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PERMIAN-TRIASSIC BOUNDARY IN MIDDLE AND EASTERN TETHYS

by

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(with 22 text-figures, 5 tables and 2 plates)

Abstract

The recent investigation on the conformable Permian-Triassic transition beds in South China revealed the existence of the mixed-fauna beds immediately above the Changhsing Formation or its equivalent, which contain the Permian-type brachiopods and the Triassic-type ammonoids and bivalves. Three successive mixed-fauna beds, numbered 1 to 3, can be distinguished at many places. The first two are referred as the *Otoceras* Zone and the last one as the *Ophiceras* Zone based on the new discovery of *Otoceras* sp. from the mixed-fauna bed no. 1 and a common occurrence of *Ophiceras* and *Claraia* in bed no. 3.

The correlation of the Chinese sections with Permian-Triassic sequences in other parts of the Tethys province, such as Iran, Pakistan, and India, shows some time gap between the Upper Permian and Lower Triassic in those regions with the exception of Kashmir region. The Chinese sequences contain abundant ammonoids, brachiopods and conodonts that are useful for international correlation. Thus, the Chinese section, especially of the Changxing area, is considered to be a candidate of the stratotype of the Upper Permian and the Permian-Triassic boundary.

Introduction and acknowledgements

The transition between the Permian and Triassic Periods has been traditionally interpreted to represent the greatest biologic revolution in the history of the earth. Many scientists have successively given an outline of this event for many years. About a dozen years ago, an International Permian-Triassic Conference was held to discuss these subjects at the University of Calgary in Canada, and then was published the volume as to the boundary problems including the biostratigraphic as well as palaeontologic evidences on the world-wide basis. Some important problems are, however, still left in doubt even to the present day. The problems are, for instance, the cause of the biologic revolution and the biostratigraphic relationship between the Permian and Triassic sequences in the world. The successive sequences from the latest Permian to the earliest Triassic accompanied with a good exposure are limited in distribution, but certain favourable areas are expected to be found in South China, Kashmir, the Salt Range,

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the Julfa region of Soviet Armenia and Iranian Julfa in the northwestern part of Iran, the Abadeh region of central Iran, and the region of Kap Stosch in East Greenland, as already mentioned by Teichert et al. (1973).

In South China, Zhao and his colleagues of Nanjing Institute of Geology and Palaeontology have contributed much to the Permian and Triassic stratigraphy and palaeontology and described the details of the Permian-Triassic boundary in South China. On the other hand, the Japanese members and their colleagues have engaged in the stratigraphic and palaeontologic examinations of the Permian-Triassic boundary in Kashmir (Nakazawa et al., 1970, 1975), Afghanistan (Ishii et al., 1971), Iran (Iranian-Japanese Research Group, 1981) and the Salt and Surghar Ranges (Pakistani-Japanese Research Group, 1981, and in preparation). In those contributions, the classification of the stages of the Upper Permian and the characteristic faunal assemblages in Late Permian were discussed in detail. Some questions, however, have remained unsettled, especially those regarding the correlation of the Upper Permian of the world.

During the course of the study on the Permian and Triassic sequences in the Central and Eastern Tethys, all members of the Japanese team noticed the importance of the investigation of the Chinese sections in order to work out a solution to the boundary problems, and they wished to organize a cooperative study with Chinese team. On the other hand, Chinese specialists have desired to correlate reasonably the Chinese Permian and Triassic sections with other reference sections of the Tethyan realm.

The present study has been performed by the specialists of the Permian and Triassic of the Nanjing Institute of Geology and Palaeontology of Academia Sinica and of Japanese universities. The research group of this study consists of the following members: from the People's Republic of China: Professor Sheng Jin-zhang, Professor Chen Chu-zhen, Dr. Wang Yi-gang, Dr. Rui Lin and Dr. Liao Zhuo-ting of the Nanjing Institute of Geology and Palaeontology, Academia Sinica; from Japan: Professor Yuji Bando, Kagawa University, Professor Ken-ichi Ishii, Himeji Institute of Technology, Professor Keiji Nakazawa, Kyoto University and Dr. Koji Nakamura, Hokkaido University.

First joint work was proceeded by all members in November to December, 1981 at the Nanjing Institute of Geology and Palaeontology in Nanjing. They spent a half month in the field to examine the outcrops at Changxing, Longtan, Hushan and Mashishan in Xidongtingshan Island. After the field survey, they actively discussed the problems of the Permian-Triassic boundary in the Tethyan realm at the Nanjing Institute. The following year (1982) they met again for the preparation of joint paper at the Nanjing Institute in September. This paper is the result of these cooperative works by the Chinese and Japanese scientists.

The present cooperative works were made possible by financial and material aids of the Academia Sinica of the Government of People's Republic of China and the International Cooperative Research Project promoted by the Japan Society of Promotion of Science of the Japanese Government. All the members wish to express their cordial appreciation to both the governments for their kind supports.

The Chinese members are most grateful to Professor Zhao Jin-ke, the director of the Nanjing Institute of Geology and Palaeontology, who gave them kind encouragements and valuable suggestions. They are also obliged to many other persons for identification of fossils: to Dr. Wang Ke-liang for non-fusuline foraminifers; Drs. Wu Wang-shi and Zhao Jia-ming for rugose corals; to Drs. Wang Cheng-yuan and Wang Zhi-hao for conodonts; to Dr. Mu Xi-nan for calcareous algae, and lastly thanks are due to Mr. Zhou Qi-yi for drawing and copying the range-chart of fossils and to Mr. Mao Ji-liang and Mr. Zhu Chun-liu for photographs of the boundary sections.

Japanese members are obliged to the Director, Professor Zhao Jin-ke and the other staff members of the Nanjing Institute of Geology and Palaeontology who helped in various ways, when they visited the Institute. Thanks are due to the following persons for the field surveys of the previous works in Kashmir, Salt Range, and Iran; Dr. Yuji Okimura of Hiroshima University, Dr. Takao Tokuoka of Shimane University, Professor Masafumi Murata of Kumamoto University, Dr. Daikichiro Shimizu and Dr. Yasuo Nogami of Kyoto University, Professor Sumio Sakagami of Chiba University, Professor Tadashi Maegoya and Professor Susumu Noda of Kyoto Industrial University, Dr. Yasuji Saito of National Science Museum in Tokyo, Mr. Tetsuo Matsuda of Osaka City University, and the late Professor Akio Inazumi of Kagawa University. They owe to Mr. Hari Mohan Kapoor, Director of Palaeontology and Stratigraphy Division of the Geological Survey of India, for the cooperative study in Kashmir in 1969 and 1972; Dr. Hooshang Taraz, former director of the Geological Survey of Iran and Mr. Farrokh Golshani of the Geological and Mineral Survey of Iran, for the joint works in Iran in 1969, 1972 and 1975; and Mr. S. Tayyab Ali, Mr. Tanqir Ahmed Shuja, and Mr. Akhtar Qureshi Kaleem of the Geological Survey of Pakistan in Lahore for the cooperative study in the Salt Range and the Surghar Range in Pakistan in 1975 and 1979. Also, Japanese members wish to express appreciation to many other staff members of the Geological Survey of India, Iran and Pakistan, for their help in the course of each survey.

Lastly but not least, all Chinese and Japanese members wish to express many thanks to Mrs. Zhang Ying-zhen of Nanjing Solid State Devices Research Institute for her reliable translation between Chinese and Japanese; and Dr. W.W. Nassichuk and Dr. T.T. Uyeno of Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada for reviewing the manuscript and making innumerable valuable suggestions.

History of research

1. South China

In South China the problems of the Permian-Triassic boundary have attracted their particular attention, while Chinese scientists surveyed the Permian and Triassic sequences in the seventies (Chen, 1978; Chen et al., 1979; Zhao et al., 1978; Liao, 1979, 1980; Yao et al., 1980; Fan et al., 1980; Yang et al., 1980).

In the winter of 1977, a Permian-Triassic boundary Research Group, consisting of Zhao Jin-ke (chief of this group), Sheng Jin-zhang (vice-chief of this group), Liang

Xi-luo, Chen Chu-zhen, Rui Lin, Liao Zhuo-ting, Yao Zhao-qi and Jiang Na-yan, was organized at the Nanjing Institute of Geology and Palaeontology, Academia Sinica. Zhao and his colleagues, then, contributed data to the problems of the Permian-Triassic boundary in Zhejiang (Meishan of Changxing), Anhui (Dushan and Chaoxian), Jiangsu (Longtan and Hushan in the suburbs of Nanjing, Yixing and Wuxian) Provinces and Guangxi (Heshan and Fushui) Autonomous region for four years (1977-1980).

The important results were reported in the Bulletin of Nanjing Institute of Geology and Palaeontology, Academia Sinica (no. 2, 1981) and in the Journal of Stratigraphy (vol. 6, no. 1, 1982). The classification of the uppermost Permian Stage, the Changhsingian* and its faunal assemblages, the mixed faunal beds and the Permian-Triassic boundary of South China are described and discussed in detail in these contributions.

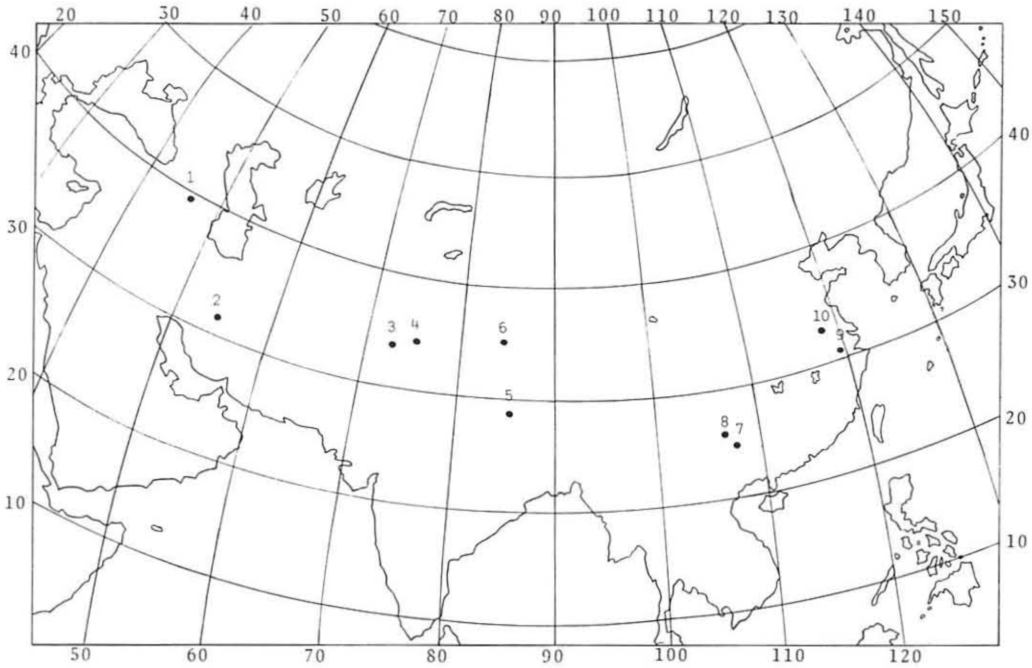
At the same time, many Chinese geologists belonging to various organizations have also paid attention to the problems of the Permian-Triassic boundary in South China, but the results have mostly been unpublished.

The main results on the Permian-Triassic boundary in China achieved by the Chinese Research Group and by Chinese geologists are: (1) South China is the only known place where the Dzhulfian, Changhsingian and Griesbachian ammonoids occur in a stratigraphic sequence, including the youngest Permian stage Changhsingian, and succeeded by the earliest Triassic ammonoid, *Otoceras*; (2) a transitional bed containing earliest Triassic ammonoids, *Otoceras, Hypophiceras*, etc., associated with Permian-type brachiopods (i.e., chonetids, productids and *Crurithyris* etc.) has been discovered at many places in South China; (3) Hsu's *Octoceras* cf. *woodwardi*, which was revised most recently by Wang as *Koninckites* (in Sheng et al., 1982), was located 42 m above the base of the Chinglung Group of the Lower Triassic at Longtan; (4) the contact between the Permian and Triassic formations in South China, though locally disconformable, is mostly conformable.

In October of 1978, a Canadian scientific delegation of the Permian-Triassic boundary led by Dr. W.W. Nassichuk visited South China and accompanied by members of the Chinese Research Group to examine some Permian and Triassic sections. The following year, Dr. E.T. Tozer (1979) wrote a paper partly based on this trip.

During November and December of 1981, the first joint work of the Chinese-Japanese Research Group was proceeded in Nanjing and the members spent half a month in the field to survey the contact between the uppermost Permian and the lowermost Triassic at five localities: (1) Meishan, Changxing of the Zhejiang Province, where the type section of the Changhsing Limestone is located and is the stratotype of the Changhsingian Stage. At this time, a firmly identified specimen of *Otoceras* was discovered by Wang and Bando from the mudstone layer of the mixed faunal bed 1 of

* The terms "Changhsing Formation" and "Changhsingian" (derived from the "Changhsing Limestone") have appeared in past publications, and are still currently in use. However, since these terms are originally from the name of a county, Changxing, they should read "Changxing Formation" and "Changxingian" in accordance with the scheme of the currently used Chinese Phonetic Alphabet.



Text-fig. 1 Map of distribution of sections concerned in this paper.
1: Transcaucasia, 2: Abadeh, 3: Salt Range, 4: Kashmir, 5: South Tibet, 6: North Tibet, 7: South Guizhou, 8: Central Guizhou, 9: Changxing, 10: Nanjing

the Lower Triassic at a quarry about 100 m west of the Zhongxin Dadui quarry in Meishan of Changxing; (2) Longtan; (3) Hushan near Nanjing; (4) Baiyangtang of Yixing; and (5) Mashishan of Xidongtinshan Island, Wuxian in the Jiangsu Province.

2. Kashmir region; the Salt Range and Surghar Range in Pakistan; and Abadeh region in Iran.

Only the highlights of the history of research performed outsie of China are given, to focus those studies by the Japanese team and associated foreign scientists. Details of each area have been already introduced elsewhere.

a. Kashmir

In 1969, 1970, 1973 and 1977, K. Nakazawa and H.M. Kapoor and their collaborators surveyed the Permian-Triassic transitional beds at Guryul Ravine and 3 km north of Barus in Kashmir and elucidated the stratigraphic and palaeontologic relationships between the Permian and Triassic Systems. The stratigraphic details of these systems were described in two reports published at Kyoto University (1970, 1975). On the other hand, the results of the palaeontologic studies of the fossils collected from the Permian Zewan and the Triassic Khunamuh Formations recently appeared in the volume of the Palaeontologia Indica published by the Geological Survey of India in 1982.

The sequences from the Late Permian to Early Triassic in this area were divided into two formations, based on the difference of lithofacies, viz., Upper Permian Zewan and uppermost Permian-Lower Triassic Khunamuh. According to their observation in the fields, the relationship between the Permian and Triassic seems to be conformable and there is no discernible gap between the two systems. The erathem boundary was first placed at the base of the Khunamuh Formation (Nakazawa et al., 1970), but was later revised to within the lowermost unit of the Khunamuh Formation (Nakazawa et al., 1975). It is noteworthy that the *Otoceras woodwardi* Zone, the oldest Triassic ammonoid zone, was first established in this area (Nakazawa et al., 1970). The age of the Zewan Formation was concluded to be Abadehian-Dorashamian, and that of the lowermost Khunamuh Formation as latest Dorashamian, based mainly on the foraminifers and conodonts (Iranian-Japanese Research Group, 1981).

b. The Salt Range and the Surghar Range, Pakistan

Pakistani-Japanese Research Group was organized in September, 1975 to investigate the nature of the boundary between the Permian and the Triassic Systems in the Salt Range and the Trans Indus Ranges in North Pakistan. Field survey was performed twice in 1975-1976 and 1979 by the Pakistani and Japanese members of the group. Detailed measuring and observation were made mainly along gorges of Kathwai, Chhidru, Nammal and Zaluch of the Salt Range, as well as at Narmia and Kuch of the Surghar Range. A preliminary report of this investigation was published by the Pakistani-Japanese Research Group in March, 1981 and a more extensive report is in preparation under the editorial work of K. Nakazawa.

As to the Permian, worth noting are the discoveries of *Neoschwagerina* aff. *margaritae* in the basal part of the Wargal Formation and of the *Codonofusiella-Reichelina* and *Colaniella* faunas in the upper part of the Wargal Formation and the entire Chhidru Formation. Based on the analysis of these palaeontologic evidences, the Amb Formation may be correlated with the interval from the *Cancellina* to *Neoschwagerina simplex* Zones in the Tethys province. The Wargal Formation is referred to Capitanian-Abadehian, while the Chhidru Formation is concluded to be Abadehian-Dzhulfian in age.

The Dolomite Unit of the Kathwai Member can be divided into three parts. The lower part containing typical Permian brachiopods, such as the Narmia fauna, is Permian in age and may be concluded to be Dorashamian equivalent. The Main Dolomite Unit with Early Triassic bivalves and ammonoids is correlated with the upper part of the *Otoceras* Zone in Kashmir based on conodont zonation, although it often contains some Permian-type brachiopods including chonetids and *Crurithyris*. The lowest Triassic (lower part of the *Otoceras* Zone) is regarded to be missing in the Salt Range region due to starved deposition during this time. The Permian-Triassic boundary is located within the Dolomite Unit of the Kathwai Member.

c. Iran

Geological Survey of Iran made arrangements for detailed cooperative studies with Japanese universities of the Permian and Triassic sequences in Iran in 1972. The joint Iranian and Japanese team, consisting of staff members of the Geological Survey of

Iran and Japanese universities, was organized in 1972 to survey the Permian and Triassic strata developed in the Julfa region, the Elikah valley region in 1975 and the Abadeh region both in 1972 and 1975. Among these three regions, the section of the Abadeh region was most extensively investigated in terms of stratigraphy and palaeontology. The stratigraphic and palaeontologic results of these studies were published by Kyoto University, and the Geological Survey of Iran, respectively, in 1981.

The Permian strata in the Abadeh region were initially divided into seven lithologic units by Taraz (1971 and 1974). Subsequently the joint team grouped the units into three formations, viz. the Surmaq, Abadeh and Hambast Formations in ascending order, on the basis of gross lithology and stratigraphic distributions of various fossils. Eight fusulinid zones were established within the interval from the Surmaq Formation to the lowest part of the Hambast Formation. In addition, five ammonoid zones or subzones were recognized in the Hambast Formation, as well as seven conodont zones in the Abadeh and the Hambast Formations. The age of the Hambast Formation was considered to be Dorashamian and Dzhulfian, and that of the Surmaq Formation, Artinskian and Guadalupian in general. Taraz (1971), on the other hand, proposed the Abadeh Stage, based on the Abadeh Formation as its stratotype, and considered it as post-Guadalupian, pre-Dzhulfian in age. The stratigraphy and palaeontology of the Julfa region are similar to those of the Abadeh region, while those of the Elikah region are somewhat different.

Comparing with conodont zones in Kashmir, the *Hindeodus parvus* Zone established in the lowermost part of the Triassic both in Abadeh and Julfa regions, can be correlated with the upper part of the *Otoceras woodwardi* Zone of Kashmir. The lower part of the *Otoceras woodwardi* Zone is most probably missing, and the Permian-Triassic relation is paraconformable in Abadeh and Julfa regions.

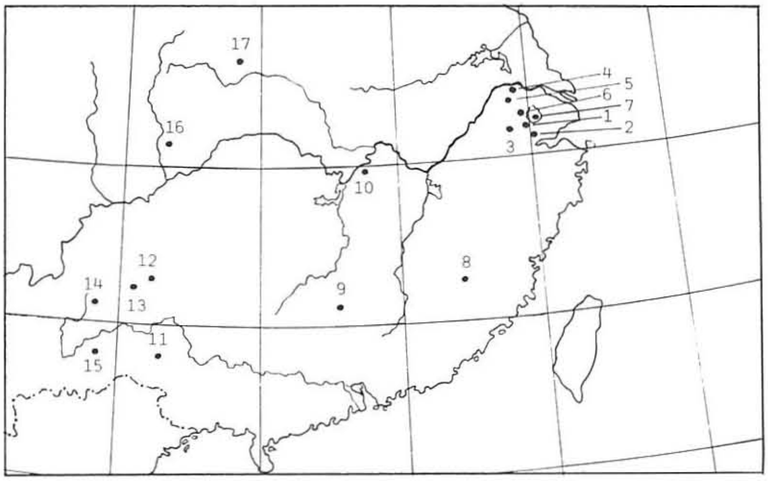
Biostratigraphic and lithologic division of each section

With regards to the Permian-Triassic boundary in South China, a number of reports were published resulting from various studies by Chinese specialists. Most of them, however, were written in Chinese and new data on the boundary have accumulated until present. Accordingly, description of the Chinese sections will be presented in some detail. On the other hand, description of the sections of Kashmir, the Salt Range and Abadeh are overly simplified and reproduced, for the readers' convenience, mainly from the previously published three reports (Nakazawa et al., 1975; Iranian-Japanese Research Group, 1981 and Pakistani-Japanese Research Group. 1981).

