

# 长江三峡地区 地层参观指南

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**STRATIGRAPHIC EXCURSION GUIDEBOOK  
IN THE YANGTZE GORGES AREA**

**Yichang Institute of Geology and Mineral Resources**

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## CONTENTS

Preface.....	Wang Xiaofeng (1)
The Sinian System.....	Chen Ping (2)
The Cambrian System .....	Zhou Tianmei and Xu Guanghong (8)
The Ordovician System .....	Zeng Qingluan and Xu Guanghong (14)
The Silurian System.....	Ni Shizhao (21)
The Devonian System.....	Feng Shaonan (28)
The Carboniferous System .....	Yang Deli and Xu Shouyong (35)
The Permian System.....	Lin Jiaxing (42)
The Triassic System.....	Zhang Zhenlai (47)
The Jurassic System.....	Meng Fansong (59)
The Cretaceous System.....	Lei Yizhen (65)
The Paleogene System.....	Lei Yizhen (73)

## PREFACE

This book deals with an area that covers the eastern part of Sichuan and western part of Hubei Provinces, including the well-known Yangtze Gorges (Qutang Gorge, Wu Gorge and Xiling Gorge) and the western fringe of the Jiangnan Basin (see the General Geological Map of the Yangtze Gorges). The gorges area has become one of the world-famous spots not only because of its marvellous scenery of mountains and rivers (Fig.2), but also because of the well-exposed strata ranging from the Sinian to Tertiary, which are richly fossiliferous. Hence, it is an important area for the understanding of biostratigraphy, historical geology and tectonic development history of the Yangtze platform, and it is an ideal place for geological training and tourism.

The Xiannüshan fault cutting across Xiangxi and Yuyang subdivides the present area into two parts: the eastern and western parts. The Sinian and Paleozoic strata, consisting mainly of marine deposits, are mostly exposed in the eastern part and distributed belt-like around the Huangling Anticline, of which the basement is formed of the Pre-Sinian granites, schists and gneisses, and the Renheping Syncline with its core formed of the Triassic. The Mesozoic strata are composed of rocks of marine facies, marine-nonmarine alternative facies and nonmarine facies, cropping out in the Zigui Basin in the western part, and the Danyang Basin in the eastern part. The nonmarine Cenozoic strata are distributed in Yidu, Zhicheng and Danyang counties and adjacent areas. The rocks from Sinian to Tertiary, except the Devonian and Carboniferous, are well-developed and richly fossiliferous here. The Sinian section of Liantuo, the Ordovician section of Huanghuachang, and the Ordovician-Silurian boundary section of Wangjiawan are becoming the focus of world attention in the stratigraphic subdivision and correlation.

It has been more than sixty years ago since Professor J.S. Lee (Li Siguang) began his work on the stratigraphy and paleontology in the Yangtze Gorges in 1924. Unfortunately, no guide-book for a geological excursion to this area has yet been published. The aim of the "Stratigraphic Excursion Guidebook in the Yangtze Gorges Area" is to introduce the latest research results with regard to the stratigraphy and paleontology from the Sinian to the Tertiary Systems of the present area to the geologists, teachers and students who would like to make field investigations or excursions here. Moreover, this book might be taken as a contribution to the International Symposium on the Terminal Pre-Cambrian and Cambrian Geology to be held at Yichang City in 1987. For these reasons this book is composed of also brief texts and accompanied by pictures and figures.

We are very grateful to Prof. Dr. Erdtmann at the University of Göttingen, FRG for his help in correcting the English text. We are also greatly indebted to Mrs. Fan Huizhu and Mr. Duan Wanjun for their careful drawing of the text-figures, and many thanks are due to Mr. Zhang Guoxin, Chen Dayou, Min Xin, and Ye Xin for their assistance in taking the photographs.

Wang Xiaofeng

# The Sinian System

Chen Ping

The Sinian System is well developed in continuous sequence in the Yangtze Gorges area, and is mainly exposed around the Huangling Anticline and in the core of Changyang Anticline. Since the Sinian System was established as the standard sequence in Liantuo area, Yichang by Professor J. S. Lee (Li Siguang) in 1924, it has fully been accepted as the type for subdivision and correlation in China.

The Sinian System, occupying an important stage of the Earth history, is rich in various mineral resources, such as phosphate, iron, manganese, silver, vanadium and abundant oil. Obviously, the study of the Sinian System is given great significance not only for better understanding the development of the Earth's history and biotic origin and evolution but also for the search and prospecting of mineral resources.

## Stratigraphic Subdivision

Through the studies over the last half century, undertaken by many geologists (Lee, 1924; Liu Hongyun and Sha Qing'an, 1963; Wang Yuelun, 1963; Zhao Zhiqiang et al., 1980; and others) the Sinian System in the eastern Yangtze Gorges area might be divided into two Series and six formations as follows (see Fig. 1-1):

The lower series includes the Liantuo, Gucheng, Datangpo and Nantuo Formations; the upper series may be divided into the Doushantuo and Dengying Formations.

