Member 3 (Asaphid-Raphiophorid Association). NIGP 133779.

9. *Pseudocalymene transversa* (Lu)

Internal mould of incomplete cranidium , x 10. Member 1b (? Asaphid-Raphiophorid Association). NIGP 133780.

10, 11. *Ovalocephalus primitivus* (Lu)

10. Cranidium , x 10. Member 1b (? Asaphid-Raphiophorid Association). NIGP 133781.

11. Internal mould of pygidium , x 15. Member 3 (Asaphid-Raphiophorid Association). NIGP 133782.

12. *Incaia* sp.

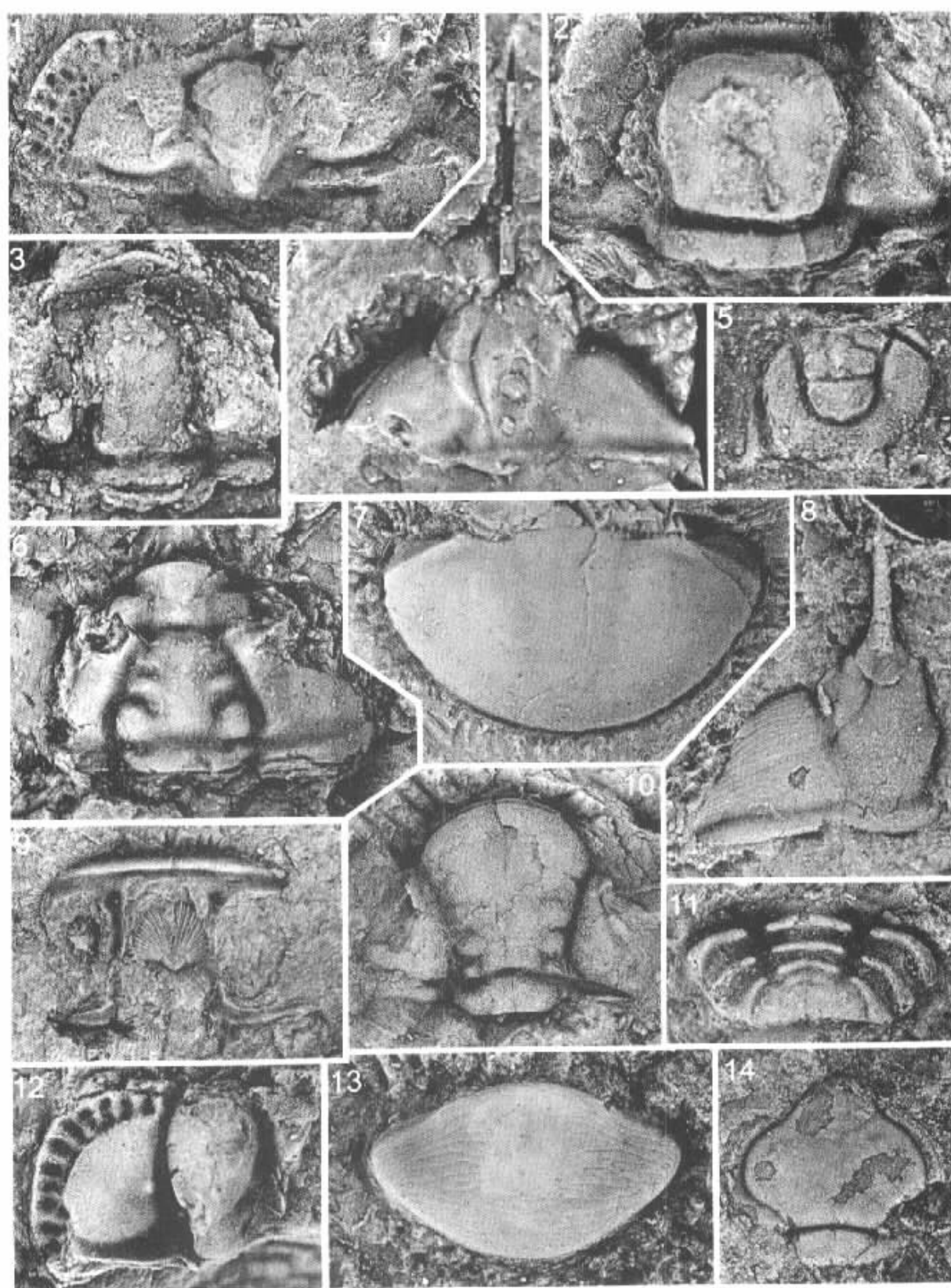
Internal mould of cephalon , x 15. Member 3 (Asaphid-Raphiophorid Association). NIGP 133783.

13. *Nileus walcotti* Endo

Pygidium , x 10. Member 2 (Trinucleid Association). NIGP 133784.

14. *Hexacopyge nasuta* (Lu)

Internal mould of cranidium , x 15. Member 3 (Trinucleid Association). NIGP 133785.



作者: S·T·图凡伊, 周志毅
作者单位: S·T·图凡伊(牛津大学地球科学系, 牛津, 英国), 周志毅(中国科学院南京地质古生物研究所, 南京, 210008)
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