1. South China

In South China the marine Permian and Triassic rocks including the latest Permian (Changhsingian) and the earliest Triassic, which contain the *Otoceras, Hypophiceras* fauna, are extensively distributed and form continuous sequences in many places. In general the classification of the Upper Permian and Lower Triassic rocks in our investigated areas is as follows:

Lower Triassic: Lower Chinglung Formation
Upper Permian: Changhsing Fm. / Talung Fm.
Wuchiaping Fm. / Lungtan Fm.



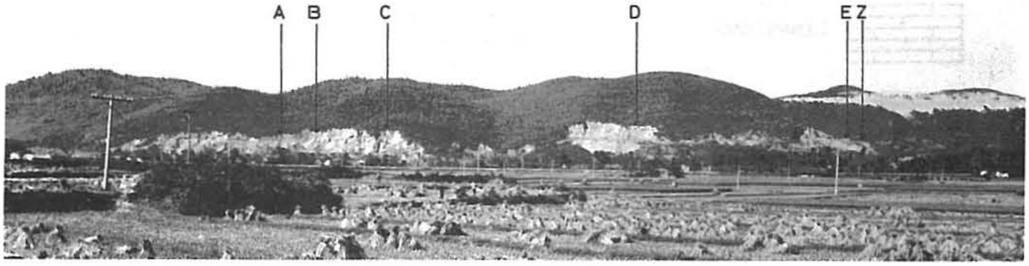
Text-fig. 2 Map of South China, showing localities of "Mixed fauna" bed in the lowest strata of the Triassic.
1: Changxing, 2: Huangzhishan, Wuxing, 3: Gouwa, Guangde, 4: Longtan, Nanjing, 5: Hushan, Nanjing, 6: Baiyangtang, Yixing, 7: Western hill, Wuxian, 8: Fushi, Yongding, 9: Meitian, Yizhang, 10: Puqi, 11: Gumi, Baise, 12: Jiaozishan, Anshun, 13: Heilaga, Langdai, 14: Qingyun, Fuyuan, 15: Qiubei, 16: Huayunshan, 17: Liangchahe, Zhenan.

a. Changxing, Zhejiang

In Meishan of Changxing, the continuous sequences of the Upper Permian and Lower Triassic are well exposed. Here is the type-locality of the Changhsing Limestone and is the stratotype section of the changhsingian.

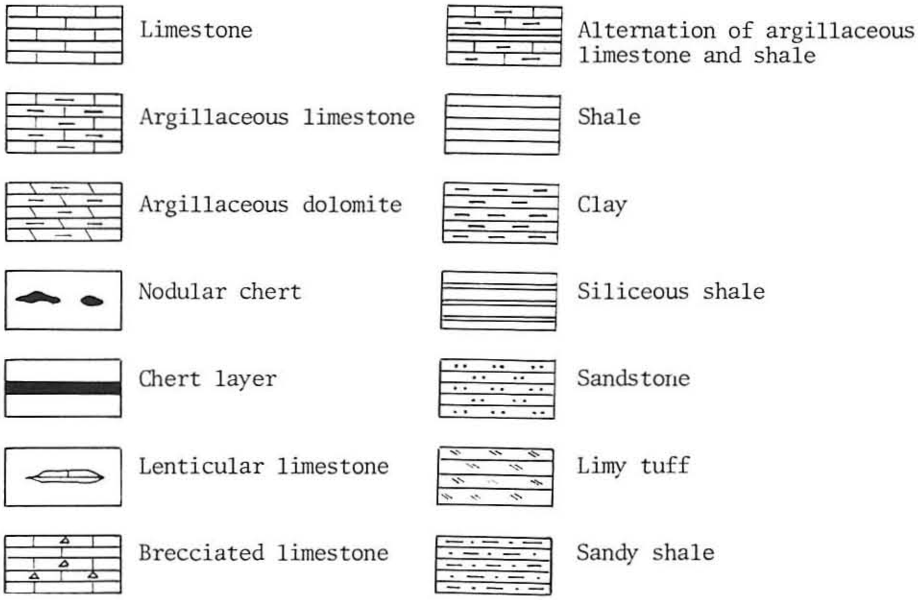
Grabau (1923) first took notice of the Changhsingian fauna and first used the name Changhsing Limestone in 1931. In the following year, Huang (1932) classified the Changhsing Limestone as a formal stratigraphic unit of the uppermost Permian in South China.

The contact between the Permian and Triassic formations in Changxing was described by Chi (1934) as unconformable. However, Sheng and Chang (1958) believed that the contact between the Changhsing Limestone and Lower Triassic rocks at Meishan is conformable. In 1962, Sheng formally named the Changhsing Formation instead of the Changhsing Limestone. Zhao, Liang and Zheng (1978) studied the Changhsing Formation in detail and subdivided it into two parts, the Meishan Member above and the Baoqing Member below. In October of 1978, a Canadian scientific delegation of the Permian-Triassic boundary visited Meishan. Tozer (1979) believed that the Permian-type brachiopods of the Lower Triassic bed were derived from



Text-fig. 3 Distal view of site of surveyed sections around Meishan, Changxing (looking north). A: section A, B: section B, C: section C, D: section D, E: section E, Z: section of Zhongxin Dadui.

Text-fig. 4 Section of Zhongxin Dadui, showing the Permian-Triassic boundary and mixed faunal beds 1 to 3 (looking north). LC1: Lower Chinglung Formation, P-Tb: Permian-Triassic boundary, UCs: Upper Changhsing Formation, M3: mixed faunal bed 3, M2: mixed faunal bed 2, M1: mixed faunal bed 1.



Text-fig. 5 Legend of Text-figures 6, 7, 8 and 10-16.

Permian sediments and were not of a mixed fauna. Meanwhile, the Chinese Research Group (1977-1980) have repeatedly surveyed the stratotypes of the Changhsingian and the Permian-Triassic boundary, and the significant conclusions and descriptions of main fossil groups have been published in the Bulletin of Nanjing Institute of Geology and Palaeontology, Academia Sinica (No. 2, 1981). Furthermore, the fossil fish and the depositional characters and microfacies were studied by Liu et Chang (1963), Wang and Liu (1981), Wei (1977), Yang and Jiang (1980, 1981) and He (1981).

Six sections for the Changhsingian and the Permian-Triassic boundary of the Meishan region are reported in this paper. They are section of Zhongxin Dadui quarry; and sections E, D, C, B and A.

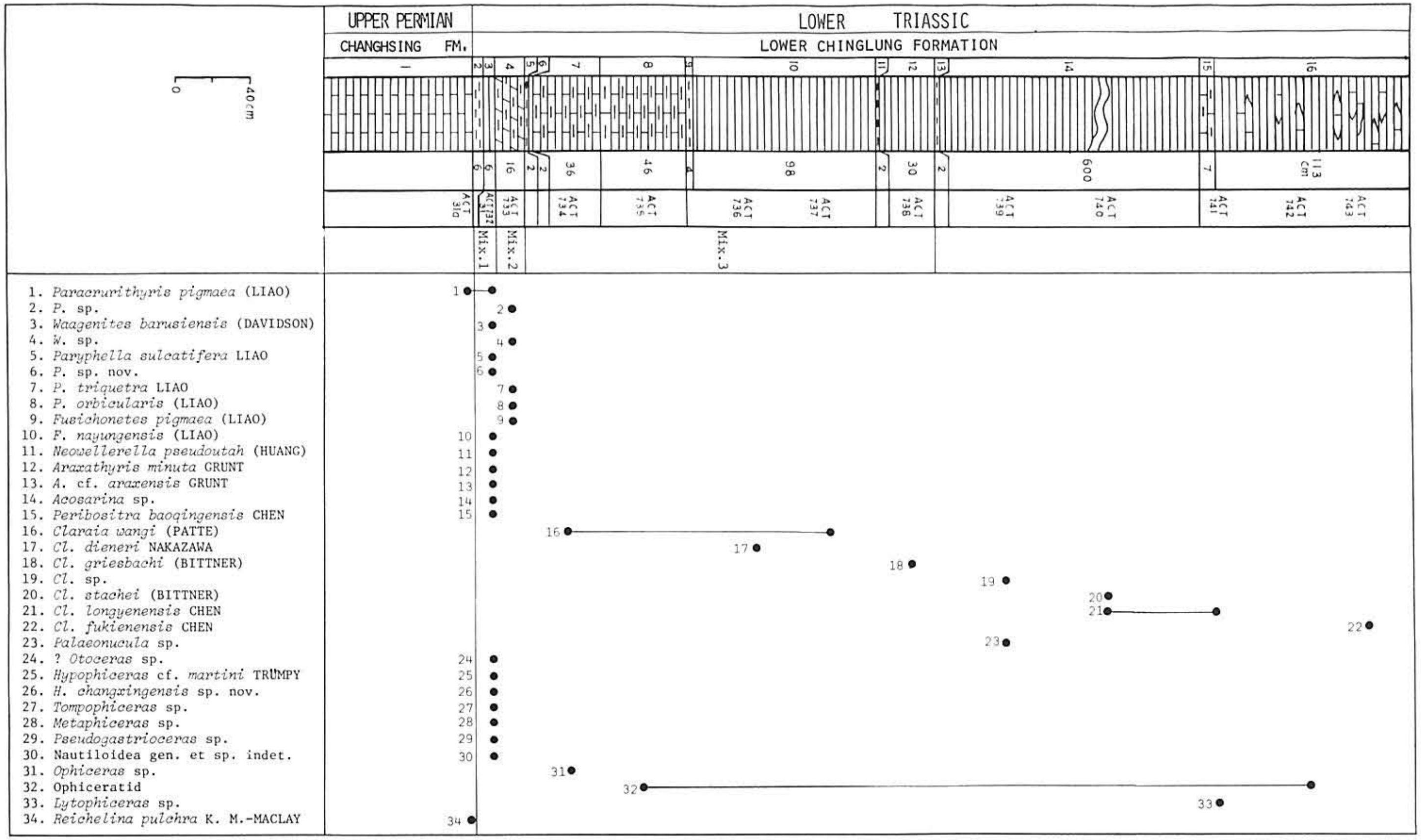
(1) Section of Zhongxin Dadui quarry

This is the stratotype section of the Permian-Triassic boundary in South China. It is well exposed in a small quarry, located about 0.5 km east of section D at the west end of Meishan. Here the Changhsingian is represented by a limestone sequence with *Palaeofusulina* fauna. The earliest Triassic horizon is proven by the presence of *Hypophiceras* fauna (i.e. *Hypophiceras, Otoceras*?, *Tompophiceras* and *Claraia wangi* assemblage, Permian-type chonetids, etc.). This mixed faunal horizon, in ascending order, can be subdivided into Mixed bed 1, Mixed bed 2 and Mixed bed 3.

The sequence of the present boundary beds, in descending order, is as follows:

Lower Triassic — Lower Chinglung Formation

15. Greyish green mudstone intercalated with thin-bedded argillaceous limestone and limestone increasing upward, containing bivalves *Claraia fukienensis* Chen, *Cl. longyenensis* Chen; ammonoids ophiceratids and *Lytophiceras* sp.



Text-fig. 6 Columnar section and stratigraphic distribution of fossils in the Permian-Triassic boundary beds at section of Zhongxin Dadui quarry (Meishan).

14. Greyish yellow mudstone with concretions of limestone, yielding *Cl. stachei* (Bittner) in the middle part and *Palaeonucula* sp., *Claraia* sp., in the lower .... 6.00 m
13. Yellow illite-montmorillonite clay .... 0.02 m

Mixed bed 3

12. Greyish yellow marl containing *Cl. griesbachi* (Bittner) .... 0.30 m
11. Yellow illite-montmorillonite clay .... 0.02 m
10. Greyish yellow mudstone yielding *Cl. wangi* (Patte), *Cl. dieneri* Nakazawa .... 0.98 m
9. Yellow illite-montmorillonite clay .... 0.04 m
8. Bluish grey marl containing ophiceratids .... 0.46 m
7. Greyish yellow marl yielding *Cl. wangi* and ophiceratids....................................... 0.36 m
6. Greyish yellow mudstone.. 0.02 m
5. Greyish yellow clay .... 0.01-0.02 m

Mixed bed 2

4. Light grey dolomitic marl containing brachiopods *Paryphella triquetra* (Liao), *P. orbicularis* (Liao), *Waagenites* sp., *Paracrurithyris* sp., *Fusichonetes pigmaea* (Liao) .... 0.16 m

Mixed bed 1

3. Greyish yellow mudstone with small crystals of pyrite, purple-red in weathering colour, yielding ammonoids *Otoceras*? sp., *Hypophiceras* cf. *martini* (Trümpy), *H. chàngxingense* Wang sp. nov., *Tompophiceras* sp., *Metophiceras* sp., *Pseudogastrioceras* sp.; bivalves *Peribositra baoqingensis* Chen; brachiopods *Paracrurithyris pigmaea* (Liao), *Waagenites barusiensis* (Davidson), *Paryphella sulcatifera* Liao, *Neowellerella pseudoutah* (Huang), *Araxathyris minuta* Grunt .... 0.06 m
2. Yellow or purple illite-montmorillonite clay .... 0.06 m

— Conformity —

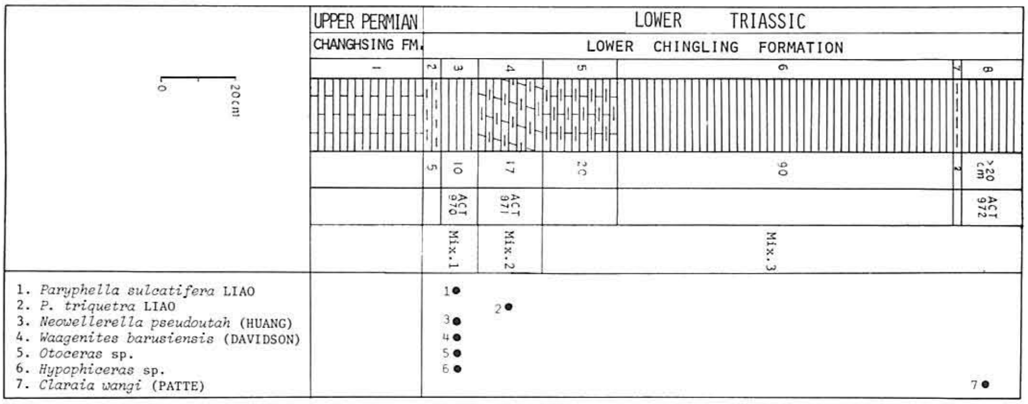
Upper Permian Changhsing Formation

1. Light grey thin-bedded limestone with chert nodules, bearing *Palaeofusulina*.

The beds nos. 2 to 4 were referred to the unnamed ammonoid zone as uppermost Permian by Zhao, Liang and Zheng (1978). It is now placed in the *Otoceras* beds of Lower Triassic.

(2) Section E

This section is situated at 100 m west of the Zhongxin Dadui quarry. Here the Permian-Triassic boundary is well exposed. A specimen firmly identified as *Otoceras* was found in the mixed faunal bed 1. The mixed faunal beds in this section are as follows:



Text-fig. 7 Columnar section and stratigraphic distribution of fossils in the Permian-Triassic boundary beds at section E (Meishan).

Mixed bed 3 (beds nos. 5-8) is composed of grey dolomitic marl and yellowish green mudstone with clay intercalations.

Mixed bed 2 (bed no. 4), 0.17 m thick, consists of grey marl, containing *Paryphella triquetra.*

Mixed bed 1 (bed no. 3), 0.10 m thick, comprises dark grey mudstone, containing ammonoids *Otoceras* sp., *Hypophiceras* sp.; brachiopods *Paryphella sulcatifera, Neowellerella pseudoutah* and *Waagenites barusiensis.*

Basal clay (bed no. 2), 0.06 m in thickness.

Text-fig. 9 Distal view of section D, showing the Lungtan, Changhsing and Chinglung Formations (looking north). LCl: Lower Chinglung Formation, P-Tb: Permian-Triassic boundary, UCs: Upper Changhsing Formation, LCs: Lower Changhsing Formation, Lt: Lungtan Formation, F: fault.

(3) Section D

This section is selected as the stratotype of the Changhsingian Stage. It is situated at Baoqing of Meishan, a quarry north of Baoqing mechanical repair factory.

The base of this section is the uppermost part of Lungtan Formation which is exposed by a fault and is composed of grey mudstone and brecciated limestone with the conodont *Gondolella orientalis* and some brachiopods.

The Changhsing Formation overlies conformably the Lungtan Formation and is subdivided into two members by Zhao and his colleagues (1981). The upper member corresponds to the upper part of Meishan Member of Zhao and others (1978) and the lower member corresponds to the lower part of Meishan Member and the Baoqing Member.

The Lower member (beds nos. 2-13) is 23.58 m thick, consisting mainly of dark grey bituminous limestones with well developed lamination intercalated with some clay layers. A limy tuff bed (bed no. 3) occurs about 5 m from the base of the formation. Fusulinids in this member are characterized by the primitive *Palaeofusulina*, such as *P.*

minima Sheng et Chang, *P. simplex* Sheng et Chang associated with *Reichelina* and non-fusuline foraminifers *Colaniella minima* Wang, *C. nana* K.M.-Maclay, *Geinitzina* and *Astaeolus*, etc. Conodonts occur in great abundance and are referred to as the Zone of *Gondolella subcarinata subcarinata-G. subcarinata elongata*. The ammonoids are characterized by the dominance of the family Tapashanitidae, and the *Pseudostephanites-Tapashanites* Zone is recognized. Corals of solitary forms are rare. Ostracods and brachiopods are common.

The upper member (beds nos. 14-21), 17.95 m thick, consists of dark medium bedded limestone with chert bands intercalated with clay layers. The base of this member is a clay layer of illite-montmorillonite composition. Fusulinids in this member are characterized by the advanced form of *Palaeofusulina* such as *P.* cf. *sinensis*, etc. in association with *Reichelina*. The conodont *Gondolella deflecta-G. subcarinata changxingensis* Zone is recognized. The succession of lowermost part in this section, in descending order, is as follows:

Lower Triassic — Lower Chinglung Formation
Mixed bed 3
26-27. Greyish black marl mudstone yielding *Claraia*; ophiceratids.
25. Clay .... 0.02 m
Mixed bed 2
24. Grey dolomitic marl containing *Paryphella triquetra, P. orbicularis* (Liao), *Waagenites* sp. and *Crurithyris* sp. .... 0.15-0.17 m
Mixed bed 1
23. Greyish black mudstone yielding *Paryphella triquetra, P. orbicularis, Neowellerella pseudoutah* .... 0.09 m
22. Greyish yellow illite-montmorillonite clay .... 0.05 m
— Conformity—
Upper Permian Changhsing Formation
Upper member
21. Grey limestone with chert nodules, containing *Palaeofusulina* fauna.

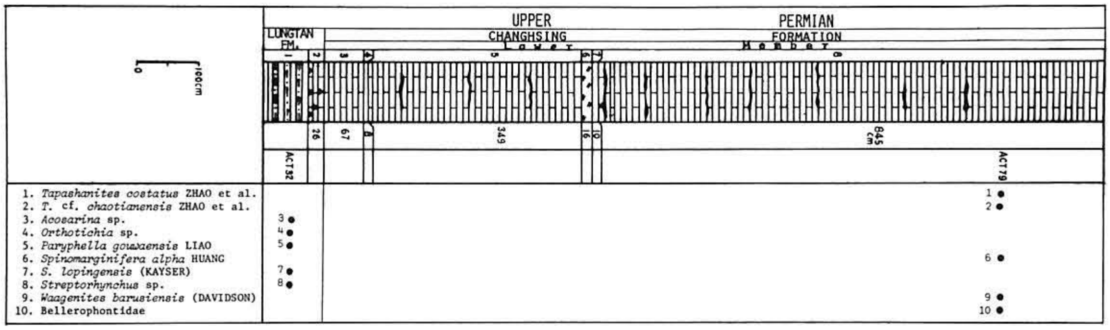
(4) Section C

It is situated in the Boaqing quarry, about 300 m west of section D. The strata are the same as in section D, but a fault passes through the upper part of the lower member of the Changhsing Formation. The ammonoid *Tapashanites* fauna has been found in bed no. 5 of the lower member.