### 1. The Liantuo Formation

The Liantuo Formation is 50—247 m thick, at the type section of Liantuo the thickness is 102 m. It thins out at Tanjiaba 8 km northeast of Liantuo, and may reach over 300 m in thickness in northern Changyang. The Liantuo Formation overlies unconformably the biotite plagioclase granite in the southern limb of Huangling Anticline and the Kongling Group in the western and northern limbs. The lower part of the Liantuo Formation consists of purplish-red, thick-bedded arkose with gravels, feldspathic quartzose sandstones and arkoses, the upper part is mainly composed of purplish-red, grey-green fine grained lithic sandstone, feldspathic sandstone and siltstone and rhyolitic-crystalloclastic-hyalinoclastic tuffs. In general, the pyroclastic rock changes from coarser at the base to finer at the top. The Liantuo Formation contains the following microflora fossils: *Laminaritos abtiquissmu* Eichw., *Trematosphaeridium holtedahlii* Tim., etc.

### 2. The Gucheng Formation

The Gucheng Formation is 0—10 m thick, and it is only found in the Changyang Anticline. The lower part consists of tillite in which the gravels are composed of sandstone or siltstone with some vein quartz. The upper part consists of sandy conglomerate,

System	Series	Formation	Member	Columnar section	Thickness (m)	Main rock and fossils
Sinian	Upper	Dengying Fm.	Bamatu Mem.		390	Grey - white dolomite with phosphatic bands. intercalated with irregular siliceous, phosphatic bands. Rich in small shelly fossils.
					2.5	Upp. part: black thin - moderately bedded limestone. intercalated with carbonaceous shale. Low part: siliceous dolomite. silicilith. Rich in small shelly fossils.
					148	Grey - white massive cryptomereous dolomite. siliceous intercalated with chert of or crumbs.
					135	Black thin - bedded asphaltene limestone and siliceous limestone.
					230	Grey - white siliceous. intercalated with oolitic dolomite. dolomitic phosphate rock.
	Lower	Doushantuo Fm.	Shibantan Mem.		64	Grey - brown - grey cryptomereous dolomite. and cryptomereous dolomite intercalated with black carbonaceous shale.
					20	Dark - green moraine gompohite.
					10	Black thin - bedded carbonaceous siltstone and arenaceous shale. intercalated with manganese - bearing limestone.
					10	Grey - green tillite the middle part is characterized by moraine laminated clay layer.
					102	Purple - red thick - bedded feldspar quartzose sandstone with gravels. purple - red fine grained debris sandstone. feldspathic sandstone. crystalline hyaline - clastic tuff.
Presinian System	Series	Nantuo Fm.	Datanpo Fm.		64	Dark - green moraine gompohite.
					20	Black thin - bedded carbonaceous siltstone and arenaceous shale. intercalated with manganese - bearing limestone.
Presinian System	Series	Gucheng Fm.	Liantuo Fm.		10	Grey - green tillite the middle part is characterized by moraine laminated clay layer.
					102	Purple - red thick - bedded feldspar quartzose sandstone with gravels. purple - red fine grained debris sandstone. feldspathic sandstone. crystalline hyaline - clastic tuff.
Presinian System	Series	Kongling gneiss	Biotite plagioclase granite		102	Purple - red thick - bedded feldspar quartzose sandstone with gravels. purple - red fine grained debris sandstone. feldspathic sandstone. crystalline hyaline - clastic tuff.

Fig. 1-1 The stratigraphic columnar section of the Sinian System in the eastern Yangtze Gorges area

a. Shujingtuo Fm. e. Tianzhushan Mem. d. Yanjiahe Fm.

gravelly sandstone and glacial varve clay layers. small gravels are found occasionally in the varve clay layers and have buckled the bedding. The Gucheng Formation overlies disconformably the Liantuo Formation. Several microfloras appear in the varve clay layers: *Trechysphaeridium?rude* Sin et Liu, *Anguloplunia rhombica* Rod. and so on.

### 3. The Datangpo Formation

The Datangpo Formation is 20 m in thickness and overlies conformably the Gucheng Formation in the Guchengling area, Changyang. It mainly consists of black thin-bedded carbonaceous siltstones and arenaceous shales, intercalated with manganiferous limestones and is one of the important manganiferous beds of the Sinian System in south China.

### 4. The Nantuo Formation

The Nantuo Formation varies clearly in thickness at different locations. It is 64 m thick at type section, Wangfenggang, Liantuo, and becomes quickly thinner and even absent in the northern part of the Huangling Anticline. In the Miaohe area, Zigui, the southern limb of the anticline, it is generally 117 m and 60 — 120 m in thickness. It is disconformable with the underlying Datangpo Formation in the Changyang Anticline and directly overlies the Liantuo Formation or the Kongling Group or even the Huangling Granite in the Huangling Anticline. It mainly consists of dark green, grey green shales, intercalated with purple red nagelfluh. Granite, gneiss, schist, phyllitic marble, basic rocks, stromatolite-bearing limestones, vein quartz and so on are the components of the gravels. On the surface of the gravels there are clear striations, engraving grooves and so on. The cement is of sandy-mud material. This yields mainly the following microflora: *Trematosphaeridium holtedahlii* Tim., *T. minutum* Sin et Liu etc..

