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Geology of the coal and petroleum deposits in the Ordos basin, China

by

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ABSTRACT

This report presents a concise and detailed digest of recently published literature on the geology of Late Carboniferous, Permian, Triassic, Jurassic, and Cretaceous coal and petroleum deposits in the Ordos basin, which is situated in the west-central part of the Sino-Korean platform. The initial depositional framework of the basin took shape during the Variscan orogeny with the development of the Helanshan-Liupanshan foldbelt on the west, the Qinling-Kunlun foldbelt on the south, and the Yin-shan uplift on the north. The closed basin form was achieved by the Taihang-Wuling-Xuefengshan uplift to the east in Late Triassic during the latest episode of the Indosinian orogeny.

The Ordos basin is one of the largest Mesozoic basins in China and contains thick Mesozoic continental sedimentary sequences. In Middle Triassic time, the Ordos basin became a large inland fresh-water lake. This lake had two flourishing stages; one was in Middle Triassic to Late Triassic Tongchuan-Yanchang time and the other in Middle Jurassic Yanan time. The fluvial and lacustrine detrital sediments were derived chiefly from highlands adjacent to the basin.

During the Yanshanian movement from early Late Jurassic to early Late Cretaceous, the Ordos basin was affected by active diastrophic movements. In the period from the end of Late Jurassic to the beginning of Early Cretaceous, the basin was tilted westerly and synkinematically was overthrust northeasterly along the west border, resulting in its present basin configuration. Sedimentary rocks in the basin were folded into a north-northeasterly trending, asymmetrical, broad synclinorium with a gently dipping eastern limb and a steeply dipping western limb. Subsequently, the western limb was again broken by a recumbent overthrust faulting system as well as by reactivation of the Yanshanian overthrusts during the Himalayan orogeny.

The mineable coal deposits of the Ordos basin are the Wayaobao Coal Series in the upper part of the Late Triassic Yanchang Formation and the Middle Jurassic Yanan Formation, located chiefly in the central and southern parts of the basin. Coal accumulated in areas of overbank and lakeside marshes and swamps under moist climatic conditions. Individual coal beds are as much as 34 m thick in the Yishicun Coal Series. The Late Carboniferous Taiyuan and Early Permian Shanxi coal beds are mined only in the vicinities of Hancheng, Jungarqi, and Zhuozishan near the basin borders.

Petroleum deposits occur mainly in the Triassic Yanchang Formations and in the Jurassic Fuxian, Yanan, and Zhiluo Formations. The distribution of Jurassic sandstone reservoirs, however, was controlled by the paleogeomorphic features of the Yanchang erosional surface. Chemical analyses of sterane and triterpane compounds from crude oil and extracts of source rock indicate that

the principal source rocks are in the Triassic Tongchuan and Yanchang Formations and the Jurassic Yanan Formation. Oil and gas shows are reported from the Late Carboniferous and Early Permian coal-bearing strata in the northwestern and northern parts of the Ordos. Most of the Late Carboniferous and Early Permian source rocks, however, have evolved into a highly mature gas within the basin. Further prospecting of natural gas resources, therefore, is favorable in the west-central, northwestern, and northern parts of the basin.

INTRODUCTION

General Statement

The Ordos basin, now called the Shaanganning basin, is a north-south trending intermontane Mesozoic depression confined chiefly within the northern part of the Shaanxi (Shensi) Province and the southwestern part of the Neimeng (Inner Mongolian) Autonomous Region. On the east, the Ordos borders the western part of Shanxi (Shansi) Province, and on the west, the eastern part of Ningxia (Ningsia Hui) Autonomous Region and the southeastern part of Gansu (Kansu) Province (figs. 1, 2, and 3). The Late Carboniferous and Permian marine and continental sedimentary strata and the Triassic through Early Cretaceous fluvial and lacustrine sedimentary sequences contain the source, reservoir, and cap rocks of the oil and gas deposits, and many mineable coal beds (table 1).

Regional Setting

The Ordos basin is situated in the west-central region of the Sino-Korean platform and evolved from the Paleozoic basement during the Variscan orogeny (Huang and others, 1980, p. 35) (table 2). Subsequently, the Indosinian and Yanshanian (Yenshanian) orogenies promoted further development of the Ordos into its present shape (figs. 3 and 4).