(5) Section B

This section occurs 70 m west of section C. Here the upper member (beds nos. 1-4) of the Changhsing Formation, consisting chiefly of dark grey limestone with chert nodules, outcrops, the exposed thickness being 5 m.

The fusulinids in this section are rich in advanced *Palaeofusulina* (i.e., *P.* cf. *sinensis, P. ovata, P. nana, P. pulchra*) associated with *Reichelina*. The non-fusuline foraminifers are abundant, consisting of 33 genera and 49 species, and include *Geinitzina spandeli, Hemigordius, Pseudoglandulina* and *Frondicularia* in association with *Abadehella, Nodosaria*, etc. The conodont *Gondolella deflecta-G. subcarinata changxingensis* Zone is the same as in section D. The brachiopods are: *Paracrurithyris pigmaea, Paryphella orbicularis, Spinomarginifera* etc. The succession near the erathem boundary is as follows:



Text-fig. 10 Columnar section and stratigraphic distribution of fossils in the Upper Permian at section C (Meishan).

Lower Triassic — Lower Chinglung Formation

Mixed bed 3

11. Bluish grey mudstone intercalated with marl yielding *Claraia* sp. and *Neowellerella* sp. 3.20 m
10. Dark grey mudstone with 2-3 clay intercalations containing *Claraia* sp. and *Crurithyris* sp. .... 0.80 m
9. Grey marl .... 0.05 m
8. Whitish clay .... 0.03 m

Mixed bed 2

7. Grey dolomitic marl with crystals of pyrite, containing *Geinitzina* sp., *Nodosaria* sp., *Crurithyris* sp., *Fusichonetes* sp., *Paracrurithyris* sp., *Waagenites* sp. and *Paryphella* sp. .... 0.17-0.18 m

Mixed bed 1

6. Black mudstone containing *Acosarina* sp., *Araxathyris* sp., *Fusichonetes* sp., *Claraia*? sp., *Peribositra baoqingensis, Hypophiceras* sp. and ophiceratids .... 0.08 m
5. Grey illite-montmorillonite clay .... 0.06 m

— Conformity —

Upper Permian — Changhsing Formation

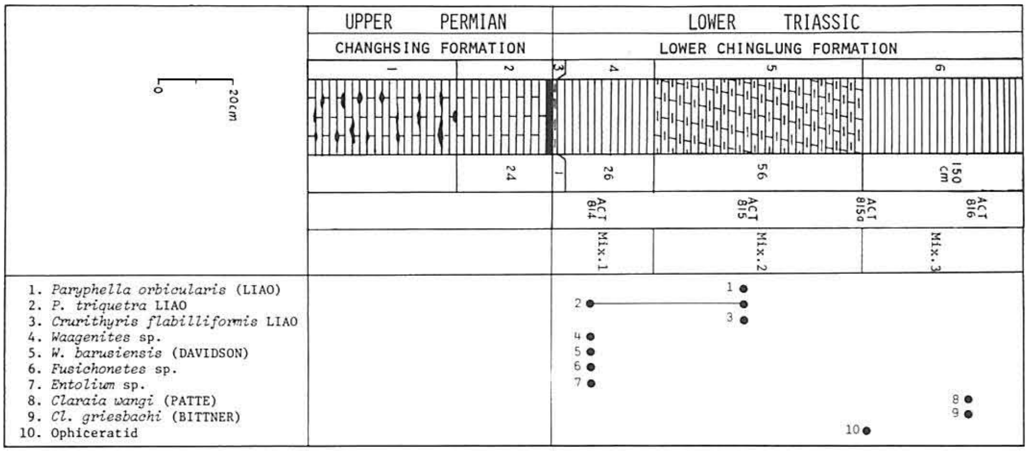
(6) Section A

This section is situated at 80 m west of section B. Here the upper member (beds nos. 4-10) of the Changhsing Formation is well exposed, having total thickness of 16.81 m; the lower member (beds nos. 1-3) has an exposed thickness of about 7 m. The aspect of main fossils is similar to those of sections B and D, but some forms of Gymnocodiaceae (*Gymnocodium, Permocalculus*) are obtained from the upper member. The mixed faunal beds of the lowermost Triassic can be clearly seen in this section and some Triassic elements, such as *Otoceras*?, *Claraia*? associated with Permian-type brachiopods, *Waagenites* and *Paryphella*, are found.

b. Baiyangtang, Yixing

This region was mapped and investigated by geologists of Jiangsu and Zhejiang Bureau of Geology in seventies, and the results were published in <Regional stratigraphic chart of East China> in 1978. The sequences of the Upper Permian and the Lower Triassic herein are similar to those of Meishan in Changxing.

In May of 1980, the Chinese Research Group investigated a well exposed but short section, containing a mixed faunal bed between the Permian and Triassic rocks. In the autumn of the following year, members of the Chinese-Japanese Research Group



Text-fig. 13 Columnar section and stratigraphic distribution of fossils in the Permian-Triassic boundary beds at Baiyangtan section (Baiyangtang, Yixing).

jointly visited this section.

The Baiyangtang section is located in front of the Baiyangtang village along the side of a highway from Zhanggong cavern to Linggu cavern, about 5 km NW of Hufu,Yixing. Here the Changhsingian Stage is represented by a dark grey limestone bed of the upper member of the Changhsing Formation, and the overlying greyish yellow mudstone belongs to the base of the Lower Triassic. No erosional features are observed between them and they are conformable. The exposed thickness of these rocks is only about 6 m, since the rocks are mostly covered by a paddy field. The details of this section are stated below in descending order:

Lower Triassic — Lower Chinglung Formation

Mixed bed 3

6. Greyish yellow mudstone, mostly covered by paddy field, exposed thickness is about 1.5 m, containing *Claraia wangi* and ophiceratids.

Mixed bed 2

5. Greyish yellow argillaceous dolomite, yielding *Paryphella orbicularis, P. triquetra, Crurithyris flabelliformis* Liao .... 0.56 m

Mixed bed 1

4. Greyish yellow mudstone with small crystals of pyrite, containing *P. triquetra, P.* sp., *Waagenites barusiensis, Fusichonetes* sp. and *Entolium* sp. .... 0.25 m
3. Whitish clay .... 0.005-0.01 m

— Conformity —

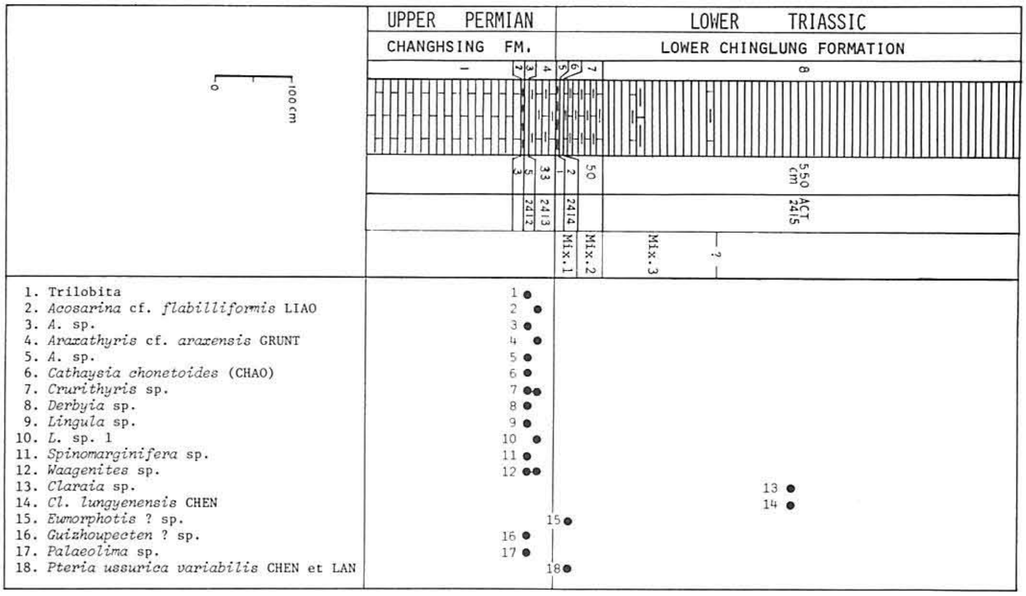
Upper Permian — Changhsing Formation

2. Greyish black thin-bedded limestone, bearing a siliceous layer at the top .... 0.24 m
1. Black, dark grey medium-bedded limestone with chert nodules intercalated with three clay layers .... 2.00 m

c. Mashishan of Xidongtingshan Island

Xidongtingshan is an island in Tai Lake in Wuxian of the Jiangsu Province. The strata of this island were investigated by the geologists of the Jiangsu Bureau of Geology in the seventies.

The Upper Permian and Lower Triassic are also much the same as in the Meishan



Text-fig. 14 Columnar section and stratigraphic distribution of fossils in the Upper Permian and Lower Triassic at Mashishan section (Mashishan of Xidongtingshan Island, Wuxian)

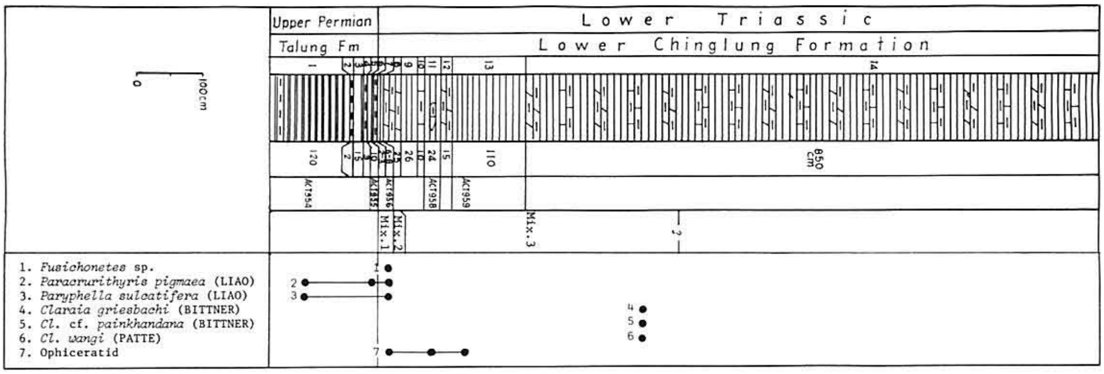
section of Changxing. A section containing the Permian-Triassic boundary is exposed in a quarry at Mashishan. The rocks strike 225° with a dip of 40°-90°, and are inverted so that the Changhsing Formation overlies the Lower Triassic rocks.

The Changhsing Formation, here about 86 m thick, is composed of greyish white thick-bedded limestone, intercalated with a few argillaceous limestone, mudstone and dolomite in the lower part. Two fusulinid zones have been known: *Gallowayinella* Zone below and *Palaeofusulina sinensis* Zone above. A rich *Colaniella* fauna occurs in the latter zone.

The beds nos. 2-4 of this section are composed of clay, mudstone and argillaceous limestone, about 41 cm thick, and were formerly referred to the Triassic by many Chinese geologists. However, in 1980, members of the Chinese Research Group discovered a pygidium of trilobite, Permian bivalve *Guizhoupecten* and Changhsingian brachiopods such as *Cathaysia, Spinomarginifera*, etc. It is evident, therefore, that these beds are of Changhsingian age and the Permian-Triassic boundary is thus to be drawn between bed no. 4 and bed no. 5.

d. Suburbs of Nanjing

The Upper Permian in the suburbs of Nanjing is divided into two formations, the Lungtan Formation below and the Talung Formation above; the lower Lower Triassic is represented by the Lower Chinglung Formation. The two localities with continuous sequences of these formations are known, according to Sheng and his colleagues (1982). One is situated at the northern foot of the Chinglung Mts. near Longtan and the other is at Hushan near the town of Tangshan. The former is the type locality of the



Text-fig. 16 Columnar section and stratigraphic distribution of fossils in the Upper Permian and Lower Triassic at Hushan section (Hushan, Jiangsu).

Lungtan coal-bearing Formation and of the Chinglung Limestone. Hsu's (1936-37) "*Otoceras* cf. *woodwardi* Griesbach" occurs herein. Zhao, Chen and Liang (1962) suggested that the lower Triassic rocks were named the Lower Chinglung Formation and the equivalent of the Changhsingian was named the Talung Formation (Sheng, 1962). Traditionally, the contact between the Permian and Triassic in this region has been considered to be disconformable (Pan, 1956; Sheng, 1962; Zhao et al., 1978); but most recently the relationship is thought to be conformable (Min et al., 1981; Sheng et al., 1982).

In the summer of 1980 the Chinese Research Group dug out a trench at the northern foot of the Chinglung Mts. in which only the top of the Lungtan Formation was exposed, about 5.7 m thick, containing Anderssonoceratidae, etc. (beds nos. 1-6). According to Zhao and others (1978), this formation is about 114 m thick, and can be subdivided into two parts. The upper part is composed of black mudstone intercalated with lenticular limestone yielding *Prototoceras*, etc. and the lower is coal-bearing.

The Lungtan Formation is conformably overlain by the Talung Formation. The latter can be subdivided into two parts: the lower (beds nos. 7-9, about 7 m thick) is composed of black mudstone intercalated with clay layers, and contains brachiopods *Lingula* and *Paracrurithyris*, bivalve Palaeotaxodonta and ammonoid *Pleuronodoceras*; the upper part (beds nos. 10-15; about 4 m thick) of this formation is composed of black siliceous mudstones with clay intercalations, and contains abundant but small forms of brachiopods belonging to the *Paryphella sulcatifera-Paracrurithyris pigmaea* assemblage. In addition, the bivalves Aviculopectinidae, Palaeotaxodonta and ammonoids *Pleuronodoceras, Pseudogastrioceras* are also present.

The Talung clastic facies is different from the Changhsing limestone facies along a line drawn from Jiangyin to Yixing in the Jiangsu Province. The reason for the difference was interpreted as owing to a land barrier lying between Jiangyin and Yixing, but Sheng and his colleagues (1982) considered the difference as resulting from environments of deep or shallow sea basins rather than the land barrier.

The Lower Chinglung Formation rests on the Talung Formation with traditional boundary. In lithologic and faunal characteristics, it can be, in ascending order, divided into three parts: the first part (beds nos. 17-23) is the mixed faunal bed comprising clay, mudstone and marls, and is 1.6 m thick. Small forms of ophiceratids associated with the Permian type brachiopods *Fusichonetes, Paryphella* and *Paracrurithyris*, etc. are found. It represents the base of Lower Triassic in the suburbs of Nanjing and corresponds to the mixed faunal beds 1 to 2 bearing the *Hypophiceras* fauna at Meishan, Changxing.

The second part (beds nos. 24-32) is composed of greenish grey mudstone and marls, about 26.5 m thick. There are two fossiliferous horizons: the lower containing Gyronitidae and the *Claraia aurita* assemblage, and the upper with the *Cl. stachei, Cl. wangi* assemblages and *Ophiceras.*

The third part (beds nos. 33-43) consists of alternating yellow mudstone and grey limestone, about 14.2 m thick. The ammonoids *Koninckites, Flemingites, Paranorites* and *Pseudosageceras* are found in the lower middle part (about 7.5 m from the bottom). This ammonoid horizon corresponds to Hsu's locality No. LS15 yielding *Otoceras* cf. *woodwardi* and which has more recently been transferred to *Koninckites* by Wang.

The upper Lower Triassic is composed of limestone and nodular limestones, about 350 m or more in thickness, containing the ammonoids *Columbites, Subcolumbites,* etc.

In the Hushan section the lower part of the Lower Triassic increases in mudstones and the contact between the Permian and the Triassic is much the same as in the Longtan section. (See Text-figure 16.)

e. Central Guizhou

The Permian rocks of central Guizhou are known in Jiaozishan of Anshun county.

The Permian account is here taken mainly from Yao and others (1980) and references are made to Huang (1932) and Sheng (1962). The Upper Permian succession in this area is as follows, in descending order:

Talung Formation / Changhsing Formation
Lungtan Formation / Wuchiaping Formation
Omeishan basalt formation

The Omeishan basalt formation with a total thickness of 84,5 m, rests disconformably on Lower Permian limestones. It comprises greyish green tuff, basalt, tuff breccia without any trace of fossils. The Lungtan Formation overlies conformably the Omeishan basalt formation, is about 305 m in thickness, and consists of greyish green, grey siltstone, mudstone with limestone intercalations. The fusulinid fauna is known from the limestone including *Codonofusiella, Reichelina, Nankinella* and is referred to as the Zone of *Codonofusiella*. Molluscs, corals, ostracods, brachiopods and foraminifers are common.

The Changhsing Formation, 77 m thick, overlies conformably the Lungtan Formation, and comprises three divisions. The lower division, 43.5 m thick, consists of alternating greyish green siltstone, sandy mudstone and limestone with coal seams, with two fossil levels, the *Paratirolites-Shevyrevites* Subzone and *Palaeofusulina minima-*

Nankinella guizhouensis Subzone. Brachiopods, gastropods, bivalves and ostracods are also common. The middle division, 17.7 m thick, is mainly grey limestone with chert bands and yields *Palaeofusulina sinensis* and ammonoids (*Pseudotirolites*, etc.), corals and brachiopods, etc. The upper division, about 15.7 m thick, is characterized by black siliceous mudstone intercalated with clay layers. Ammonoids *Rotodiscoceras, Pleuronodoceras, Pseudotirolites*, etc. are dominant and are named the Subzone of *Rotodiscoceras-Pleuronodoceras*. In addition, *Reichelina, Ullmannia*, brachiopods, bivalves and gastropods are also present.

The Lower Triassic succession herein is divided into two formations (Chen et al., 1979): the lower Yelang Formation, comprising yellowish green mudstone, marl and thin-bedded limestone rests with transistion boundary on the Changhsing Frmation. A mixed faunal bed was found in the basal mudstone, which yielded *Ophiceras, Claraia* cf. *wangi, Cl.* cf. *griesbachi* and *Paracrurithyris pigmaea*. Above this bed are the *Cl. stachei* and *Cl. concentrica* horizons. The upper Anshun Formation consists of grey, thick-bedded limestone and dolomites yielding the ammonoid *Tirolites spinosus* and bivalves.

f. South Guizhou

The Upper Permian and Lower Triassic formations in south Guizhou are well exposed at the Ziyun area. The Upper Permian is composed mostly of a limestone sequence intercalated with a few layers of sandy mudstone and mudstone in the middle part. The Triassic formations consist mainly of clastic rocks with the exception of limestones in the lower part. Wang, Sheng, Chen and Lu (1963), and Wang, Chen and Lu (1963) first distinguished these formations from those of central Guizhou. Many well preserved fossils have been described, including Permian corals by Wu (1963), Permian and Triassic bivalves by Chen (1962, 1976) and by Yin et Gan (1978), Permian fusulinids by Sheng (1963), and Lower Triassic ammonoids by Wang (1978).

The subdivisions of these Permian and Triassic sequences are as follows:

Middle Triassic: Kingdongkou Formation (Ladinian)
Xinyuan Formation (Anisian)
Lower Triassic: Luolou Group (Griesbachian to Spathian)
----- Disconformity -----
Upper Permian: Changhsing Formation
Wuchiaping Formation
Mulaichung Member
Kanchao Member
Chiyaopo Member

The Wuchiaping Formation has a total thickness of about 370 m and can be subdivided into three members in descending order, Mulaichung, Kanchao and Chiyaopo Members.

The Chiyaopo Member, 120 m thick, is composed of grey and whitish grey thick-bedded limestones. Fusulinids are abundant, including *Codonofusiella lui, C. tenuissima, C. schubertelloides, Nankinella, Dunbarula, Sphaerulina*, and are associated with corals such as *Ipciphyllum* and *Liangshanophyllum.*

The Kanchao Member, 45 m thick, consists of greenish grey mudstone intercalated with sandy mudstone and limestone lens; brachiopods (*Leptodus, Schellwienella, Spiriferellina, Punctospirifer*) and bivalves (*Guizhoupecten, Girtypecten, Permoperna*, etc.) are dominant in this member but the fusulinids are very rare, only *Nankinella* having been found.

The Mulaichung Member, about 205 m thick, is characterized by light grey thick-bedded limestones with chert concretions. Fusulinids are very abundant in this member, among which *Codonofusiella* and *Reichelina* are dominant, in association with a few *Nankinella* and *Sphaerulina*. Brachiopods, bivalves and bryozoans are very rare.

The fusulinids of the Wuchiaping Formation, as a whole, are referred to the Zone of *Codonofusiella* (Sheng, 1963).