### 5. The Doushantuo Formation

The Doushantuo Formation is 130 — 520 m thick in general. The type section is 230 m thick at Tianjiayuanzi. The Doushantuo Formation is in disconformable contact with the underlying Nantuo Formation. It mainly consists of medium to thin-bedded grey, brown-grey and greyish white cryptomereous dolomite intercalated with black carbonaceous shale. Chert nodules and chert masses are often found in the dolomite. There is a thin bed of cryptomereous dolomite with gravel at the base. The top is characterized by the black carbonaceous shale, intercalated with argillaceous dolomite. There are often siliceous phosphatic nodules in the middle and lower parts, which constitute one of the most important phosphate-bearing beds in south China. The following microflora are found in the middle part: *Asperatosphaera* aff. *umishanensis* Sin et Liu, etc and some Porifera in the lenticular limestones close to the base: *Eospicula yichangensis* Ding et al., *Hazelia liantuoensis* Ding et al..

### 6. The Dengying Formation

The Dengying Formation continuously overlies the Doushantuo Formation and is subdivided in ascending order into four lithological members.

(1) The Hamajing Member: it is 135 m thick and consists of grey-white siliceous intraclast dolomite, intercalated with oolitic dolomite and rudaceous dolomite with a small amount of chert bands or crumbs at its top. Near the top of it the following microflora is observed: *Asperatosphaera* cf. *paetialis* Sin et Liu etc..

(2) The Shibantan Member: it is 148 m thick and consists of black thin bedded cryptomereous limestone with organic material, containing chert bands or crumbs and the following microflora: *Margominuscula verrucosa* Naum., and it is rich in banded algae: *Vendotaenia* sp., *Tyrasotania* cf. *podolica* Gnil., and Pennatulid *Charnia* etc..

(3) The Baimatuo Member: the thickness is 390 m. It is composed of light grey,

grey-white massive cryptomeros dolomite, siliceous dolomite intercalated with chert bands or crumbs. Bird's eye structure are developed at the top. Worm fossils and a number of microflora were found at the base part: *Sinotubulithes baimatuoensis*, *Saurina* and *Taeniatum crassum* Sin et Liu.

(4) The Tianzhushan Member: thickness is 0.7 — 5 m. It is composed of laminated dolomite, intercalated with irregular siliceous, phosphatic bands. The upper part is rich in various small shelly fossils represented by Hyolithids, monoplacophorans, gastropods, chancellorids etc. and the lower part yields trace fossils *Planolithes taishanmiaensis* Ding et al, *Skolithos*, etc. In the Jijiapo and Yanjiahe area of Sandouping, at the southern limb of the Huangling Anticline, the strata called the Yanjiahe Formation are 35.6 m thick, which roughly corresponds to the Tianzhushan Member consisting of the dark grey, grey-white thin to medium-bedded siliceous dolomite, which is intercalated with black silicilith and sandy shale in the lower part, and of the black thin to medium-bedded limestone intercalated with carbonaceous shale, grey-white medium-bedded dolomite intercalated with thin silicilith, intraclast dolomitic limestone and intraclast limestone in the upper part. It is rich in small shelly fossils which are divided into the following two assemblages: in ascending order the *Circotheca-Anabarites-Protohertzina* and the *Ovalitheca-Alddanella-Maidipingconus*. The Tianzhushan Member / Yanjiahe Formation has a continuous transition with the underlying Baimatuo Member and contacts disconformably the overlying Shuijingtuo Formation (Fig. 1-2).

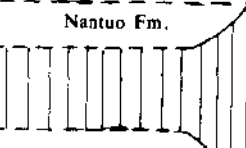
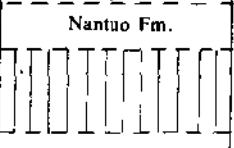
Eastern limb of the Huangling Liantuo — Shipai anticline					Southern and western limbs of the Huangling anticline Shandouping Yanjiahe					The Changyang anticline													
Lower Cambrian Series		Meishucun Stage		Shuijingtuo Fm.			Lower Cambrian Series		Shuijingtuo Fm.		Lower Cambrian Series		Shuijingtuo Fm.										
Sinian System		Upper Series		Dengyingxia Stage		Dengying Fm.		Tianzhushan Mem.		Yanjiahe Fm.		Dengying Fm.		Yanjiahe Fm.									
								Baimatuo Mem.						Baimatuo Mem.									
								Shibantan Mem.						Shibantan Mem.									
								Hamajing Mem.						Hamajing Mem.									
		Lower Series		Doushantuo Fm.		Nantuo Fm.				Doushantuo Fm.		Nantuo Fm.				Doushantuo Fm.							
Liantuo Fm.																		Datanpo Fm.		Guchen Fm.		Liantuo Fm.	
Presinian System		Huangling Granite and Kongling Group			Presinian System		Huangling Granite and Kongling Group			Presinian System													

Fig. 1-2 Subdivision and correlation of the Sinian system in eastern Yangtze Gorges area



## Lower and Upper Boundaries

The lower boundary; the subdivision within Late Precambrian is one of the globally important geological questions which remains unresolved to date. At present, there are three opinions concerning the definition of the lower boundary of the Sinian System in China: 1) the base of the Liantuo Formation; 2) the base of the tillite unit; 3) the base of the Doushantuo Formation. However, in the present paper the suggestion proposed by the National Classification and Naming Conference on the Late Precambrian Strata, Beijing, in 1982 is adopted, and the base of the Sinian System is temporarily fixed at the base of Liantuo Formation as developed in the eastern Yangtze Gorges area.