The study region occupies the principal part of a loess plateau with an altitude ranging from 800 to 1,200 m. It is limited by latitudes 34°00' N to 40°35' N and by longitudes 106°50' E to 111°10' E, and covers about 320,000 km^2 with a sedimentary fill amounting to about 576,000 km^3 (figs. 1, 2, and 3). This basin is the largest interior basin of the Yellow River drainage system. It is bounded on the south by the Qingling, Shaanxi Province; on the north by the Yinshan and Langshan, Neimeng Autonomous region; on the east by the Luliangshan, Shanxi Province; and on the west by the Helanshan and Liupanshan, Ningxia Autonomous region (fig. 4). Generally the inhabitants of the basin are loess-cave dwellers. Rich farm lands are confined to the southern part of the basin, and scattered desert lands occur in the north. The climate ranges from temperate in the south to semiarid in the north.

Purpose, Method, and Scope of the Report

The primary purpose of this report is to provide a digest of available recent literature with a perspective on the geology of coal and petroleum deposits in the Ordos basin. The Chinese Pinyin system is used for transliterating Chinese names, which are followed in some cases by the conventional Wade-Giles spelling in parentheses for better understanding of cited references.

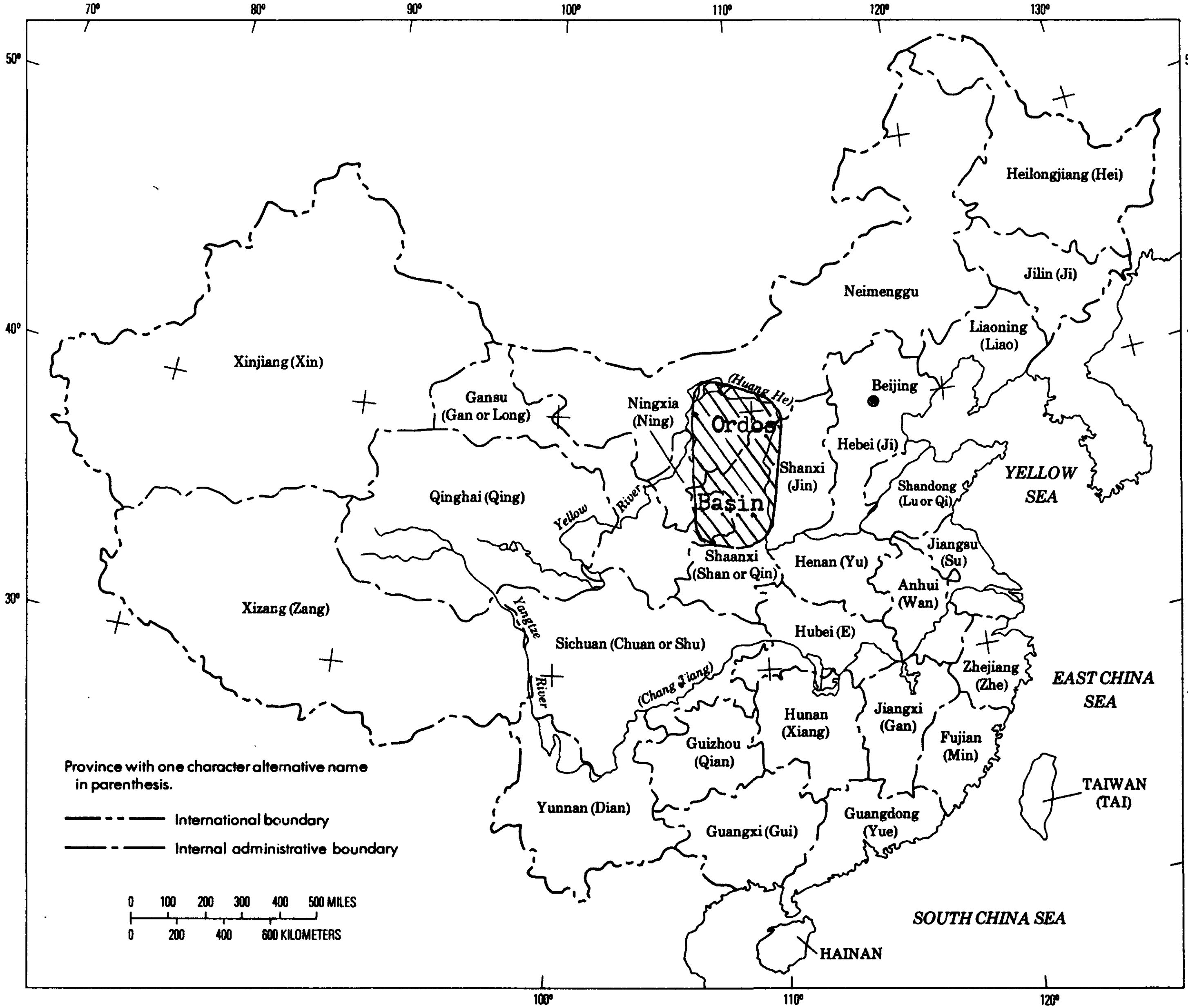


Figure 1. Index map of China showing the location of study area.