The Changhsing Formation, 105 m thick, rests conformably on the Wuchiaping Formation. It is also composed of light grey thick-bedded limestone with some chert nodules in the lower part. The fusulinid genus *Palaeofusulina* is abundant in association with some species of *Reichelina* and *Nankinella* and is referred to the Zone of *Palaeofusulina* (Sheng, 1963)

The Luolou Group of the Lower Triassic is divisible into two parts, the lower part composed of yellowish green mudstones with the *Claraia* fauna, and the upper one of thin-bedded limestone with an abundant ammonoid fauna at the top. The ammonoids are *Procarnites, Isculitoides, Albanites, Xenoceltites, Cordillerites, Metadagnoceras, Eophyllites* and *Leiophyllites*, etc. (Wang, 1978). The Luolou Group varies in thickness from zero to 80 m and, in some places, the Anisian Xinyuan Formation with *Daonella* rests directly on the Changhsing Formation. It is evident that the contact between these formations is disconformable and that the transitional bed or mixed faunal bed has not yet been found in this area.

The Middle Triassic comprises mainly clastic rocks yielding bivalves *Daonella, Posidonia*, etc. and ammonoids *Protrachyceras*, etc.

g. North Tibet

The continuous sequences of the Upper Permian and Lower Triassic in North Tibet were recently discovered in the Shuanghu area (Long. 86.8°E, Lat. 33.6°N) along the centre of the NE Qiangtang plateau, attaining a thickness of about 1000 m, consisting mainly of limestones, mudstones, sandstones with coal seams. They are divided by Wen (1979) into, in ascending order, the Raggyorcake, Kanglu and Ningshuiquan Formations. His collections have been studied and published in 1981 and 1982, the brachiopods by Ching and Sun: the fusulinids by Wang, Sheng and Zhang; the bivalves by Chen; the ammonoids by Wang and He; and the plants by Lee and others.

The Reggyorcaka Formation of Changhsingian age is divided into two parts: the lower, about 140 m thick, composed of dark grey sandy mudstone and limestone, having a Changhsingian fusulinid fauna (*Palaeofusulina sinensis, P. fusiformis, P. nana*, etc.) and brachiopods *Cathaysia, Peltichia, Squamularia, Leptodus*; and the upper part of black sandstone, mudstone intercalated with coal seams yielding a Cathaysian flora such as *Gigantonoclea, Annularia*, etc.

The Lower Triassic Kanglu Formation has a total thickness of 310 m and can be subdivided into two parts: the lower, about 60 m thick, of grey sandstone, light grey fine-grained sandstone, siltstone with coal seams, in which no fossils have been found; and the upper part of dark red sandstone, mudstone, and of blackish grey siltstone, sandy mudstone and a few marls at the top. Bivalves are abundant in the upper part of this formation and two assemblages are recognized: the lower *Claraia stachei* assemblage including *Cl. stachei, Cl. guizhouensis, Unionites fassaensis*, etc., which corresponds to the same assemblage found in South China; and the upper *Claraia aurita* assemblage (*Cl. aurita, Cl. intermedia* and *Neoschizodus*, etc.) similarly corresponding to the same assemblage in South China. The *Cl. wangi* assemblage of South China has not been found. It is probable that the lower part of the Kanglu Formation, though no fossils have been found, may be equivalent to the *Cl. wangi* assemblage zone.

The Ningshuiquan Formation, roughly corresponding to the Smithian to Spathian, is reported to consist of alternating thin-bedded limestones and mudstones, about 453 m thick. Many bivalves have been found in the mudstones, including *Eumorphotis inaequicostata, E. rugosa, Costatoria costata, Entolium discites microtis* and *Bakevellia exporrecta*, etc.

2. West China

South Tibet

In South Tibet, the basal part of Triassic Kanshare Formation with the *Otoceras* fauna is well exposed at Xishan of Selung (Yin et al., 1974; Wang et al., 1980). It consists mostly of grey limestone, with a total thickness of 6 m. The succession, in descending order, is as follows:

Upper member

4. Light red and light grey limestone, with the ammonoids *Procarnites* cf. *kokeni* (Arthaber), *Anasibirites kinglanus* (Waagen), *Pseudoceltites angustecostatus* (Welter), *Keyserlingites bearrivarensis* Kummel, *Xenoceltites* sp., and the conodont *Neospathodus cristagalli* (Huckriede) .... 3 m

Lower member

3. Light grey limestone containing *Priondobus plicatilis* (Waagen) and *Gyronites* cf. *superio* Waagen .... about 2 m
2. Light grey thin-bedded limestone yielding *Anotoceras nala* (Diener), *Ophiceras demissum* (Oppel), *O. tibeticum* Griesbach and *O.* (*Lytophiceras*) *sakuntala* (Diener) .... about 0.7 m
1. Light grey, weathering brownish yellow, dolomitic limestone and dolomite, containing *Otoceras latilobatum* Wang and He, *O.* sp. and "*Glyptophiceras*" cf. *lissarense* (Diener) .... generally 0.2 m, sometimes 0.7 m

----- Disconformity -----

Lower Permian Selung Group

The Kanshare Formation increases in thickness eastward to 103 m at Tulung, the type-locality of the Tulung Group (Mu et al., 1973). In Tulung, this formation also comprises the upper and lower members. The upper member, 40 m thick, is composed mostly of light red limestone, with two ammonoid zones: the *Proconites-Anasibirites*

Zone above and the *Owenites* Zone below: the lower member, about 63 m thick, consists mostly of light red mudstone, with only *Gyronites psilogyrus* present. No. fossils have been found in the basal dolomite.

Five ammonoid zones of the Lower Triassic have been established by Wang and He (1976) in South Tibet. They can be correlated with those of the Lower Triassic in the world.

The Permian rocks in South Tibet are named the Selung Group by the Shisha-Pomgma Scientific Research Party in 1964. This group is widely distributed in the southern part of this region and is composed mostly of limestone, sandstone and sandy mudstone with exposed thickness about 218 m. In Selung area this group consists mostly of limestones, intercalated with a few sandstones and mudstones in the middle and lower parts; toward the east to the Nasin area. It is composed of marls intercalated with sandstone and mudstone beds; farther eastward, it changes into sandstones and mudstones with only a few limestones.

The brachiopod assemblages of the Selung Group have been established by Zhang and Ching (1976), which in descending order are: the *Chonetella, Collimarginatia* and *Taeniothaerus* assemblages. These assemblages are very similar to those of the Kalabagh Member and the Chhidru Formation of the Salt Range. The corals (*Lytvolasma, Cyathocarinia, Wannerophyllum*, etc.) are common in the Selung Group. They are considered to be of cold-water forms and are named by Wu (1975) the *Lytvolasma* fauna.

The contact between the Kanshare Formation and the Selung Group is disconformable, because the Changhsingian fossils have not been found.

3. Kashmir, the Salt Range and Abadeh regions

a. Kashmir

The Upper Permian and Lower Triassic strata at Guryul Ravine and a spur 3 km. north of Barus in Kashmir were examined. They are classified into two formations, the Zewan and the overlying Khunamuh based on the difference in lithology, and the relation between them is apparently conformable.

The Zewan Formation can be divided into four members, A to D at Guryul Ravine and five members, a to e at a spur 3 km north of Barus, both in ascending order. On the other hand, the Khunamuh Formation is divisible into four members, E to H, at Guryul Ravine and three, f to h, at the Barus section, both in ascending order, on the basis of limestone-shale ratio. Each member at these two localities are comparable to one another, based on stratigraphic position as well as on lithologic and palaeontologic criteria. As the Permian and Triassic strata at the Barus section contain less numerous fossil horizons, in comparison with those at Guryul Ravine, the following stratigraphic and palaeontologic description is based on the latter section.

Member A of the Zewan Formation is composed mainly of carbonate rocks accompanied by sandy shale, and palaeontologically characterized by an association of bryozoans, brachiopods and foraminifers including *Colaniella* cf. *minima, C. cylindrica* and *Abadehella* cf. *coniformis*. Member B is mainly shale with some carbonate rocks and poorly fossiliferous except for brachiopods represented by *Costiferina indica, Callispirina ornata, Leptodus nobilis* and *Fusispirifer nitiensis*. A solitary coral from Member b at a spur 3 km north of Barus was determined to be *Euryphyllum cainodon* (De Koninck). Member C is characterized by rhythmic alternation of calcareous sandstone and sandy shale, of which shale is the predominant. The appearance of gastropods and bivalves is characteristic of this member. Foraminifers and bryozoans are more abundant compared with Member B. A characteristic ammonoid species, *Cyclolobus walkeri* as well as conodont species *Hindeodus minutus* and *Gondolella carinata* were found in the uppermost bed of this member. Member D is mainly represented by thick-bedded sandy limestone. Although foraminifers and bryozoans are rare, abundant bivalves, gastropods and brachiopods are concentrated at some horizons. *Gondolella carinata* and *Xenodiscus* sp. were found in the middle or lower part of this member, ranging from the underlying member.

Member E of the Khunamuh Formation is composed of alternating shale and subordinate limestone, and is divided into three units, viz., E_1, E_2 and E_3 from bottom to top on the basis of different lithologies of the shale. Unit E_1 consists of dark grey to black shale intercalating several thin limestone layers. *Claraia bioni* occurs scattered in the shale and does not coexist with other fossils which include the brachiopods *Linoproductus* cf. *lineatus, Waagenoconcha purdoni* and *Marginifera himalayensis*, and the pelecypods *Etheripecten haydeni, Palaeoneilo* and "*Palaeolima*" *middlemissi* etc. Judging from this distribution, specimens of *Claraia bioni* are considered to have been buried in situ. On the other hand, other fossils have been transported for some distance before burial, but are not interpreted as being reworked from the underlying Zewan Formation, in view of the good preservation of the shells, and the presence of new forms unknown in the Zewan Formation. In addition to these brachiopods and bivalves, two species of foraminifers, one of gastropod, a very few conodont specimens of *Gondolella carinata* and *Ellisonia triassica*, and an ophiceratid ammonoid "*Glyptophiceras*" are found in the limestone part. Unit E_2 is composed of black to dark grey, sometimes greenish, shale with interbeds of dark limestone layers. The calcareous intervals are rich in ammonoids and bivalves, including *Otoceras woodwardi, Lytophiceras sakuntala,* "*Glyptophiceras*" *himalayanum, Eumorphotis venetiana,* and *Leptochondria minima*, throughout Unit E_2, but the occurrence of *Claraia*, including *Cl. dieneri* and *Cl.* cf. *griesbachi*, are restricted only to the upper part of the unit. A few fragmental specimens identified as *Claraia bioni, Etheripecten haydeni* and *Pustula* sp., which are common in the underlying unit, have been collected from the basal part of this unit. It is not certain whether these fossils were reworked or represent relict species. Conodonts become suddenly abundant, but are represented only by two long-ranging species, *Hindeodus minutus* and *Gondolella carinata*, both of which continue from the Zewan to the lower part of Unit E_2. On the other, conodont species *Hindeodus parvus* and *Isarcicella isarsica* appear in the upper part of Unit E_2 (Matsuda, 1981). Unit E_3 consists of black shale intercalating with limestone layers as in Unit E_2, but distinguished from the latter by a less fissile character of the shale. This unit contains a number of ammonoids, bivalves and conodonts. Ammonoids are represented almost exclusively by the genus *Ophiceras* including *O. tibeticum*, *O. serpentinum*, while bivalve faunule is composed of *Eumorphotis* aff. *bakharica*, *E. venetiana*, *Claraia* cf. *griesbachi*, *Cl. concentrica* and *Leptochondria minima*. Conodont species are represented by *Gondolella carinata* and *Neospathodus cristagalli*. Member F consists of alternating shale and limestone, and is faunistically characterized by the presence of *Ophiceras*, *Paranorites*, *Vishnuites* and *Koninckites*. In addition, the bivalve *Leptochondria minima* and the conodont *Neospathodus cristagalli* are present in this member. Member G consists of limestone intercalated with thin shale parting. It is pooly fossiliferous and only a few specimens of *Prionites* aff. *undatus* were collected from the lower part and *Koninckites* sp. from the middle part. Sweet (1970) reported the presence of two conodont species, *Neospathodus cristagalli* and *Ellisonia triassica* from the basal part. Matsuda (1982, 1983) described *N. cristagalli*, *N. nepalensis* and *N. pakistanensis* from the lower part and *N. waageni* from the upper part of this member.

b. The Salt Range

The Upper Permian in the Salt Range is represented, in ascending order, by the upper part of the Wargal Formation, entire Chhidru Formation and the lowest part of Mianwali Formation. The Wargal Formation is divided into five units, 1 to 5 in ascending order, by mean of the texture of the carbonate rocks, of which units 1 to 3 were estimated to be "Guadalupian" in age (Pakistani-Japanese Research Group, 1981). Unit 4, represented mainly by calcarenite facies, is further divided into the lower 4a, and the upper 4b. The *Codonofusiella-Reichelina* fauna first appears in the upper. Accordingly, the Upper Permian in the Salt Range is considered to start in Unit 4b. The lithology of Unit 4 is areally varied. Unit 4b in the Zaluch section is represented by biomicritic-intrasparitic, pelloidal, thin bedded limestone facies, in Chhidru by intrasparite-biomicrite facies and in Nammal by mixed facies of the both. Waagenophylliod corals are commonly found at Chhidru, but not in other sections. Bryozoans and brachiopods are not common and the occurrence of them are limited to certain horizons. Unit 5 consists of dark grey, wavy bedded or nodular limestones which are texturally named biomicrite-biomicrudite of mud support type. This unit was called the Kalabagh Limestone by Waagen (1881) and later Kalabagh Member by Teichert (1966). Brachiopods, bryozoans, algae and sponges are common or abundant. Waagenophyllid corals are mostly restricted to the upper one-third of the unit at Zaluch. Primitive *Colaniella*, such as *C. minuta*, *C. pseudominima*, first appear at 16 m above the base of this unit. *Colaniella nana* and *C. minima* occur a little higher, and the more advanced forms, *C. cylindrica* and *C. pseudolepida*, are found above the middle of Unit 5 (about 9 m above the *minuta* horizon).

The Chhidru Formation forms the uppermost part of the Permian in the Salt Range and can be divided into four lithic units. The Wargal-Chhidru boundary is diachronous. The lowest Unit 1 is characterized by a predominance of muddy rocks. The basal part of this unit is lithologically varied at different sections. Unit 2 consists of alternating limestone, calcareous sandstone and sandstone with shale intercalation. Unit 3 is represented by calcareous sandstone and sandstone. Cross bedding and trace fossils are found in the upper part. Unit 4 is lithologically characteristic with rather massive sandstone and alternating sandstone and shale, the uppermost part of which was labelled "White sandstone unit" by Kummel and Teichert (1970). Apart from the rather abundant occurrences of brachiopods, the *Codonofusiella-Reichelina* fauna similar to that of the underlying Wargal, sporadically occur throughout the Chhidru Formation. The uppermost part of Unit 3 and the entire Unit 4 are marked by common occurrences of bivalves, such as *Schizodus, Permophorus* and *Pteria*, and a few ammonoids including *Cyclolobus, Eumedlicottia* and *Xenodiscus*.

The Mianwali Formation rests upon the "White sandstone unit" of the Chhidru Formation and is conformably overlain by the Middle Triassic Tredian Formation of continental origin. A remarkable lithologic change is noticed at the boundary between the Chhidru and Mianwali Formations. The Mianwali Formation was divided into three members, namely, the Kathwai, Mittiwali and Narmia Members, in ascending order, by Kummel (1966).

The Kathwai Member has been further divided into two units, the Dolomite Unit below, and the Limestone Unit above, based more on biostratigraphic evidence, and less on lithology. Consequently, it is difficult to pick the boundary between the two units in the field, especially since the Dolomite Unit undergoes lateral lithofacies change.

The Dolomite Unit comprises dolostones and, in some places, intercalated terrigenous clastic rocks. A careful field observation makes it possible to divide the unit into three parts on the basis of lithology. The lower part consists of dolomitic sandstone or sandy dolostones and sandstones, which are usually parallel or cross-laminated. Various Permian-type brachiopods as well as foraminifers, including *Reichelina* sp., are present at three levels within the lower part at Narmia. The middle part is represented by massive or faintly bedded dolostones. Thin, greenish, muddy dolostone layers are intercalated at several horizons. Permian-type chonetids and *Crurithyris*, together with Early Triassic bivalves, *Eumorphotis* and *Entolium*, were found at the base of this part. In conodont zonation, this part is included in the *Hindeodus parvus* Zone, and characterized by the coexistence of *Isarcicella isarcica, Hindeodus parvus* and *H. minutus*. The upper part is represented by medium-bedded dolostones with glauconite grains or films. The lithologic lateral change from dolostone to limestone of this part is confirmed by conodont evidence. According to Kummel (1966) and Kummel and Teichert (1970), the Limestone Unit is defined to be of bedded limestones which are characterized by the occurrence of *Ophiceras*. The upper part of the Dolomite Unit and the Limestone Unit are referable to the conodont *Gondolella carinata* Zone.

The Kathwai-Mittiwali boundary is placed usually within limestone beds, based on biostratigraphic evidence, that is the base of *Gyronites* Zone is referred to as the base of the Mittiwali Member. The Mittiwali Member includes *Ceratite* Beds (Lower *Ceratite* limestone, *Ceratite* marls and *Ceratite* sandstone) and Bivalve Limestone (Upper *Ceratite* limestone and Bivalve beds) of Waagen (1895). Four conodont zones are present its lower part. They are the *Neospathodus kummeli, N. dieneri, N. cristagalli* and

N. pakistanensis-nepalensis Zones, from bottom to top. Three ammonoid zones, *Gyronites rotula, Koninckites davidsonianus* and *Paranorites-Proptychites* Zones, in ascending order, are also recognized at the Nammal section.

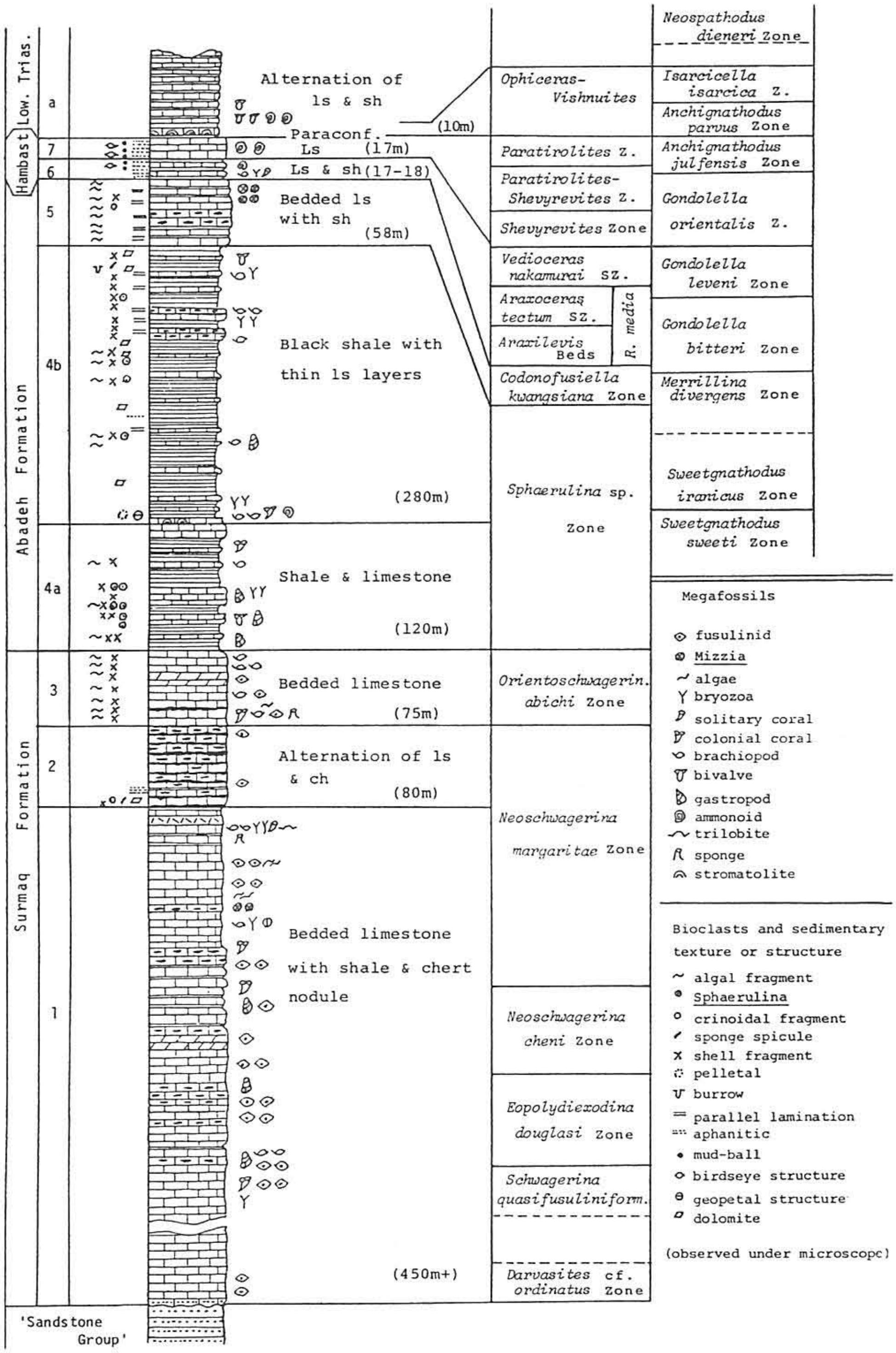
c. Abadeh

Taraz (1969) first surveyed the Permian and Triassic rocks developed in the Abadeh region and classified them into twelve lithologic units, of which Units 1 to 7 are Permian, while Units 8 to 12 Triassic in age. Taraz (1974) later referred to Units 8 to 12 as Units a to e, respectively.