Based on the isotopic data obtained by different methods, the U-Pb age of zircon from Huangling Granite is  $819 \pm 7$  Ma (Ma Guogan et al., 1984), the K-Ar age of biotite is  $823 \pm 7$  Ma (Ma Guogan et al., 1984) and Rb-Sr age is  $806 \pm 5$  Ma (Ma Guogan et al., 1984), the age of zircon from the tuffs of the Liantuo Formation is  $748 \pm 12$  Ma (Ma Guogan et al., 1984) also obtained by ion probe. We would infer that the figure of  $760 \pm 20$  Ma (Ma Guogan et al., 1984) might be the best age estimate for the lower boundary at the present time.

The upper boundary; the definition of the upper boundary of the Sinian System or the base of the Cambrian System is also a much disputed question. At present, an unanimous opinion for international division of the Precambrian-Cambrian (Sinian-Cambrian) boundary has been taken as follows: "the Precambrian-Cambrian boundary stratotype point should be as close as practicable to the base of the earliest sequence with diverse small shelly assemblages with a good potential for correlation (Bristol Conference in May, 1983)".

According to the result of the vote by the Working Group on Precambrian-Cambrian Boundary, the I.U.G.S.-I.G.C.P. Project No. 29 China, the point "B" in the Meishucun Stage, that is between the *Anabarites-Circotheca-Protohertzina* assemblage and *Paragloborilus-Siphonochites* assemblage, is taken as a candidate for the global stratotype point of the Precambrian-Cambrian boundary. In the Yangtze Gorges area, it corresponds to the base of the upper fossil assemblage within the Yanjiahe Formation, that is, between the *Circotheca-Anabarites-Protohertzina* assemblage and the *Ovalithea-Aldanella-Maidipingconus* assemblage. Based on the age data, that would mean:  $602 \pm 15$  Ma (Ma Guogan et al., 1984) by the Rb-Sr method for the Tianzhushan Member;  $568 \pm 12$  Ma (Ma Guogan et al., 1984) by the U-Pb method and  $573 \pm 7$  Ma (Ma Guogan et al., 1984) by the Rb-Sr method for black shale of the Shuijinguo Formation. We prefer to apply the figure  $605 \pm 10$  Ma (Ma Guogan et al., 1984) for the boundary age of the Precambrian-Cambrian Systems.

## Excursion Routes

The vicinity of Liantuo town is the site of the type section for the Sinian System in China. The location is approximately 33 km west of Yichang, about one hour travel by public bus or two hours by boat. The Gucheng Formation and Datangpo Formation are only exposed at the core of Changyang Anticline, and most completely at Guchengling of Gaojiayan in Changyang. By taking an automobile or taxi one can easily get to Guchengling, which is about 60 km from Yichang. The type section of Yanjiahe Formation is located at Jijiapo and Yanjiahe, the southern limb of Huangling Anticline,

to where one needs 48 km of driving from Yichang.

At the eastern end of Liantuo bridge, the Sinian System lies unconformably on the Huangling biotite plagioclase granite with marked boundary between the red-color Liantuo Formation and the white-color Huangling Granite.

On the hillside north of Wangfenggang village, there is an observation point for lithological characters of the upper part of the Liantuo Formation, please note the grey crystallinoclastic tuffs and cross-bedding within it.

A disconformable contact between the Liantuo and Nantuo Formations with a distinct boundary can be seen at the highway slope to the north of Wangfenggang village: go up along a path, there you can observe the whole section of the Nantuo Formation. Note the striations and engraving grooves on the gravel surface and the gravel composition, the contact relation between the Nantuo and overlying Doushantuo Formations, the lithological characters of the middle and lower parts of the Doushantuo Formation, at the base of which occur irregular siliceous skin shells. Many small rounded gravels are found at the base of the Doushantuo Formation as well.

On the hillside south of Tianjiayuanzi village, on the southern bank of the Yangtze River, you have to go along a path through the Doushantuo village to the south. One can see a good exposure of biotite plagioclase granite and of the Liantuo Formation which unconformably overlies the granite. Note lithological characters of the Doushantuo Formation and its contact relation with the overlying Dengying Formation and underlying Nantuo Formation. This is a standard section of the Doushantuo Formation established by J. S. Lee in 1924.

The section of the Dengying Gorge along the river (southern bank of Yangtze River): the Dengying Gorge is a small gorge of the Xiling Gorge and is situated between the Nantuo and Shipai villages. Along a path at south bank of the Yangtze River from Nantuo to Shipai, one can observe the lithological and facies characters of the whole Dengying Formation. Please pay attention to look at the oolitic dolomite and intraclast dolomite in the lower part of the Hamajing Member, and at the giant-type *Vendotaenia*-banded algae within the black bituminous limestone at the top of the Shibantan Member and at *Sinotubulites baimatuoensis* fossils at the base of the Baimatuo Member.

Guchengling in Gaojiayan, Changyang: all the lithological characters of the Datangpo and Gucheng Formations may be found here. Please observe the tillites in the lower part of the Gucheng Formation, and the varve clay layers which are buckled by small gravels in the upper part, as well as the contact relations between the Liantuo and Gucheng Formations.

The boundary section of the Sinian and Cambrian, about 300 m NW 295° of Tianzhushan school, Liantuo: note the small shelly fossils mainly to be found in siliceous phosphatic clastic rocks within intraclastic dolomite in the upper part of the Tianzhushan Member; these fossils are generally with phosphatic shells and several mm long.

The boundary section of Precambrian-Cambrian on the hillside in Yanjiahe, Jijiapo, Sandouping: here rocks of another sedimentary type composed of black carbonaceous shale and interbedded with medium-bedded, black medium-coarse crystalline carbonaceous limestone can be found, which differ from those of the Tianzhushan Member in the eastern limb. Note that the lower small shelly fossils assemblage of this section occurs in siliceous phosphatic clastic dolomitic limestone, but they are not easily found with unaided eyes. The upper fossil assemblages, to be observed in siliceous phosphatic clastic or massive limestone close to the top, are very easily found.

## The Cambrian System

Zhou Tianmei and Xu Guanghong

The Cambrian of the Yangtze Gorges area is well developed and widespread with a complete sequence and a relatively simple structure. Around the eastern and western limbs of the Huangling Anticline, the Cambrian is extensively exposed in Yichang, Zigui, Changyang and Yidu. Its sediments are mainly composed of carbonates and minor clastic rocks. The Lower Cambrian is fairly rich in fossils, but in the Middle Cambrian fossils are rare. In the Upper Cambrian, only a few conodonts and isolated occurrences of brachiopods have been found near the top. The Cambrian of the eastern Yangtze Gorges area is considered as a typical area for the Cambrian of south China. Rocks of Cambrian are of interest with regard to both its well-developed strata and its mineral resources, such as rare elements, phosphate and gypsum-salt minerals.

### Excursion Routes

The Cambrian in the eastern Yangtze Gorges is over 1000 m in thickness, with a gentle dip and extensive areal distribution. The observation of the whole Cambrian sequence has to be carried out in separate sections due to soil covering and its geomorphological expression. The Sinian-Cambrian boundary is separately represented by the Tianzhushan section of Liantuo and the Yanjiahe section of Sanduoping. The former is located at 3 km southeast of Liantuo in Yichang county. The visitor will pass through Zhaojiping by bus along the Yichang-Liantuo highway and then turn to another road entering the Tianzhushan section. The latter is zig-zagging up at the northern slope of Yanjiahe village, Sanduoping, Yichang. There is a bus service from Yichang City passing through Tucheng to the Yanjiahe section. If you want to visit the original named section of Lower Cambrian in this area, be advised to take a boat to Shipai, where you can observe the sequence from the Shuijingtuo to Shilongdong Formation along the southern bank of the Yangtze River. However, a part of this section is drowned by waters upon construction of the Gezhouba Dam, instead a newly built roadside section going through Huangshandong-Wangjiaping is museured (see Fig. 2-2) <sup>(1)</sup>. This section starts from a stone-marker indicating Sinian-Cambrian boundary and ends at the Wangjiaping village, composed of the Tianzhushan Member of Dengying Formation and the Shuijingtuo, Shipai and Tianheban Formations. Along the highway from the Wangjiaping village to Sanyoudong, the visitor will be able to observe the Lower Cambrian Shilongdong Formation, the Middle Cambrian Kexibao, Guanshannao, and Xinping Formations, and the Upper Cambrian Wuduhe Formation.

<sup>(1)</sup> For figures see those of relevant numbers in the Chinese text.

and the Lower-Middle Cambrian and Middle-Upper Cambrian boundaries along the same route. Near the Sanyoudong bridge, there is a highway leading to the Qinjiamao village, where the section of Shilongdong Formation (see Fig. 2-4) and the named sections of the Kexibao and Guanshannao Formation can be observed (see Fig. 2-5, 2-6). In addition, there is a well exposed Cambrian section along the Yichang City-Xinshan highway. This section starts from Taishanmiao, passes Xinping, and ends at the vicinity of Lianhekou, where it joins up with the remarkable Huanghuachang Ordovician section. The Lower and Upper boundaries of the Cambrian are very distinct. Small shelly fossils and trilobites can separately be collected from the Tianzhushan Member and the Shuijingtuo and Shipai Formations. The type section for the Xinping and Wuduhe Formations of the Sanyoudong Group are exposed between Xinping bridge and Lianhekou (see Fig. 2-3). The locations of the sections are shown in the Fig. 2-1.

## Stratigraphic Subdivision

The Cambrian of the eastern Yangtze Gorges area may be subdivided into three series, eight formations and one member, this being shown in Table 2-1. The rock characteristics and fossils for each formation would be introduced below, except the Tianzhushan Member and the Yanjiahe Formation which have been described in the section on the Sinian System of the present book.