The seven Permian units were grouped into three formations, the Surmaq, Abadeh and Hambast Formations, in ascending order (Iranian-Japanese Research Group, 1981). Of these, the Upper Permian of this region is represented by the Abadeh and Hambast Formations. The Abadeh Formation corresponds to an interval from the upper half of Unit 3 to Unit 5 in Taraz's (1974) classification, while the Hambast Formation is referable to Units 6 and 7. The upper half of Unit 3 and Unit 4 of Taraz (ibid.) were later revised to Units 4a and 4b, respectively, by the Iranian-Japanese Research Group (1981).

The Abadeh Formation, comprising Units 4a, 4b and 5, 458 m thick, is characterized, as a whole, by a large amount of dark grey to black shale with intercalation of thin-bedded, dark grey limestone. In Unit 5, however, limy facies is more prevalent than in Unit 4. That is, Unit 5 of 58 m thickness, consists of cliff-forming bedded limestone, in which some chert nodules are sporadically distributed. Unit 4, containing *Sphaerulina, Schubertella* and *Codonofusiella*, was designated as the *Sphaerulina* sp. Zone. There are no diagnostic fusulinids in this unit, but the disappearance of larger fusulinids belonging to the Verbeekinidae is characteristic. In contrast, the fusulinid fauna of Unit 5 is represented by *Reichelina* cf. *mirabilis, Codonofusiella lui* and *C. kwangsiana*, and larger fusulinids are completely lacking. Apart from the occurrence of fusuline fossils, the presence of *Cyclolobus, Xenodiscus* and *Abadehella* at the base of Unit 4b seems to be important for correlation as well as age determination.

The Hambast Formation, comprising Units 6 and 7, rests conformably on the Abadeh Formation, and constitutes the uppermost part of the Permian in the Abadeh region. Unit 6, 17 to 18 m thick, consists of alternating greenish shale and grey limestone. The lowest part of this unit is characterized by the abundant occurrence of brachiopods referable to *Araxilevis, Orthothetina, Leptodus, Araxathyris* etc., and is called *Araxilevis* bed. The remainder of Unit 6, with the exception of the *Araxilevis* bed, can be divided into two zones, *Araxoceras* Zone below, and *Vedioceras* Zone above. These two ammonoid zones coincide with the fusulinid zone of *Reichelina media*. The lithologic change between Units 6 and 7 is rather remarkable, that is, Unit 6 consists mainly of greenish shale with thin beds of light greenish limestone, while Unit 7 of reddish bedded limestone with white limestone bands. The boundary between Units 6 and 7 is marked by the disappearance of *Araxoceras* and *Vedioceras* as well as by the appearance of *Shevyrevites*. Unit 7 is divided into three ammonoid zones, which are, in ascending order, the *Shevyrevites, Paratirolites-Shevyrevites* and *Paratirolites* Zones. Two conodont zones are established in Unit 7, the *Gondolella orientalis* Zone



Text-fig. 18 Generalized columnar section of the Permian-Lower Triassic in Abadeh region, showing fusulinid and conodont zones, fossil occurrence and sedimentary texture (after Iranian-Japanese Research Group, 1981).

below and the *Hindeodus julfensis* Zone above. The boundary between the two conodont zones may be placed in the middle part of the *Paratirolites-Shevyrevites* Zone.

The Permian-Triassic boundary was placed at the Unit 7-Unit a boundary by the Iranian-Japanese Research Group (1981). The uppermost part of Unit 7 consists of thin-bedded pinkish limestone and contains a typical Dorashamian ammonoid *Paratirolites*. Unit a begins with a brownish to greenish shale beds of 10 to 31 cm thick. A small solitary body of "colonial limestone" first appears in this bed, but distinct fossil remains are absent. No erosional features are observed between this and the underlying *Paratirolites* bed. The regression at the Permian-Triassic boundary is reflected in the high content of insoluble residue and in the reduction of boron as well as lithium content (Iranian-Japanese Research Group, 1981; Inazumi and Bando, 1981).

The shale beds are succeeded upwards by stromatolite limestone beds, less than 2 m thick. In this part *Xenodiscus* sp., *Claraia* sp., *Hindeodus minutus* and *H. parvus* were found. Accordingly, this part is assigned to the conodont *H. parvus* Zone. The main part of Unit a, excepting the shale beds and stromatolite limestone beds, is composed mostly of alternations of limestones, yellow shales and thin-bedded limestones. The 10 m interval above the stromatolite limestone beds is referred to the *Isarcicella isarcica* Zone, based on the confined occurrence of *I. isarcica* in this part. *Ophiceras (Lytophiceras) dubium, Acanthophiceras golshanii, Ophiceras* sp. and *Vishnuites pralambha* were found in the upper part of the *I. isarcica* Zone. *Neospathodus dieneri* appears at about 17 m above the base, by which the *N. dieneri* Zone can be established. No diagnostic conodonts were obtained from the interval between *I. isarcica* and *N. dieneri* Zones. The bivalve *Claraia radialis julfensis* occurs from the *I. isarcica* to *N. dieneri* Zones, and *Claraia aurita* appears just above the *I. isarcica* Zone and ranges to the *N. dieneri* Zone.

Correlation

The correlation for the Permian-Triassic boundary of selected ten sections in the middle and east Tethys described above is given in Table 1. The transversal line shows the isochronous surface, the solid line conformity and the broken line disconformity or a questionable isochronous surface between two formations. A lacuna or hiatus is shown by parallel vertical lines.

The following explanatory notes should accompany the illustration.

1) In South China the Wuchiapingian Stage can be divided into two kinds of facies, the carbonate facies (Wuchiaping facies) and the clastic facies (Lungtan facies). The carbonate facies is rich in fusulinids and has been designated as the Zone of *Codonofusiella* (Sheng, 1956). Ammonoids are very rare in the limestones, but fairly common in the clastic facies. Three ammonoid zones, in ascending order, the *Anderssonoceras-Prototoceras, Araxoceras-Konglingites* and *Sanyangites* Zones were distinguished by Zhao, Liang and Zheng (1978) and by Zheng and Ma (1982) in the clastic facies.

A *Codonofusiella-Reichelina* fauna which includes *C. lui, C. kwangsiana, C.*

tenuissima, C. schubertelloides and *Reichelina* spp., etc., similar to that occurring in the Wuchiapingian in South China, was recognized in the Abadeh Formation, especially in its upper part (Unit 5) and the lower Hambast Formation (*Araxilevis* beds and *Araxilevis* beds in Iran, can be correlated with the upper part of the *Codonofusiella* Zone in the Wuchiaping Formation. This correlation is based on two lines of evidence: a) the *Codonofusiella* assemblages in these distant regions are identical, and ammonoid zones of the Wuchiapingian Stage, but the correlation of the *Araxilevis* beds is achieved more indirectly. The *Sanyangites* Zone found in the uppermost part of the Lungtan Formation is directly correlated with the *Vedioceras* Zone of the Dzhulfian in Abadeh. *Araxilevis* has not yet been found in the Wuchiapingian beds of South China. However, the lower part of the *Reichelina media* Zone, which occurs in the *Araxilevis* beds in Iran, can be correlated with the upper part of the *Codonofusiella* Zone in the Wuchiaping Formation. This correlation is based on two lines of evidence: a) the *Codonofusiella* assemblages in these distant regions are identical, and b) *Reichelina media* was recently discovered in the upper part of the Wuchiaping Formation (Rui et al., in preparation).

The *Cyclolobus*-bearing Chhidru Formation in the Salt Range and the Zewan Formation in Kashmir were believed to be Early Permian in age by Zhao, Liang and Zheng (1978). However, a foraminiferal fauna comprising *Codonofusiella, Reichelina* and *Colaniella* has recently been found in the upper part of the Wargal Formation (Units 4b and 5) and from the Chhidru Formation (Pakistani-Japanese Research Group, 1981). Although the *Colaniella* assemblage resembles that of the Changhsing Formation of South China, the characteristic Changhsingian fusulinid genus *Palaeofusulina* has not yet been detected either in the upper part of the Wargal Formation (including Kalabagh Member) or in the Chhidru Formation. Furthermore, the genus *Cyclolobus* has not yet been recorded in beds of Changhsingian or Dorashamian age.

In addition, certain aspects of the brachiopods found in the Chhidru and Zewan Formations are more similar to those occurring in the Wuchiaping Formation than to those from the Changhsingian beds. Therefore, with the exception of its uppermost part, we correlate the Chhidru Formation with the Wuchiaping Formation of South China.

A similar foraminiferal fauna containing *Colaniella* sp., *Reichelina changhsingensis, R. tenuissima,* and *R. gaqoiensis*, has recently been recorded from the Gaqoi Limestone in South Tibet (Wang, Sheng and Zhang, 1981).

Unit 3 of the Chhidru Formation and Member C of the Zewan Formation have yielded *Cyclolobus* and *Xenodiscus*. The brachiopod zone C_3 of the Chhidru Formation (upper part of Unit 3) is characterized by the *Megasteges nepalensis-Derbyia altestriata* assemblage. *Megasteges nepalensis* occurs in the main part of the Senja Formation in Nepal, and that part was referred to as the Vedian (= *Phisonites* Zone) in the youngest by Waterhouse (1978). If this correlation is correct, the *Cyclolobus*-bearing beds in the Chhidru and Zewan Formations may be correlated with the basal part of the Dorasham Formation, in accordance with the definition of Rostovtsev and Azaryan (1973), but the assumption is not convincing. In this paper only the Unit 4 (uppermost Chhidru Formation), characterized by *Enteletes socialis* assemblage, and Member D of the Zewan Formation are referred to the Dorashamian Stage, based on the occurrence of *Gondolella subcarinata* in Member D (Murata in Nakazawa and Kapoor, eds., 1981).

2) The Changhsingian is the youngest Permian Stage in the world. The upper limit of the ammonoids *Rotodiscoceras, Pseudotirolites, Pleuronodoceras* and the fusulinids *Palaeofusulina* is the upper boundary of the Changhsingian, while its lower boundary marks the extinction of the Araxoceratidae. The bases of the fusulinid *Gallowaynella meitienensis* Subzone, the conodont *Gondolella subcarinata subcarinata-G. subcarinata elongata* assemblage zone, and the brachiopod *Peltichia zigzag-Paryphella sulcatifera* assemblage zone are also accepted as the lower boundary of the Changhsingian (Zhao et al., 1981, p. 58). Only the Dorashamian in Transcaucasia of the U.S.S.R., Ali Bashi Formation of northwest Iran and the upper part of the Hambast Formation in central Iran may be equivalent to the Changhsingian judging from their fossil zones and stratigraphic positions. Considering that these formations lack fusulinids and that the ammonoid fauna is similar to, but not identical with, that of the Changhsingian, however, the exact correlation of the Dorashamian with the Changhsingian is difficult. Three different opinions on the correlation are presented by various authors, as follows:

a) The Dorashamian is equivalent to the lower part of the Changhsingian (Zhao et al., 1978, 1981); b) the Changhsingian is correlated with the lower part of the Dorashamian (Rostovtsev and Azaryan, 1973; Kozur, 1978); and c) the Changhsingian is equivalent to Dorashamian (Tozer, 1979; Nakazawa et al., 1981). The base of the Changhsingian and of the Dorashamian is synchronous, because both are defined by the extinction of araxoceratids and the first appearance of *Shevyrevites*. In South China, the primitive form of *Pseudotirolites* appears at the base of the Changhsingian in central Guizhou.

Recently two conodont zones were recognized in the Changhsingian: the *Gondolella subcarinata subcarinata-G. subcarinata elongata* Zone below and the *G. subcarinata changxingensis-G. deflecta* Zone above*. Constituents of the former zone are similar to those of the *G. subcarinata* Zone of the Dorasham beds, or of the *Hindeodus julfensis* Zone of the Upper Hambast Formation, while characteristic elements of the latter zone, such as *G. deflecta* and *G. dicerocarinata*, are not found in the Dorasham Formation, suggesting a younger age than the Dorashamian for this zone. However, the last two species are found in the upper part of the *G. subcarinata subcarinata-G. subcarinata elongata* Zone of the Changhsingian and *G. subcarinata subcarinata* is now known throughout the *G. subcarinata changxingensis-G. deflecta* Zone. Furthermore, a close similarity between the *Pseudotirolites* fauna in China and *Paratirolites* fauna in Iran was pointed by Tozer (1979). We consider the Changhsingian Stage as roughly equivalent to the Dorashamian with the possibility that the former may include still younger horizons.

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* *Anchignathodus* (= *Hindeodus*) *parvus* described by Wang and Wang (1979, p. 115, pl. 1, fig. 20) from the Changhsingian is considered to be an incomplete specimen of *Hindeodus minutus*.

3) Unit E_1 of the Khunamuh Formation in Kashmir is placed, according to the Japanese members, in the uppermost part of the Permian in this table. The reasons are: a) Unit E_1 is conformable with the underlying Zewan Formation; b) it is overlain by the *Otoceras* beds, Unit E_2; c) brachiopod and bivalve fossils are intimately related to those of the Zewan and no Triassic elements are found at all; d) those Permian type fossils are not considered to be reworked from underlying beds based on field evidence.

However, the Chinese members still prefer to place the E_1 at the base of the Triassic. Their reasoning is as follows; a) lithologically, E_1 is similar to Unit E_2; b) the aspects of the brachiopod fauna (i.e., *Linoproductus, Dielasma?, Waagenoconcha, Neospirifer, Marginifera, Pustula* and *Derbyia*) are dissimilar to those of the Changhsingian, and this fauna may have been reworked from the Zewan Formation; c) *Etheripecten*, *Marginifera himalayensis* and *Pustula* in Unit E_1 persist into the *Otoceras* beds of Unit E_2 (Nakazawa et al., 1975, p. 59); d) another species, "*Claraia*" *bioni* of Unit E_1 seems to be congeneric with the genus *Peribositra* from the base of the Lower Triassic in Changxing and Nanjing in its outline and rounded hinge margin.

4) In the Salt Range, there are two horizons with Permian-type brachiopods in the Dolomite Unit of the Kathwai Member (Pakistani-Japanese Research Group, 1981). One is found in the basal Dolomite Unit without any Triassic fossils, but the fusulinid genus *Reichelina* is associated with it. The basal part of the Dolomite Unit is thus placed in the Permian. The other one occurs at the base of the Main Dolomite Unit. It yields some forms of *Crurithyris* and chonetid. They are very few in number and small in size and are associated with many Triassic fossils, such as *Ophiceras connectens, Eumorphotis waageni, Entolium* spp. etc. This fauna resembles that of mixed-fauna bed no. 3 in South China. The "Mixed fauna" in bed no. 1 of South China is correlated with the lower part of the *Otoceras* Zone which is roughly compared with the *Hindeodus minutus* Zone in Kashmir. The Main Dolomite Unit of the Salt Range is correlated with the *H. parvus* and *I. isarcica* Zones in Kashmir. The *H. minutus* Zone of Kashmir is missing in the Salt Range. The Main Dolomite Unit may be compared to that of the mixed-fauna beds no. 2 and 3 of the Lower Triassic in South China. Furthermore, in the Salt Range, the bed which is probably equivalent to mixed-fauna bed no. 1 in South China is missing.

5) The *Otoceras* fauna is yet to be discovered in Transcaucasia and northwest and central Iran, but the Stromatolite bed in central Iran is referred to the *H. parvus* Zone (Iranian-Japanese Research Group, 1981). The basal part of the Lower Triassic in northwest Iran and Transcaucasia, which occurs below the *I. isarcica* Zone (Kozur et al., 1978), is also correlated with the *H. parvus* Zone. The lower part of the *Otoceras* Zone (*H. minutus* Zone in Kashmir) is considered to be absent in these places.

6) In this table, the correlation of the Lower Triassic is mainly based on ammonoids and conodonts. Especially the Lower Triassic of Kashmir, the Salt Range and South China have been classically divided by characteristic ammonoid fossil zones in detail. The conodont zonation has recently been advanced, too. Therefore, the correlation seems to be reasonable.

On the other hand, the lower boundary of the *Claraia* beds in the middle and east

Tethys is not contemporaneous. In South China the *Claraia* beds are divisible into three assemblage zones, which are, in ascending order, the *Cl. wangi, Cl. stachei* and *Cl. aurita* Zones (Chen, 1974, 1980). But the *Claraia* beds of Iran and Transcaucasia were classified only into two zones, the *Cl. aurita* Zone above and the *Cl. radialis julfensis* Zone below (Nakazawa, 1977). These two zones may correspond to the *Cl. aurita* and the *Cl. stachei* Zone, respectively, based on the associating ammonoids and conodonts. The *Cl. wangi* assemblage has not yet been recorded in Iran and Transcaucasia.

Mixed-fauna beds and Permian-Triassic boundary

1. Problem of mixed fauna beds

During the last two decades, the mixed-fauna beds have been reported from various localities in South China, Nepal, Kashmir, Salt Range, Greenland and the United States (?). But these so-called mixed-fauna beds are varied, with different composi tion, their interpretation often leads to difficulty in placing the Permian-Triassic boundary.

Mixed-fauna beds in South China are characterized by a coexistence of the Triassic-type fossils (mainly ammonoids and bivalves) and the autochthonous or para-autochthonous Permian-type fossils (mostly brachiopods). Lithologically they constitute the basal part of the Lower Triassic Chinglung Group and overlie conformably the uppermost Permian Changhsing or Talung Formation. Such mixed-fauna beds are widely spread in South China, present in twenty-one sections in eleven provinces (Table 2). Permian-type fossils are represented almost exclusively by brachiopods comprising

Localities / Species	Zhejiang		Anhui	Jiangsu			Fujian	Hunan	Hubei	Guangxi	Guizhou		Yunnan		Sizhuan	Shaanxi
	Changxing *	Huangzhishan, Wuxing	Gouwa, Guangde	Longtan	Hushan	Maiyangtang	Fushi, Yongding	Meitian, Yizhang	Puqi	Gumei, Baise	Jiaozishan, Anshun	Heilaga, Langdai	Qingyun, Fuyuan	Qiubei	Huayunshan	Liangchahe, Zhenan
1. *Lingula borealis* BITTNER									1 ●	1 ●			1 ●			
2. *L. acutangula* LIAO										2 ●			2 ●			
3. *L. fuyangensis* LIAO									3 ●	3 ●			3 ●			
4. *L.* sp.		4 ●		4 ●												
5. *Acosarina minuta* (ABICH)		5 ●														
6. *A.* sp.	6 ●															
7. *Fusichonetes pigmaea* (LIAO)	7 ●		7 ●	7 ●			7 ●	7 ●			7 ●					
8. *F. nayongensis* (LIAO)	8 ●						8 ●	8 ●								
9. *F.* sp.					9 ●	9 ●										
10. *Waagenites barusiensis* (DAVIDSON)	10 ●	10 ●				10 ●		10 ●								
11. *W.* cf. *barusiensis* (DAVIDSON)	11 ●															
12. *W.* sp.	12 ●															
13. *Paryphella sulcatifera* (LIAO)	13 ●				13 ●											
14. *P. orbicularis* (LIAO)	14 ●					14 ●	14 ●									
15. *P.* sp. nov.	15 ●															
16. *P. triquetra* LIAO	16 ●			16 ●		16 ●		16 ●								
17. *P.* sp.	17 ●															
18. *Neowellerella pseudoutah* (HUANG)	18 ●	18 ●						18 ●								
19. *N.* sp.	19 ●															
20. *Crurithyris* cf. *speciosa* WANG												20 ●		20 ●		
21. *C. subspeciosa* LIAO	21 ●	21 ●														
22. *C. flabelliformis* LIAO							22 ●								22 ●	
23. *C.* sp.	23 ●										23 ●					23 ●
24. *Paracrurithyris pigmaea* (LIAO)	24 ●				24 ●					24 ●						
25. *P.* sp.	25 ●															
26. *Araxathyris araxensis* GRUNT	26 ●															
27. *A.* cf. *araxensis* GRUNT	27 ●															
28. *A. minuta* GRUNT	28 ●															

Table 2 Composition and distribution of the "Permian-type" brachiopod fauna in the lowest strata of Triassic in South China. Refer to Text-figure 2.

* From seven sections of Changxing, see Table 3 in detail.

nine genera and twenty-eight species. It is notable that all of them are known from the deposits of siliceous facies of the uppermost Permian (Liao, 1979, 1980) with the exception of *Paryphella triquetra, P.* sp. nov. and three species of *Lingula*. In addition, a Permian-type ammonoid *Pseudogastrioceras* sp. is present. They are associated with the following Triassic-type fossils; cephalopods of ten genera and twelve species, that is, *Gryptophiceras* sp., *Pseudosageceras* sp., *Otoceras* sp., *Tompophiceras* sp., *Metophiceras* sp., *Hypophiceras* cf. *martini, H.* sp. nov., *H.* sp., ophiceratid, *Ophiceras*

	Horizon	Mixed 1		Mixed 2		Mixed 3		Above Mix.3	
	Species	P.*	T.*	P.	T.	P.	T.	P.	T.
BRACHIOPODS	1. *Lingula* sp.	1●							
	2. *Acosarina* sp.	2●							
	3. *Fusichonetes pigmaea* (LIAO)	3●		3●					
	4. *F. nayongensis* (LIAO)	4●							
	5. *F.* sp.	5●							
	6. *Waagenites barusiensis* (DAVIDSON)	6●		6●					
	7. *W.* cf. *barusiensis* (DAVIDSON)	7●							
	8. *W.* sp.	8●		8●					
	9. *Paryphella sulcatifera* (LIAO)	9●							
	10. *P. orbicularis* (LIAO)	10●		10●					
	11. *P.* sp. nov.	11●							
	12. *P. triquetra* LIAO	12●		12●					
	13. *P.* sp.	13●		13●					
	14. *Neowellerella pseudoutah* (HUANG)	14●		14●					
	15. *N.* sp.					15●		15●	
	16. *Crurithyris flabelliformis* LIAO			16●					
	17. *C. subspeciosa* LIAO			17●					
	18. *C.* sp.			18●		18●			
	19. *Paracrurithyris pigmaea* (LIAO)	19●		19●					
	20. *P.* sp.			20●					
	21. *Araxathyris araxensis* GRUNT	21●							
	22. *A.* cf. *araxensis* GRUNT	22●							
	23. *A. minuta* GRUNT	23●							
CEPHALOPODS	24. *Grypoceras* sp.		24●						
	25. *Pseudogastrioceras* sp.	25●							
	26. *Pseudosageceras* sp.		26●						
	27. *Otoceras* sp.		27●						
	28. *Tompophiceras* sp.		28●						
	29. *Metophiceras* sp.		29●						
	30. *Hypophiceras* cf. *martini* TRÜNPY		30●						
	31. *H.* sp. nov.		31●						
	32. *H.* sp.		32●						
	33. Ophiceratid		33●				33●		
	34. *Ophiceras* sp.						34●		
	35. *Lytophiceras* sp.						35●		
BIVALVES	36. *Claraia wangi* (PATTE)						36●		
	37. *Cl. longyensis* CHEN						37●		
	38. *Cl. griesbachi* BITTNER						38●		
	39. *Cl.* cf. *painkhandana* (BITTNER)						39●		
	40. *Cl. dieneri* NAKAZAWA						40●		
	41. *Cl. fukienensis* CHEN						41●		
	42. *Cl.* ? sp.		42●						
	43. *Cl. stachei* (BITTNER)						43●		
	44. *Peribositra baoqingensis* CHEN		44●						
	45. *Entolium* sp.		45●						
	46. *Bakevellia* sp.		46▲						
	47. *Eumorphotis* ? sp.		47●						
	48. *Pteria ussurica variabilis* CHEN et LAN		48●						
	49. *Palaeonucula* sp.						49●		
FORA-MINIF.	50. *Nodosaria* sp.			50▲					
	51. *Pseudoglandulina* sp.			51●					

Table 3 Composition of the mixed fauna 1, 2 and 3, on the basis of seven sections of Changxing in Zhejiang and 3 sections in Jiangsu.
* P.: "Permian-type" fossils, T.: Triassic fossils, ▲: long range, from Permian to Triassic.

Table 4 Number of genera and species in Table 3.
* 9/23: number of genera/number of species
P: "Permian-type fossils, T; Triassic fossils

	Total gen./sp.		Mixed 1		Mixed 2		Mixed 3	
Brachiopods	9/23*		8/18		6/12		2/2	
Cephalopods	10/12		8/10		0/0		3/3	
Bivalves	7/14		6/6		0/0		2/8	
Foraminifers	2/2		0/0		2/2		0/0	
Four groups	28/51		22/34		8/14		7/13	
	12/26	16/25	9/19	13/15	8/14	0/0	2/2	5/11
	P.	T.	P.	T.	P.	T.	P.	T.

sp., and *Lytophiceras* sp.; bivalve of twelve genera and nineteen species, that is, *Claraia wangi, Cl. longyensis, Cl. griesbachi, Cl.* cf. *painkhandana, Cl. dieneri, Cl. fukienensis, Cl. stachei, Cl.*? sp., *Peribositra baoqingensis, Entolium* sp., *Eumorphotis*? sp., *Pteria ussurica variabilis, Palaeonucula* sp., *Towapteria scythica, Ornithopecten*? sp., *Leptochondria*? *virgelensis, Palaeolima huangzhishanensis, Bakevellia*? sp., and *Promyalina* sp. With the exception of *Towapteria* and *Palaeolima* of Permian age, and long-ranging genera, *Bakevellia* and *Palaeonucula*, and endemic genus *Peribositra*, all others are essentially Triassic in age (Table 3).

A detailed examination of seven sections located in Changxing in Zhejiang and three sections in Longtan, Hushan, and Baiyangtang in Jiangsu, reveals that the mixed-fauna beds are stratigraphically and palaeontologically divisible into three beds, no. 1, 2, and 3 in ascending order as described in the previous chapter. No. 1 consists of yellowish or greenish brown shale, about 10 cm thick, occupying the base of the Chinglung Group. Everywhere in South China a thin clay layer forms contact with the underlying uppermost Permian strata. No. 2 is a marly dolomitic limestone layer, 20 to 30 cm thick. Mixed-fauna bed no. 3 is composed mainly of greenish shale with some marly limestone interbeds, varying in thickness.

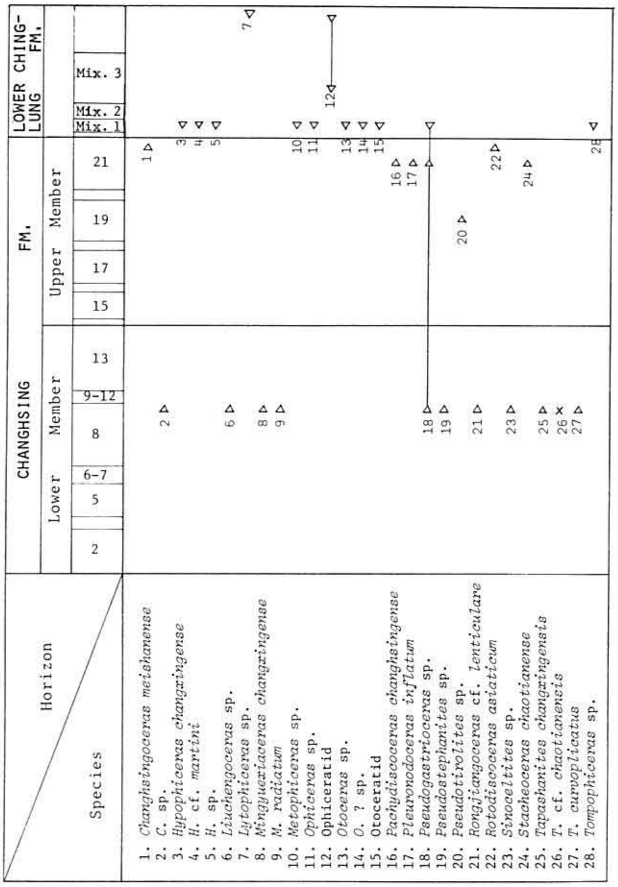
Text-figures 19 to 22 show that:

1) The Permian-type brachiopods are most abundant in Changxing sections, where they consists of nine genera and twenty-three species;

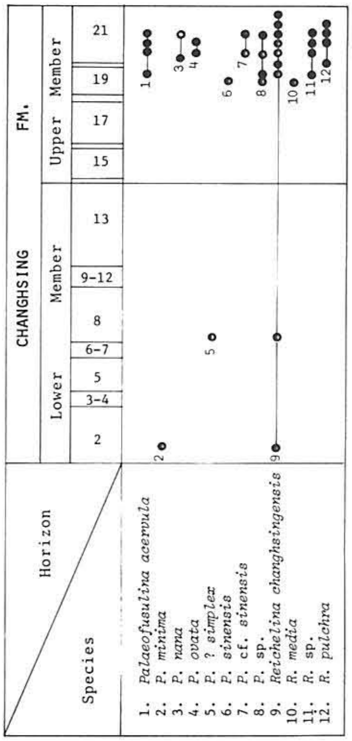
2) *Fusichonetes pigmaea* is more widely spread than others;

3) In the mixed-fauna bed no. 1, the Permian-type brachiopods and the Triassic-type cephalopods are most diverse and numerous among those three beds (Table 3).

4) In the mixed-fauna bed no. 2, only Permian-type brachiopods appear besides a few foraminifers. Several brachiopod species of mixed-fauna bed no. 1, such as *Fusichonetes nayongensis, Paryphella sulcatifera, Araxathyris araxensis*, etc. disappear in no. 2.



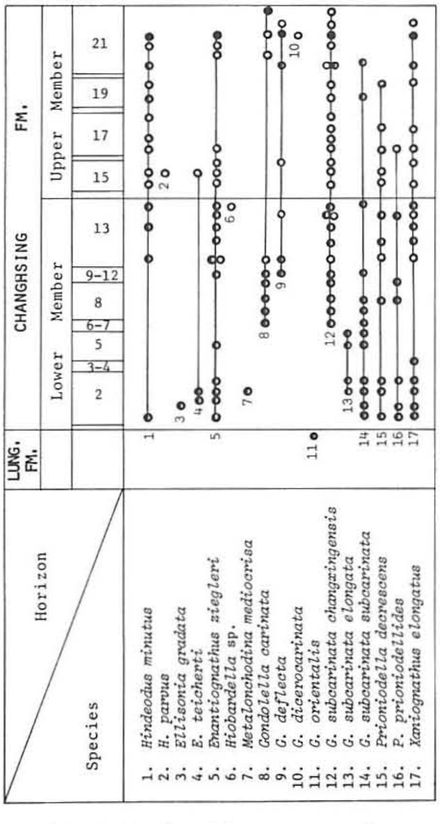
Text-fig. 19 Stratigraphic occurrence of ammonoid species common to sections of Meishan, Changxing. Data based on Section C (×), Section of Zhongxin Dadui (▽) and Zhao, Liang et Zhang, 1979 (△).



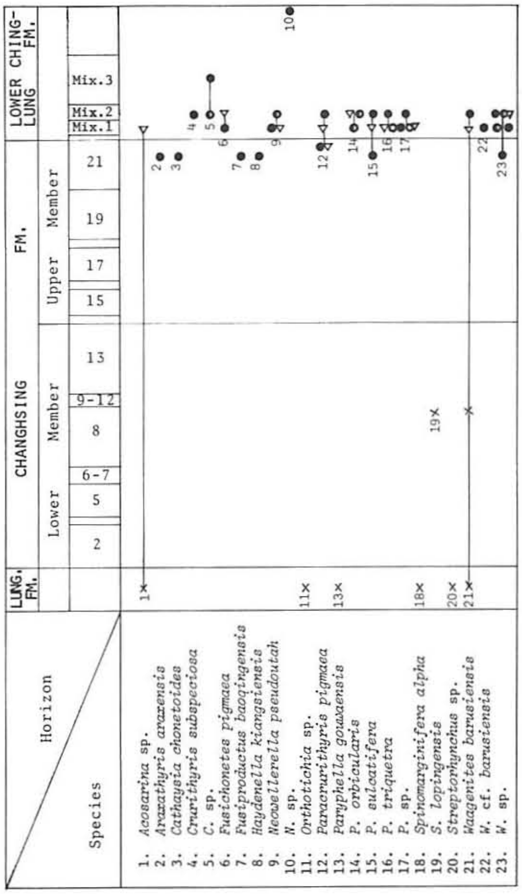
Text-fig. 20 Stratigraphic occurrence of fusulinid species common to Meishan area, Changxing. Data based on Section A (○), Section B (●) and Section D (◓).

5) The mixed-fauna bed no. 3 is dominated by Triassic-type fossils. Bivalves of *Claraia* are especially common, and cephalopods are less diverse and represented by species of *Ophiceras* and *Lytophiceras*. On the other hand, Permian-type brachiopods are markedly reduced in species and individuals. Only two species of two genera are known in this bed, and only one species, *Neowellerella* sp., passes through the mixed-fauna bed no. 3, upward to about 15—20 m above the base of the Chinglung Group.

6) Based on our correlation discussed in the previous section, mixed-fauna beds no. 1 and 2 are compared to the *Otoceras* beds (*H. minutus* Zone) of Kashmir. This part of Kashmir has some Permian-type brachiopods and bivalves, though it is not certain whether they are autochthonous or not. The occurrence of productids in the *Otoceras* beds at Pahlgam in Kashmir was reported by Bion (1914), and according to Waterhouse and Gupta (1977) and Waterhouse (1978) the *Otoceras* beds in Nepal con-



Text-fig. 21 Stratigraphic occurrence of conodont species common to sections of Meishan, Changxing. Data based on Section A (○), Section B (●) and Section D (◓).



Text-fig. 22 Stratigraphic occurrence of brachiopod species common to sections of Meishan, Changxing. Data based on Section A (○), Section B (●), Section C (×), Section D (◓) and Section of Zhongxin Dadui (▽).

tain many Permian-type brachiopods. Therefore, the *Otoceras* beds in Kashmir and central Himalayas are correlated with mixed-fauna beds no. 1 and 2, but in other parts of the Tethys this part of the sequence is missing or only partly preserved.

7) Nearly all the Permian-type brachiopods disappeared during a very short time interval represented by about 30 cm of strata of mixed-fauna beds no. 1 and 2, after the deposition of the Changhsing Formation in South China. Only two species of two genera survived into no. 3 and one species is found at a still higher horizon.

2. Permian-Triassic boundary

However one divides and correlates the boundary between the Permian and Triassic, one has to seek a singular objective, namely the actual definition of this boundary. Holding different viewpoints or even comprehension of the same definition often leads to great divergence in the interpretation of the boundary.

For a long time, except for a few authors, most scholars including the present Chinese and Japanese authors, accepted the traditional view that the base of *Otoceras woodwardi* Zone represented the base of the Triassic or the Permian-Triassic boundary (Waagen, 1895; Diener, 1912; Spath, 1934; Kiparisova and Popov, 1956; Kummel, 1957, 1972; Ruzenchev and Sarycheva, 1965; Tozer, 1965, 1967, 1969, 1971, 1972, 1979, 1981; Silberling and Tozer, 1968; Zakharov, 1968, 1971, 1973; Shevyrev, 1968; Trümpy, 1969; Nakazawa et al., 1970, 1975; Bando, 1973, 1980; Wiedemann, 1972; Wang et al., 1974, 1976, 1980; Chen, 1978; Zhao et al., 1980, 1981; Sheng et al., 1982, etc.).

During the last decades, more and more informations on the Permian-Triassic boundary have come to light as follows:

1) Many more localities with the *Otoceras* fauna have been discovered;

2) Much work on the division of the Permian, especially of the Upper Permian in South China, Kashmir, the Salt Range, Iran and Transcaucasia have been done;

3) Various fossil groups such as ammonoids, fusulinids, conodonts, bivalves, brachiopods, etc. have been studied in detail;

4) The mixed fauna of Permian and Triassic types have been found from transitional parts in many places in the world, especially in South China; and

5) The problems regarding the appearance and extinction of various biota have also been discussed among many authors from different viewpoints.

Thanks to these progresses, the traditional definition was shown to have some shortcomings. Recently, several authors including Waterhouse (1973, 1976), Newell (1978) and Kozur (1977, 1978, 1980) have dissented from the traditional definition as shown in Table 5.

The continuous and fossiliferous sections straddling the Permian-Triassic boundary in South China have a prime importance in defining the systemic boundary. As noted by Newell (1978), extinctions have taken place sporadically during the Permian and it is necessary to examine whole faunas and not a single "guide" fossil or group to define the boundary. Founded on the faunal successions in the transitional beds in South China, three possible boundaries may be drawn, that is, the base of the mixed-fauna bed no. 1, the base of the mixed-fauna bed no. 3, and the top of the latter. The last one is marked by the latest appearance of the Permian-type brachiopods excepting one species of *Neowellerella*. This roughly corresponds to Newell's definition, namely the boundary between the *Ophiceras* and *Gyronites* Zones. However, the mixed-fauna bed no. 3 is extremely poor in Permina-type brachiopods in terms of number of species and individuals, but is abundant in *Claraia,* which flourished in the Lower Triassic. Moreover, correlative beds in Kashmir and the Salt Range contain essentially Triassic genera, *Eumorphotis* and *Entolium*.

The second boundary is marked by the sudden disappearance of most of the Permian-type brachiopods and an appearance of diversified claraias, but we prefer the base of the mixed-fauna bed no. 1 as the boundary, because in terms of the entire biota, the faunal changes were greatest at this datum. Most of the Palaeozoic forms,

Table 5 Comparative table of the Permian-Triassic boundady schemes.

		This paper (Chinese-Japanese Research Group)	Traditional definition	Kozur H. 1978, 1980	Newell N. D. 1978	Waterhouse J. B. 1976
Triassic	Dienerian				*Gyronites* Z.	Dienerian ?
Triassic	Griesbachian	*Otoceras woodwardi* Z.	*Otoceras woodwardi* Z.	*Ophiceras commune* Z. *Otoceras woodwardi* Z.	*Ophiceras* Z.	Griesbachian
Permian	Changhsingian	*Rotodiscoceras* Z. or *Palaeofusulina sinensis* Z.				

such as fusulinids, rugose corals, trilobites, bryozoans and many Permian petriomorphs (particularly pectinoids) entirely disappeared at this boundary irrespective of clastic Talung facies or carbonate Changhsing facies. The upper Changhsingian *Pseudotirolites, Pleuronodoceras* and *Rotodiscoceras* faunas and the upper Dorashamian *Paratirolites* fauna were replaced by quite distinguishable *Otoceras, Ophiceras* and *Hypophiceras* faunas of Early Griesbachian (Gangetian) age, although *Otoceras* and *Hypophiceras* have close affinities with the Permian *Julfotoceras* and *Xenodiscus*, respectively.

Waterhouse (1976) proposed to draw the Permian-Triassic boundary at the top of Gangetian (lower Griesbachian *Otoceras* Zone) and later (1978) at the upper limit of the Dienerian on the evidence of the complete disappearance of productids and diversification of the Triassic ammonoids. We disagree with his opinion for the reason stated above. Furthermore, the Triassic ammonoids are believed to have first radiated from the Ophiceratidae, and not from Gyronitidae, and also a productid brachiopod has been reported from as high as Simithian *Anasibirites* beds in Japan (Nakazawa, 1977).

Kozur (1977, 1980) interpreted the *Otoceras* Zone, at least the lower two thirds, as contemporaneous with the upper part of the Changhsingian or Dorashamian on the basis of the discovery of *Otoceras* (*Julfotoceras*) from beds of Dorashamian age in central Iran, and especially, on the similarity of conodont assemblages between the Dorasham and *Otoceras* beds. His view was criticized by Chen (1978), Tozer (1979), and Nakazawa et al. (1981). It is also denied by a new discovery of *Otoceras* from the base of the Chinglung Group worked out by Zhao et al. (1981) and Sheng et al. (in press). The conodont zonation of the Changhsingian suggests the possibility that the Dorasham beds may not represent the whole Changhsingian. Today, the conodont zonation in the Permian and Triassic, especially slightly below and above the systemic boundary, is not firmly established. As it stands, conodont specialists have provided some different proposals concerning the definition of the Permian-Triassic boundary.