### 1. The Shuijingtuo Formation

The Shuijingtuo Formation is the lowest trilobite-bearing stratigraphic unit in this area. It consists of black carbonaceous shales, black shales intercalated with lenticular dolomitic limestones or of thin-bedded limestones in the lower part. In the upper part this formation is composed of the interbeds of gray black thin-bedded limestones and gray black thin-slabby marlite (or calcareous shale). This formation is characterized by yielding abundant eodiscids, such as *Tsunyiidiscus*, *Sinodiscus*, *Hupeidiscus*, and other trilobites, such as *Hunanocephalus* (*Hunanocephalu*), *H.* (*Duotingia*), *Zhenbaspis*, *Wangzishia*, *Metaredlichia*, *Pseudoredlichia* etc., but it also contains bradoriids: *Majiahanella*, *Paratsunyiella*, and brachiopods, sponges and hyolithes. Three trilobite zones can be recognized in the Shuijingtuo Formation; they are in ascending order: *Tsunyiidiscus*, *Wangzishia* and *Hunanocephalus* (*Duotingia*)-*Hupeidiscus* zones. In addition, this formation also contains abundant microflora represented by Sphaeromophitae, the principal elements are *Asperatopsophosphaera*, *Baltisphaeridium*, *Leiofusa*, *Leiopsophosphaera*, *Microconcentrica*, *Monotrematosphaeridium*, *Reticulus* etc. The Shuijingtuo Formation is 24 m to 80 m and more in thickness, and it is 52.75 m thick at Huangshandong section. In the eastern limb of the Huangling Anticline, the Shuijingtuo Formation is in disconformable contact with the underlying Tianzhushan Member of Dengying Formation. A yellow clay layer only a few cm thick was discovered by chance at the bottom of the Shuijingtuo Formation. In the southern and western limbs of the Huangling Anticline, the Shuijingtuo Formation is in conformable contact with the underlying Yanjiahe Formation or its equivalent.

### 2. The Shipai Formation

This formation consists of yellowish green and grayish arenaceous shales and siltstones intercalated with limestones or oolitic limestones, which are between 158—301 m thick. At Huangshandong section the thickness is 158.45 m. This

Tab. 2-1 The correlative table of the Cambrian in the eastern Yangtze Gorges with neighbouring area

Cambrian of China		eastern Yangtzi Gorges	eastern Yunnan	Emei, Sichuan	Yankong, Jinsha Guizhou	Merziwan, Meitan Guizhou	E. N. Guizhou	Xianfeng Hubei
Upper Cambrian	Fengshan St.	Sanyudong Group	Wuduhe Fm.			Loushanguan Group	Maotian Fm.	Daotuo Fm.
	Changshan St.						Houba Fm.	
	Gushan St.							Tuleping Fm.
Middle Cambrian	Zhangxia St.	Qinjiangmiao Group	Guanshannao Fm.	Xixiangchi Group		Loushanguan Group	Pingjing Fm.	Guangzhuling Fm.
	Xuzhuang St.		Shuanglongtan Fm.				Shilengshui Fm.	Maoping Fm.
	Maozhuang St.							
Lower Cambrian	Longwangmiao St.	Shilongdong Fm.	Longwangmiao Fm.	Douposi Fm.	Gaotai Fm.	Gaotai Fm.	Gaotai Fm.	Gaotai Fm.
	Canglangpu St.	Tianhebian Fm.	Canglangpu Fm.	Canglangpu Fm.	Jindingshan Fm.	Jindingshan Fm.	Qingxudong Fm.	Shilongdong Fm.
		Shipai Fm.			Mingxinsi Fm.	Mingxinsi Fm.	Mingxinsi Fm.	Tianhebian Fm.
	Qiongzhusi St.	Shijingtuo Fm.	Qiongzhusi Fm.	Qiongzhusi Fm.	Niutitang Fm.	Huangshanba Fm.	Niutitang Fm.	no exposed
	Meishucun St.	Tianzhushan Mem. of Dengying Fm.	Yuhucun Fm.	Maidiping Mem. of Hongchunping Fm.				

formation includes the following two trilobite zones: *Redlichia* (*Redlichia*) *meitanensis* zone in the lower part and *Palaeolenus lantenoisi* zone in the upper part. The principal trilobites of the lower zone are *Redlichia* (*Redlichia*) *meitanensis*, *Redlichia* sp., *Neocobboldia*, *Ichangia* etc.; the upper zone is characterized by the appearance of *Palaeolenus lantenoisi*, *Megapalaeolenus*, *Redlichia* sp., *R. (Pteroredlichia)*, *Kootenia* etc.. Besides trilobites, these rocks also yield brachiopods: *Nisusia*, *Iphidella*; Bradoriids: *Houlongdongella*, and microflora: *Asperatopsophasphaera*, *Baltisphaeridium*, *Glottimorpha*, *Leiofusa*, *Leioopsophasphaera*, *Nucellosphaeridium*, *Orygmato-sphaeridium*, *Pseudozonosphaeridium*, *Reticulum*, *Taeniatum*, *Trematosphaeridium* etc.. The Shipai Formation is in conformable contact with the underlying Shuijingtuo Formation and easily distinguished from the Shuijingtuo Formation by their different lithological characteristics. In the western limb of the Huangling Anticline, the lower and middle parts of this formation change into argillaceous-banded limestones intercalated with siltstone and fine sandstones with limestones.