Thus our preferred boundary coincides with the traditional boundary, which is adopted by many authors, that is, the base of the *Otoceras woodwardi* Zone. It is the upper limit of the *Pseudotirolites, Pleuronodoceras, Rotodiscoceras* Zones or the *Palaeofusulina sinensis* Zone of the upper Changsingian. This boundary is represented by an unconformity or paraconformity in many places in the world (Newell, 1967), and is considered to be more practical and useful than any other boundaries as stated by Nakazawa et al. (1975) and Tozer (1978).

As is well known, the geographic distribution of *Otoceras* is confined to Canada, Greenland, Svalbard, Siberia, the Himalayas, and now additionally South China. In South China, the continuously deposited and adequately documented transitional sequence at the Permian-Triassic boundary has been known to exist, and moreover there can be found both the *Otoceras* fauna representing the lower Griesbachian and the *Pseudotirolites* fauna indicating the latest Permian at one continuous section in the Changxing district. In other places, the *Otoceras* fauna and the Changhsingian or Dorashamian age ammonoids are, unfortunately, mutual exclusive. We consider that the Changxing sections are preferable for the definition of the boundary and hence for the stratotype of the Permian-Triassic boundary.

However, we cannot exclude the possibility that no *Otoceras* fauna occurs in the lowest Triassic in a suitable environment. It is one of the imminent problems to solve. Currently, Y.G. Wang is attempting to determine whether the *Hypophiceras* fauna, instead of *Otoceras* can be used as the base of the Triassic, on the basis of data obtained in Greenland and at Changxing of South China (Wang, in press). The conodont assemblages associated with the *Otoceras* fauna as elucidated in Kashmir are also applicable, but must await more detailed study.

Summary

1) Conformable relationship is noticed between the Permian and Triassic strata in South China as well as in Kashmir, within the Tethyan realm, because the boundary between the two indicates a nearly continuous deposition without any stratigraphic time gap (in regards to the boundary in Kashmir, the Chinese members hold a different opinion).

2) In South China, the deposition of the Lower Triassic sequences was commenced with the clay bed, situated at the lowest part of the mixed-fauna bed 1.

3) No reworked fossils are contained in the mixed-fauna beds 1-3 in South China, and the fossils in these beds are composed of both Permian and Triassic elements.

4) The fossil assemblage of the mixed-fauna bed 2 in South China can only be compared with that of the lower part of the Main Dolomite Unit of the Kathwai Member in the Salt Range, so far as the Tethyan realm is concerned.

5) The corresponding bed to the mixed-fauna bed 1 of South China is apparently missing in the Salt Range, Transcaucasia and Iran.

6) As to the age of Unit E_1 in Kashmir, the Chinese and Japanese members have diverse opinions, that is, the latter believe Unit E_1 is latest Permian in age, whereas the Chinese members prefer an earliest Triassic age.

7) The correlation between the Changhsing Formation in South China and other uppermost Permian beds distributed within the Tethyan realm has been elucidated, but correlation of older beds, i.e., of Dzhulfian and Abadehian or Wuchiapingian age correlation has not been settled yet.

8) The base of the Dorashamian Stage in Iran is considered to be synchronous with that of the Changhsingian in South China.

9) The Changhsingian Stage for the uppermost Permian and the Griesbachian Stage for the Lowest Triassic may be preferably used as a standard in the Tethyan realm; however, further consideration is needed for the proposal of a standard stage name for the pre-Changhsingian.

10) For the stratotype section of the Permian-Triassic boundary in the Tethyan realm, the Meishan section located about 25 km northwest of Changxing district in northern Zhejiang is strongly endorsed.

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Explanation of plate 1

Figs. 1, 3, 4 *Otoceras* sp. Side views (x1), 1-Coll. No. Act 31, Cat. No. 70470; 3-Coll. No. Act 31, Cat. No. 53069; 4-Coll. No. Act 970, Cat. No. 78556: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan, Changxing, South China.

Fig. 2 *Ophiceras* sp. Side view with external suture-line (x1), Coll. No. Act 741, Cat. No. 70482: found in the *Ophiceras* bed of the Lower Chinglung Formation at Meishan.

Fig. 5 *Cathaysia chonetoides* (Chao). Ventral view (x1.5), Call. No. Act 79, Cat. No. 53036: found in the Changhsing Formation at Meishan.

Figs. 6, 12 *Paryphella triquetra* Liao. 6-ventral view (x5), Coll. No. Act 3, Cat. No. 53271; 12-ventral view (x3), Coll. No. Act 3, Cat. No. 53034; found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.

Fig. 7 *Hypophiceras changxingense* Wang (MS). Side view (x1). Coll. No. Act 31, Cat. No. 70472: found in the mixed faunal bed of the Lower Changlung Formation at Meishan.

Figs. 8, 10 *Waagenites barusiensis* (Davidson). 8-group of unnumbered specimens (x3), Coll. No. Act 31; 10-ventral view (x1), Coll. No. Act 31, Cat. No. 53023; found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.

Fig. 9 *Paryphella orbicularis* (Liao). Ventral view (x3), Coll. No. Act 3, Cat. No. 53038: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.

Fig. 11 *Acosarina* sp. Dorsal internal view (x3), Coll. No. Act 31, Cat. No. 53278: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.

Figs. 13, 18 *Peribositra baoqingensis* Chen. 13-left view (x1.5), Coll. No. Act 31, Cat. No. 53048; 18-left view (x3), Coll. No. Act 31, Cat. No. 53051: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.

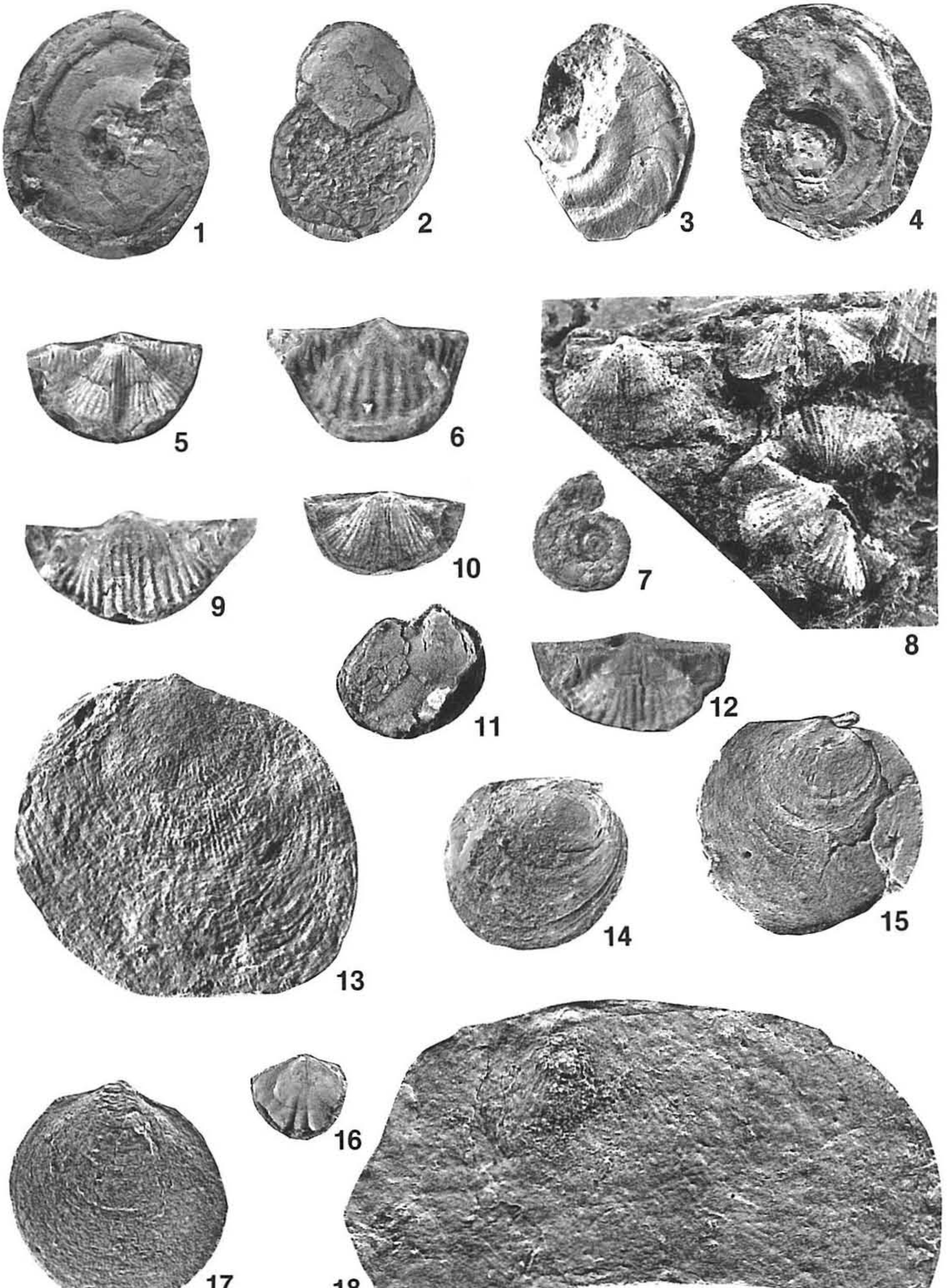
Fig. 14 *Claraia wangi* (Patte). Right view (x1.5), Coll. No. Act 1, Cat. No. 53045: found in the *Ophiceras* bed of the Chinglung Formation at Meishan.

Fig. 15 *Claraia fukienensis* Chen. Right view (x1.5), Coll. No. Act la, Cat. No. 53046: found in the *Ophiceras* bed of the Lower Chinglung Formation at Meishan.

Fig. 16 *Neowellerella pseudoutah* (Huang). Dorsal view (x1.5), Coll. No. Act. 31, Cat. No. 53017: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.

Fig. 17 *Claraia griesbachi* (Bittner). Left view (x3), Coll. No. Act 1, unnumbered specimen: found in the *Ophiceras* bed of the Lower Chinglung Formation at Meishan.

All specimens figured in this palte are preserved in the Nanjing Institute of Geology and Palaeontology, Academia Sinica.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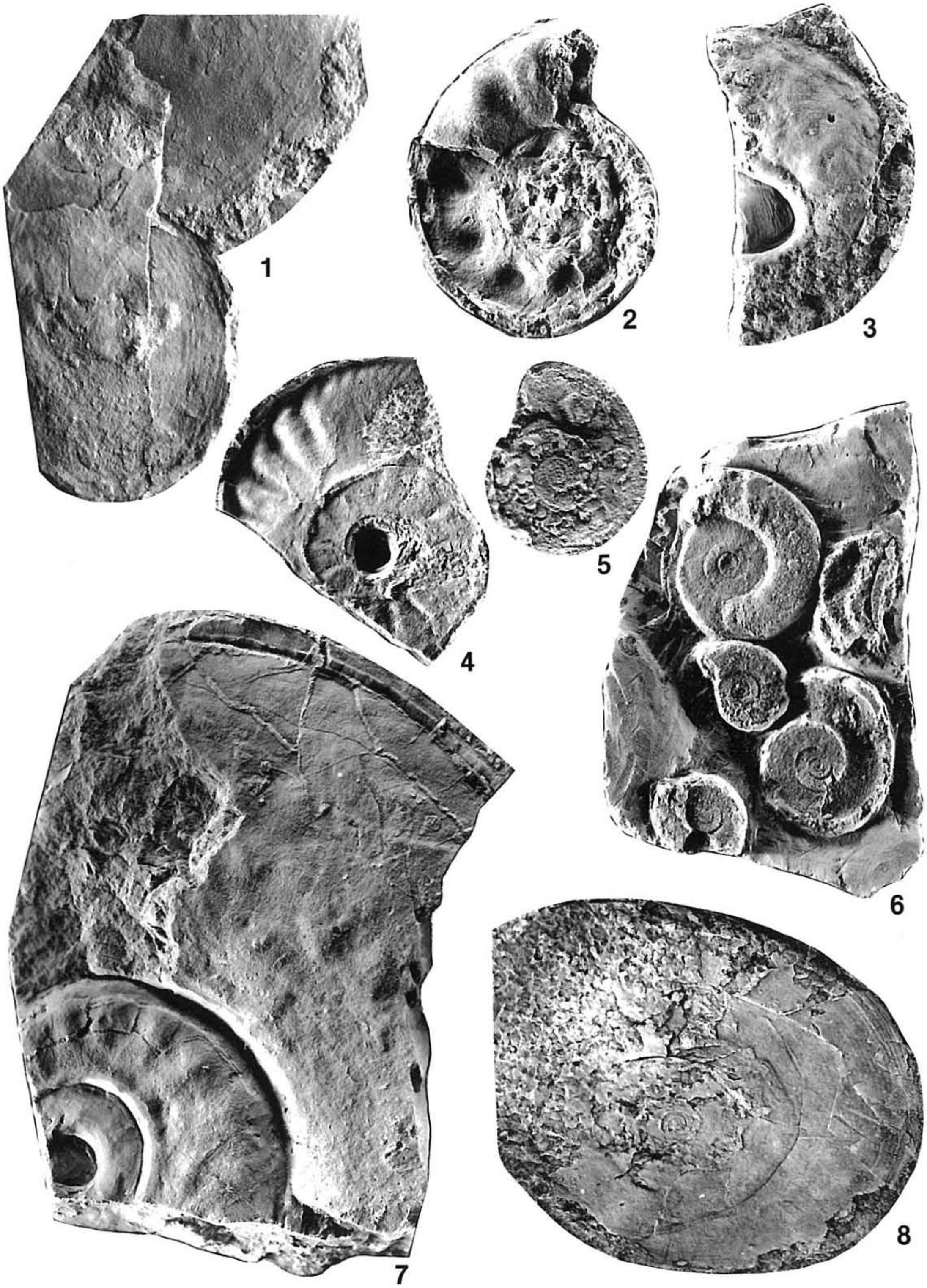
Explanation of plate 2

Fig. 1 *Pseudogastrioceras* sp. Side view with external suture-line (x1), Coll. No. Act 31, Cat. No. 70466: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan, Changxing, South China.
Fig. 2 *Tompophiceras* sp. Side view (x1), Coll. No. Act 31, Cat. No. 53062: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.
Fig. 3 *Otoceras* sp. Side view (x1), Coll. No. Act 31, Cat. No. 53072: found from the mixed faunal bed of the Lower Chinglung Formation at Meishan.
Fig. 4 *Metophiceras* sp. Side view (x1), Coll. No. Act 31, Cat. No. 53061: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.
Fig. 5 *Hypophiceras changxingense* Wang (MS) Side view (x2), Coll. No. Act 31, Cat. No. 70474: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.
Fig. 6 *Ophiceras* sp. Side view (x1), Coll. No. Act 1, Cat. No. 70479: found in the *Ophiceras* bed of the Lower Chinglung Formation at Meishan.
Fig. 7 Otoceratidae gen. et sp. indet. Side view (x1), Coll. No. Act 4a, Cat. No. 53073: found in the mixed faunal bed of the Lower Chinglung Formation at Meishan.
Fig. 8 *Flemingites* sp. Side view (x1), Coll. No. Act 929, Cat. No. 70494: found in the *Koninckites* bed of the Lower Chinglung Formation (i.e. Hsu's "*Otoceras* cf. *woodwardi*" bed) at Longtan, Nanjing, South China.

All specimens figured in this plate are preserved in the Nanjing Institute of Geology and Palaeontology, Academia Sinica.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Appendix
Place name in Chinese

Anhui	安徽	Liangchahe	两岔河
Anshun	安順	Longtan	龍潭(龙潭)
Baise	百色	Majiashan	馬家山(马家山)
Baiyangtang	白羊塘	Mashishan	馬石山(马石山)
Baoqing	葆青	Meishan	煤山
Changxing	長興(长兴)	Meitian	梅田
Chaoxian	巢縣(巢县)	Puqi	蒲圻
Chinglung Mts.	青龍山(青龙山)	Qiaozishan	橋子山(桥子山)
Dushan	獨山(独山)	Oingyun	慶雲(庆云)
Fujian	福建	Qiubei	丘北
Fushi	撫市(抚市)	Selung	色龍(色龙)
Fushui	扶綏	Shanxi	陝西(陕西)
Fuyuan	富源	Shuanghu	雙湖(双湖)
Gouwa	溝洼(沟洼)	Sichuan	四川
Guangxi	廣西(广西)	Tai lake	太湖
Guangde	廣德(广德)	Tong shan	東山(东山)
Guizhou	貴州	Tulung	土隆
Gumei	古眉	Wuxian	吳縣(吴县)
Heilaga	黑拉嘎	Wuxing	吳興(吴兴)
Heshan	合山	Yixing	宜興(宜兴)
Huangzhishan	黄芝山	Yizhang	宜章
Huayunshan	華鎣山(华蓥山)	Yongding	永定
Hubei	湖北	Yunnan	雲南(云南)
Hufu	湖汶	Xidongtingshan	西洞庭山
Hunan	湖南	Xinyuan	新苑
Hushan	湖山	Zhanggong cavern	張公洞
Jiangsu	江蘇(江苏)	Zhejiang	浙江
Jiangyin	江陰(江阴)	Zhenan	鎮安
Langdai	郎岱	Zhongxin Dadui	忠心大隊
Linggu cavern	靈谷洞(灵谷洞)	Ziyun	紫雲(紫云)

Text-fig. 11 Columnar section and stratigraphic distribution of fossils in the Upper Permian and Lower Triassic at section B (Meishan).

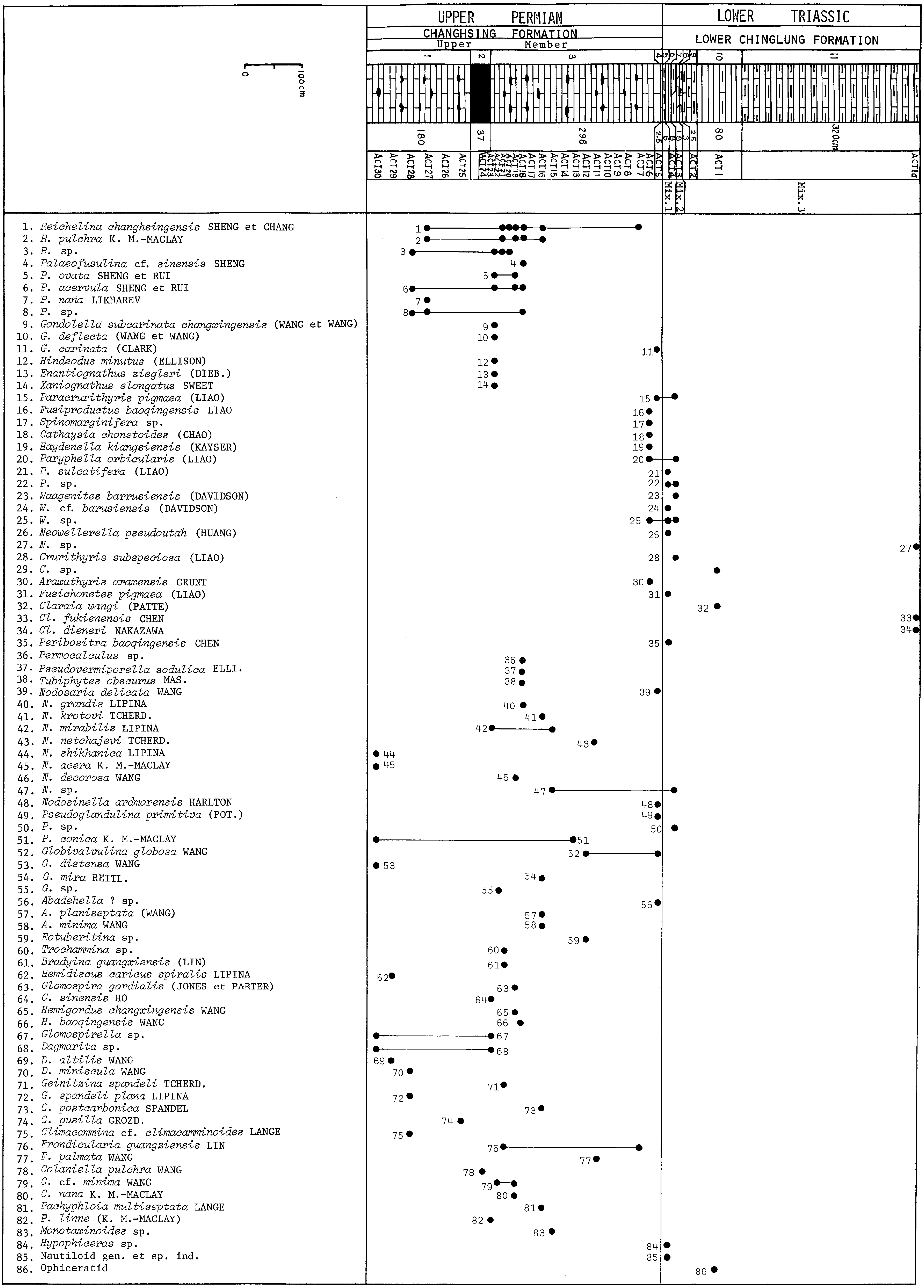
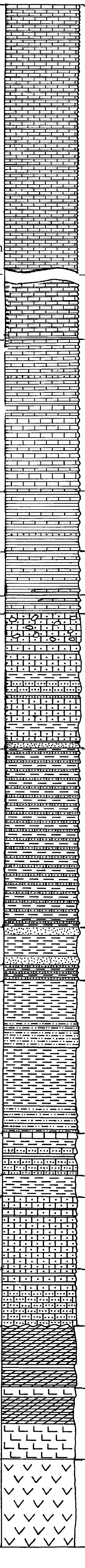


Table 1 Correlation chart of the Upper Permian and Lower Triassic in Middle and East Tethys province.

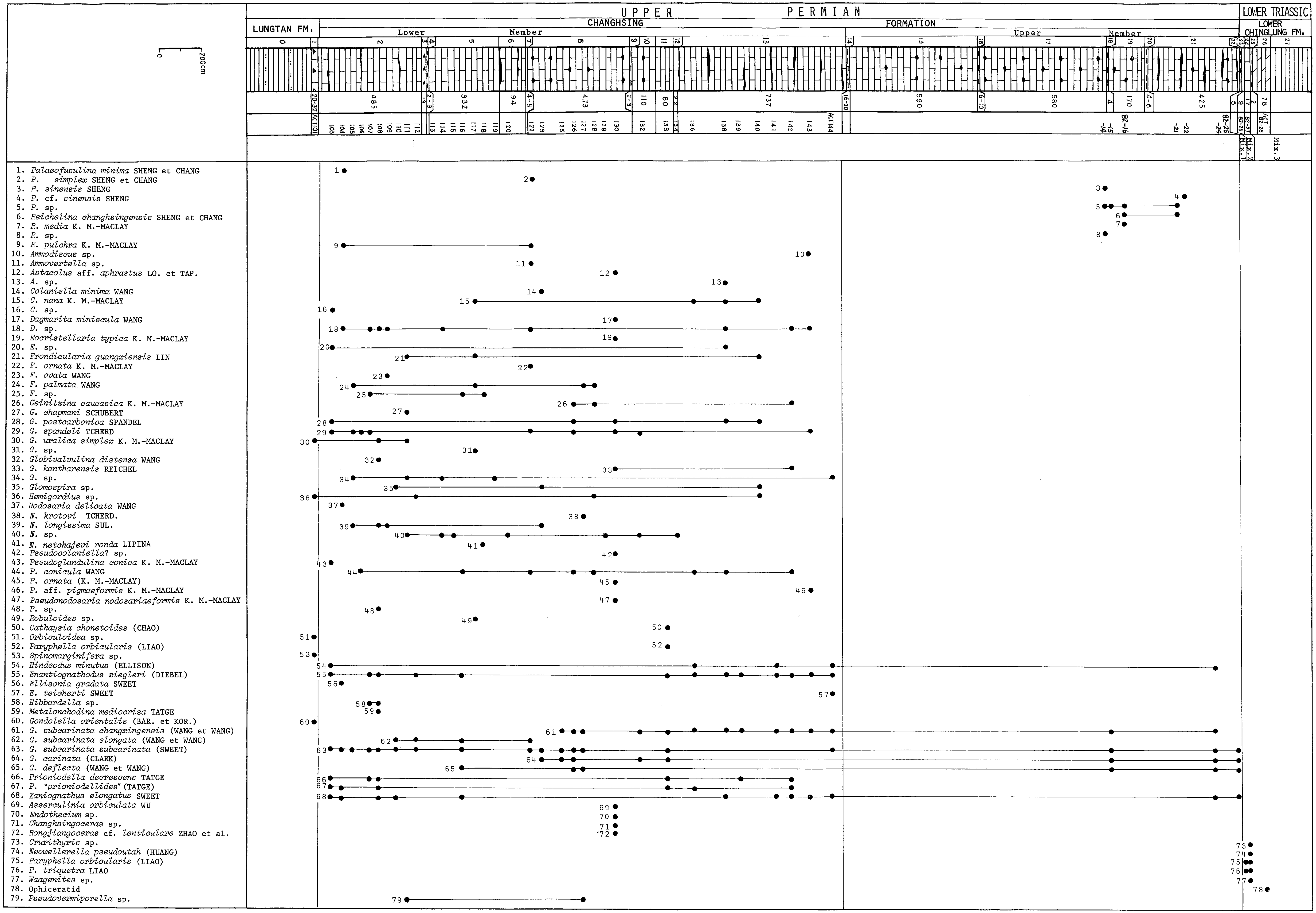
Stage	TRANSCAUCASIA RUZENCHEV et SARYCHEVA, 1965	ABADEH IRANIAN-JAPANESE RESEARCH GROUP, 1981	SALT RANGE PAKISTANI-JAPANESE RESEARCH GROUP, 1981	KASHMIR NAKAZAWA et al., 1975	SOUTH CHINA – TIBET – SOUTH YIN, WANG et CHANG, 1974	SOUTH CHINA – TIBET – NORTH WEN, 1979	SOUTH CHINA – GUIZHOU – SOUTH SHENG, 1963; CHEN et al., 1979	SOUTH CHINA – GUIZHOU – CENTRAL RUI, 1979; YAO et al., 1980	SOUTH CHINA – CHANGXING ZHAO et al., 1981	SOUTH CHINA – NANJING SHENG et al., 1982	Stage
TRIASSIC – DIENERIAN	LOWER TRIASSIC *Gyronites* *Claraia aurita*	LOWER TRIASSIC Unit a *Claraia aurita*	MIANWALI FM. Mittiwali Mb. *dieneri*, *cristagal.* *Paranorites* *Koninckites* *Gyronites*	KHUNAMUH FM. Mb. G *Prion.-Koninck. Z.*: *Prionites* - *Proptychites*; *Koninckites* Mb. F *P-V Z.*: *Paranorites*; *Vishnuites*	TULUNG GROUP, KANSHARE FM., Lower Mb. ? *Gyronites*: *Gyronites psilogyrus*, *G. evolvens*, *Prinolobus orbis*, *P. lilangenis*	KANGLU FM. *Cl. aurita*	LUOLOU FM.	YELANG FM. Lower Part *Cl. aurita*	CHINGLUNG GROUP Lower Part *Flemingites* *Gyronites*	CHINGLUNG GROUP Lower Part *Flemingites*: *Flemingites*, *Koninckites*, *Pseudosageceras*, *Paranorites* *Gyronites*: *Glypoceras*, *Paranorites*, *Prionolobus*, Gyronitidae, *Cl. aurita*, *Cl. concentrica*	DIENERIAN – TRIASSIC
TRIASSIC – GRIESBACHIAN	*Claraia stachei* *Claraia clarai* *Lytophiceras* ?	*isarcica* Z.: *Vishnuites*, *Claraia radialis julfensis*, *Ophiceras*, *Isarc. isarcica* *parvus* Z.: Colonial Ls., *H. parvus*	Kathwai Mb.; Ls; Main Dol. *kum.*, *car.*, *isar.*, *parvus-isarcica* *Ophiceras* *Ophiceras* *I. isarcica*, *H. parvus*, *Eumorphotis*, *Entolium*, "Perm."brach.	Unit E3 *Ophiceras* Z. (*isar*, *carkum*, *dien.*): *Ophi. tibeti.*; *Cl.* cf. *gries.* Unit E2 *parvus* Z.: *Cl. dieneri*, *Otoceras woodwardi* *Otoceras*, *minutus*: *Otoceras woodwardi*	*Ophiceras*, *carinata - dieneri*: *Ophiceras sakuntala*, *O. tibeticum*, *O. demissum*, *Anotoceras nala* *Otoceras*, *Hindeo. typicalis*: *Otoceras latilobatum*, "*Glyptophiceras*", *Hindeodus typicalis*, *Gondolella carinata*	*Cl. stachei*	*Claraia*	*Ophiceras*: *Pseudosageceras*, *Ophiceras*, *Cl.* cf. *griesbachi* *Otoceras*: "Permian-type" brachiopods	*Ophiceras*, Mix. bed 3: *Cl. stachei*, *Ophiceras*, *Cl. wangi* Mix.bed 2: *Geinitzina* *Otoceras*, Mix.bed 1: *Otoceras*, *Hypophiceras*, *Tompophiceras*, *Pseudogastr.*, "Perm." brach.	*Ophiceras*: *Cl. stachei*, *Ophiceras*, *Cl. griesbachi*, *Cl. wangi* *Otoceras*: Ophiceratids, *Bakevellia*, "Permian-type" brachiopods	GRIESBACHIAN – TRIASSIC
PERMIAN – CHANGHSINGIAN	DORASHAM FM. *Paratirolites* *Shevyrevites* - *Iranites* *Phisonites*	HAMBAST FM. Unit 7 *Paratir.* Z.: *Paratirolites kittli* *Paratir.-Shevyr.* Z.: *Paratirolites* - *Shevyrevites* *Shevyrevites* Z.: *Shevyrevites shevyrevi*	L.Dol.: *H. minutus Reichel.* "Perm." br. CHHIDRU FM. Unit 4: *Oldhamina decipiens*	Ut.E1: "*Gryptophiceras*", *Claraia bioni*, *Etheripec. haydeni*, *H. minut. G. cari.*, *Perm. brachio.* ZEWAN FM. Mb. D: *Gondolella carinata*		? RAGGYORCAKA FM. *Gigantopteris* *Gigantonoclea* *Lobatannularia* *Rhizomopsis* *Palaeofusulina sinensis* *Palaeofusulina nana*	CHANGHSING FM. *Palaeofusulina laxa* *Palaeofusulina mutabilis* *Reichelina changhsingensis*	CHANGHSING FM. Upper Mb. *Palaeofusulina sinensis*: *Rotodiscoceras*, *Pseudotirolites*, *Pleuronodoceras* Lower Mb. *Palaeof. minima - Nankin. guizhouensis*: *Paratirolites*, *Abichites*, *Shevyrevites*	CHANGHSING FM. Upper Mb. *Palaeofusulina* cf. *sinensis*, *N. deflecta-N. subcari. changx.*: *Rotodiscoceras*, *Pseudotirolit.*, *Pleuronodocer.* Lower Mb. *Palaeof. minima*, *N. subcari. subcari.- N. subcari. elongat.*: *Pseudostepha.* - *Tapashanites*	TALUNG FM. *Pseudotirolites* *Pleuronodoceras*	CHANGHSINGIAN – PERMIAN
PERMIAN – DZHULFIAN	DZHULFA FM. *Vedioceras* - *Haydenella* *Araxoceras* - *Oldhamina* *Araxilevis*	Unit 6 *Vedio.* Z.: *Vedioceras nakamurai* *Araxo.* Z: *Araxoceras rotoides* *Araxi.* Z.: *Araxilevis intermedius* *Reich. media*	CHHIDRU FM. Unit 1 - Unit 3, *Reichelina* Zone *Cyclolobus* *Xenodiscus* *Colaniella minima* *Colaniella media*	Mb. C: *Cyclolobus*, *Xenodiscus* Mb. B: *Hindeodus minutus*, *Gondelella carinata*	?		WUCHIAPING FM. *Codonofusiella kueichowensis* *Codonofusiella lui* *Codonofusiella kwangsiana*	"LUNGTAN FM." *Codonofusiella*	LUNGTAN FM. *Sanyangites* *Araxoceras* - *Konglingites*	LUNGTAN FM. *Hunanoceras* *Xenodiscus* Araxoceratidae gen. indet. Anderssonoceratidae gen. indet. *Pseudogastrioceras*	WUCHIAPINGIAN – PERMIAN
PERMIAN – ABADEHIAN	KHACHIK FM. *Codonofusiella* - *Reichelina*	ABADEH FM. Unit 5, Unit 4a-Unit 4b, *Codonof. - Reichel.* Zone *Codonofusiella kwangsiana* *Xenodiscus* *Cyclolobus*	Kalabagh M, Unit 5; WARGAL FM. Unit 4b; *Codonofusiella* *Colaniella minima*, *Col. nana*, *Col. minuta*, *Reichelina changhsing.* *Codonofusiella*	Mb. A: *Colaniella minima* *Abadehella*	SELUNG GROUP Upper Part Gangjiu Ls. (Ex.Bl.) *Reiche. Colani.* *Thamnopora*, *Pseudofavosites*, *Gertholites*, *Tachylasma* *Chonetella nasuta*, *Spiriferella rajah*	?			*Anderssonoceras*		

Text-fig. 17 Columnar section of the Upper Permian-Lower Triassic sequence at Guryul Ravine, Kashmir (modified from Nakazawa et al., 1975). Conodont zonation based on Nakazawa et al., 1980. G.: *Gondolella*, Isarc.: *Isarcicella*.

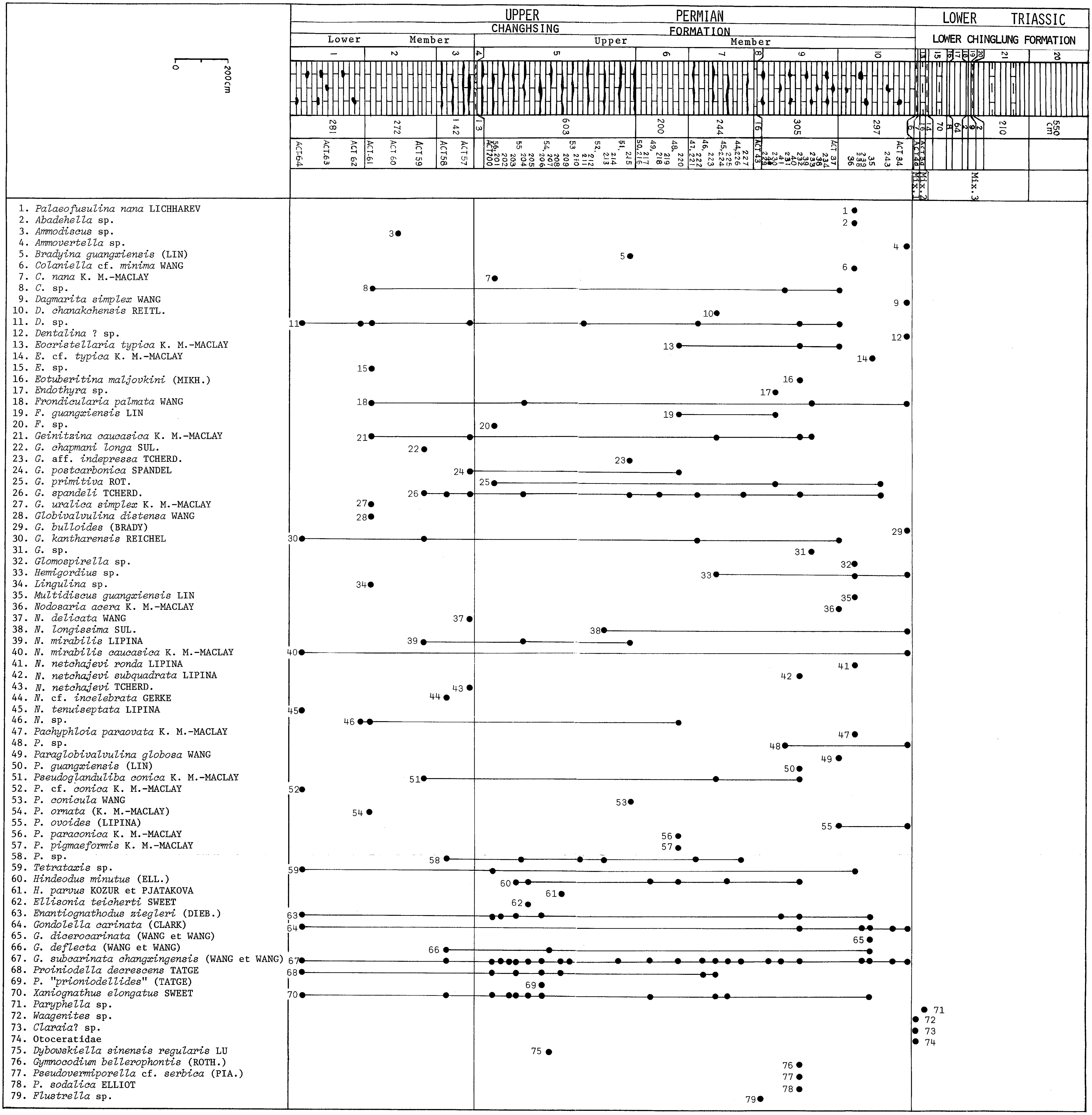


KHUNAMUH FORMATION	H	43.1 m	alternation of limestone and Shale	*Owenites-Kashmirites* Zone	
	G	26.7	bedded limestone alternating with thin shale	*Prionites-Koninckites* Zone	*Neospathodus* cf. *pakistanensis* Zone
	F	18.0	alternation of limestone and black shale	*Prionites-Vishnuites* Zone	*Neospathodus cristagalli* Zone; *N. dieneri* Zone
	E 3	9.9	black shale intercalating limestone	*Ophiceras* sp.; *O. tibeticum* Z.	*N. kummeli* Zone; *G. carinata* Zone; *Isarc. isarcica* Zone
	E 2	6.1	flaggy shale intercalating limestone	*Otoceras woodwardi* Zone	*Hindeodus parvus* Zone; *Hindeodus minutus* Zone
	E 1	2.6	shale with limest.	*Claraia bioni*, *Marginifera himalayensis*, etc.	
ZEWAN FORMATION	D	18.3	sandy limestone and calcareous ss., convoluted and nodular, with thin shale	*Linoproductus* cf. *lineatus*, "*Palaeolima*" *middlemissi*, *Permophorus* cf. *subovalis*, *Gyrtorostra* cf. *luwal.*, *Xenapsis* sp., *Gondolella carinata*, *Lunucammina* cf. *grandis*, *Globivalvulina* cf. *cyprica*, etc.	
	C	23.2	alternation of sandy shale and calcareous sandstone	*Lissochonetes bipartita*, *Dielasma*? sp. *Nuculopsis*? sp., "*Streblochondria*" sp., *Cyclolobus walkeri*, *Xenapsis* sp., *Hindeodus minutus*, *Gondolella carinata*, *Nodosinella* spp., *Lunucamm.* sp., *Plagioglypta* sp., *Bellerophon branfordianus*, *Dyscritella* sp., etc.	
	B 3	6.4	alternation of sdy. shale, calc. ss. and sandstone		
	B 2	2.1		*Costiferina indica*, *Cleiothyridina* sp.	
	B 1	20.8	sandy shale and sandstone		
	A 4	5.8	calcareous ss. and micaceous sdy. sh.	*Colaniella minima*, *Abadehella coniformis*	
	A 3	3.0	sandy shale		
	A 2	9.6	thick-bedded sandy limestone	*Colaniella cylindrica*, *C.* cf. *minima*, *Abadehella coniformis*, *Linoproductus* cf. *lineatus*, *Chonetina*? sp., *Stenopora*? *kashmirensis*, *Polypora transiens*, etc.	
	A 1	8.2	calcareous ss. and alternation of sh. and calcareous ls.		
GANGAMOPTERIS BEDS		8.0	siliceous shale intercalating carbonaceous sh.		
		7.6 m	novaculite and siliceous shale		
PANJAL VOL. ROCKS			basic volcanic rocks		

Text-fig. 8 Columnar section and stratigraphic distribution of fossils in the Upper Permian and Lower Triassic at section D (Meishan).



Text-fig. 12 Columnar section and stratigraphic distribution of fossils in the Upper Permian and Lower Triassic at section A (Meishan).



Text-fig. 15 Columnar section and stratigraphic distribution of fossils in the Upper Permian and Lower Triassic at Longtan section (Longtan, Jiangsu).