### 3. The Tianhebian Formation

The lithological features of the Tianhebian Formation are very obvious, it is composed of dark green, greenish black thin-bedded, moderately thick-bedded argillaceous banded limestones intercalated with oolitic and pisolitic limestones, and minor silty shales in the upper part. The thickness is 81—100 m. This formation is 90 m thick at Huangshandong section. It is characterized by yielding trilobites of the *Megapalaeolenus deprati* zone and achaecyathids of the *Achaecyathus-Retecyathus-Sanxiacyathus* assemblage. The principal trilobites comprise *Megapalaeolenus*, *Palaeolenus*, *Redlichia* (*Redlichia*), *Antagmus*, *Breviredlichia*, *Hoffetella*, *Xilingxia* etc. In addition, rare brachiopods occur, such as *Obolella?* sp. The Tianhebian Formation overlies conformably the underlying Shipai Formation.

### 4. The Shilongdong Formation

The Shilongdong Formation has its name derived from the particular karst cave Shilongdong which means "Stone-dragon cave". It consists of brownish-gray, gray and grayish-white massive thick-bedded dolomites and calcareous dolomites, between 106—129 m thick. In the upper part of this formation the dolomites often contains pebbles and some small karst caves. Only a few specimens of *Redlichia* have been found in it. The Shilongdong Formation can be distinguished from the Tianhebian Formation in its lithological characteristics; the Tianhebian Formation is represented by the dark coloured thin-bedded limestones, whereas the Shilongdong Formation is composed of light coloured thick-bedded dolomite. The Shilongdong Formation is conformably overlain by the Qinjiamiao Group. The boundary between the Shilongdong Formation and the Qinjiamiao Group is considered as equivalent to the Lower Cambrian and Middle boundary in the eastern Yangtze Gorges area.

### 5. The Qinjiamiao Group

The Qinjiamiao Group is equivalent to the Qinjiamiao thin-bedded limestones established by Wang in 1938. It was assigned to a Middle Cambrian age. According to the lithological characteristics, this group can be subdivided in ascending order into the Kexibao and Guanshannao Formations.

(1) The Kexibao Formation: This formation consists of gray, pale-gray, thin to moderately thick-bedded dolomites and thin-bedded argillaceous dolomites intercalated with gray and pale-gray dolomitic limestones and pebble-bearing oolitic dolomites with ripple marks. In the lower part the rocks often contains siliceous bands or concretions; and the rocks of the upper part contain halite pseudomorphs. The total thickness is

107.04 m. Until today the trilobites and brachiopods found in this formation were all collected from Niunanxi at Pingshanba and Zhaojiping at Liantuo, Yichang. *Schopfaspis*, *Xingrenaspis*, *Anomocarella*, *Solenoparia*, etc. are present the Kexibao Formation and thus indicate its Middle Cambrian age.

(2) The Guanshannao Formation: The Guanshannao Formation can be separated from the underlying Kexibao Formation by a thin to moderately thick-bedded feldspathic quartz-sandstone layer (2—2.8 m) at the bottom; the lower part of it is composed of the interbeds of thin bedded dolomites and thin-bedded argillaceous dolomites; whereas the upper part consists of moderately thick-bedded dolomites intercalated with thin-bedded argillaceous dolomites, yielding stromatolites. It is 129—166 m thick in total. It is conformably overlain by the Xinping Formation of the Sanyoudong Group. Since this formation is placed between the Xinping Formation with Late Middle Cambrian trilobites and the Kexibao Formation with true Middle Cambrian trilobites, its age is assigned to the Middle Cambrian.

#### 6. The Sanyoudong Group

The Sanyoudong is also a karst-cave, it is a famous scenic spot in the western countryside of Yichang City. The Sanyoudong Group is derived from the Sanyoudong limestone established by Wang in 1938. As a result of the discovery of Late Cambrian and Early Ordovician conodonts and cephalopods in the top of this group, and of late Middle Cambrian trilobites in its lower part, the age of the Sanyoudong Group is referred to the late Middle Cambrian extending into Early Ordovician. The Sanyoudong Group was originally divided in ascending order into the Xinping, Wuduhe and Xilingxia Formations (the latter is now referred to Early Ordovician).

(1) The Xinping Formation: The lower part of the Xinping Formation is characterized by dark gray thick-bedded limestones, and dolomitic limestones intercalated with gray dolomites, containing rippled fine bedding and trilobite fragment; the upper part consists of gray and light gray thick-bedded limestones with oolite and argillaceous banded limestones intercalated with dolomitic limestones and dolomites. The total thickness is 99.67 m. The trilobites found in this formation include *Paranomocare*, *Poshania*, *Paramenocephalites*. This formation is in conformable contact with the underlying Guanshannao Formation. The boundary between Xinping and Guanshannao Formations represents the boundary between the Qinjiamiao and Sanyoudong Groups.

(2) The Wuduhe Formation: The lower part of the Wuduhe Formation is composed of light-gray, gray, and dark-gray thick-bedded, massive dolomites intercalated with a few light-gray thin-bedded dolomites and pale-greenish gray dolomites, partly possessing siliceous stripes; the middle part of it is characterized by light-purplish gray, light-gray and gray thick-bedded, massive dolomites with many cross-beddings, oblique beddings and many small caves and some other karst features; the upper part consists of light-gray, light-yellowish gray thick and very thick-bedded dolomites and syngenetic brecciated siliceous dolomites intercalated with calcareous dolomites with siliceous stripes or concretions, containing conodonts: *Teriodontus nakamurai*, *Eoconodontus notchpeakensis*, *Cordylodus proavus*, *Hirsutodontus rarus*, with rare brachiopods. The total thickness is 578.26 m. It is placed between the Xinping Formation containing the late Middle Cambrian trilobites and the Xilingxia Formation yielding the Early Ordovician conodonts and cephalopods. The upper part of this formation corresponds to the latest Cambrian from North America, Australia and North China. Hence, it is referred to Late Cambrian in age. It overlies conformably the underlying Xinping Formation.

## Lower and Upper Boundaries

In the eastern Yangtze Gorges area the lower boundary of Cambrian was separately drawn either at the base of the *Anabarites-Circotheca-Paragloborilus* assemblage derived from the Tianzhushan Member of the Dengying Formation or at the base of the *Circotheca-Anabarites-Protohertzina* assemblage of the Yanjiahe Formation. This boundary may correspond to the Precambrian-Cambrian boundary stratotype and its reference point "A" at Meishucun section in Yunnan. An isotopic dating age of  $610 \pm 10$  Ma has been suggested for this boundary. If the lower boundary of Cambrian in the eastern Yangtze Gorges area were compared with the Precambrian/Cambrian boundary stratotype reference point "B" of the Meishucun section in Yunnan, the lower boundary should be drawn at the base of *Aldanella-Maidipingoconus-Lophothica* assemblage in the southern limb of the Huangling Anticline, where the isotopic dating age is  $605 \pm 15$  Ma. However, an equivalent boundary is not easy to define in the eastern limb of the Huangling Anticline.

The upper boundary of Cambrian was traditionally placed at the top of the Sanyoudong Group in the eastern Yangtze Gorges area, which coincided with a biocalcarenite bed at the base of the Nanjinguan Formation belonging to the Early Ordovician, containing the trilobite *Asaphillus inflatus* or the benthonic graptolite *Dictyonema yichangense*. Upon the discoveries of the Early Ordovician conodonts and cephalopods in the top beds of the Sanyoudong Group, the Cambrian-Ordovician boundary of the present area was drawn downward to between the *Hirsutodontus simplex-Monocostodus sevierensis* zone of the Xilingxia Formation and the *Eoconodontus notchpeakensis-Cordylodus proavus* zone of the Wuduhe Formation within Sanyoudong Group.

The Lower-Middle Cambrian and Middle-Upper Cambrian boundaries are placed between the Shilongdong Formation and the Kexibao Formation of the lowest Qinjiamiao Group, and between the Xinping Formation and the Wuduhe Formation respectively in the eastern Yangtze Gorges area.



## The Ordovician System

Zeng Qingluan and Xu Guanghong

The Ordovician System in the Yangtze Gorges area is extensively exposed around the Huangling Anticline. In this area the Huanghuachang and Fenxiang sections located in the eastern limb of the Anticline are most representative. The Xintan and Longmaxi sections of Zigui at the western limb of the Anticline and the Huaqiao section of Changyang at the southeast of the Anticline are also quite excellent. The Ordovician System of the Present area is characterized by simple structures, quite a perfectly continuous succession and an abundance of various fossils. The Ordovician belongs to a typical sedimentation of mixed facies, having the lithofacies features of both the North China type and the South China type. This region is a stratotype area for the classification and correlation of the Ordovician in the whole China. The section of the Latest Ordovician-Earliest Silurian boundary strata represented by the Huanghuachang, Fenxiang and Wangjiawang sections, are most spectacular, not only for China but also for other parts of the world.

### Excursion Route

The Huanghuachang village is located about 22.5 km north of Yichang City; its location is just at the junction of three roads leading to Yichang in the south, to Baokang in the north and to the Xingshan highway in the west, respectively. The Ordovician section of Huanghuachang was measured basically along both sides of the Xingshan highway (Fig. 3-1) ①. This section starts at the Lianghekou locality and ends at the "Trench 502" in the pine-woods on the east side of a small reservoir southwest of Huanghuachang village. Along the road side the visitor can see some marks made of stone tablets showing the boundaries between systems and formations. Various megafossils, particularly trilobites, cephalopods, brachiopods, graptolites, etc. are easily found and conveniently collected.

### Stratigraphic Subdivision

The total thickness of the Ordovician System at Huanghuachang is about 336.46 m. It is divided into 2 series, 7 stages and 10 formations (Table 3-1), which are briefly described as follows in ascending order:

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① For figures see those of relevant numbers in the Chinese text.