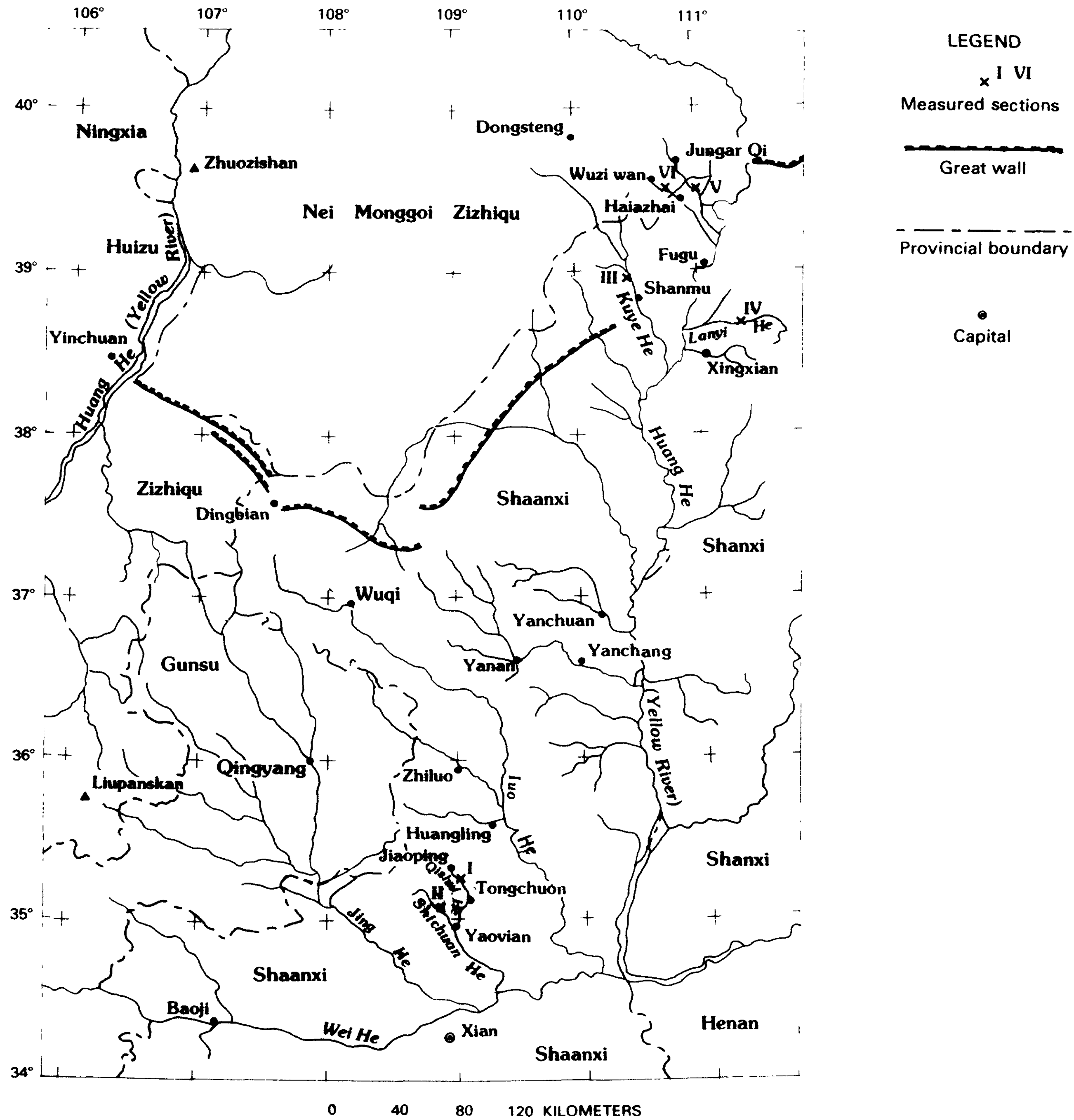
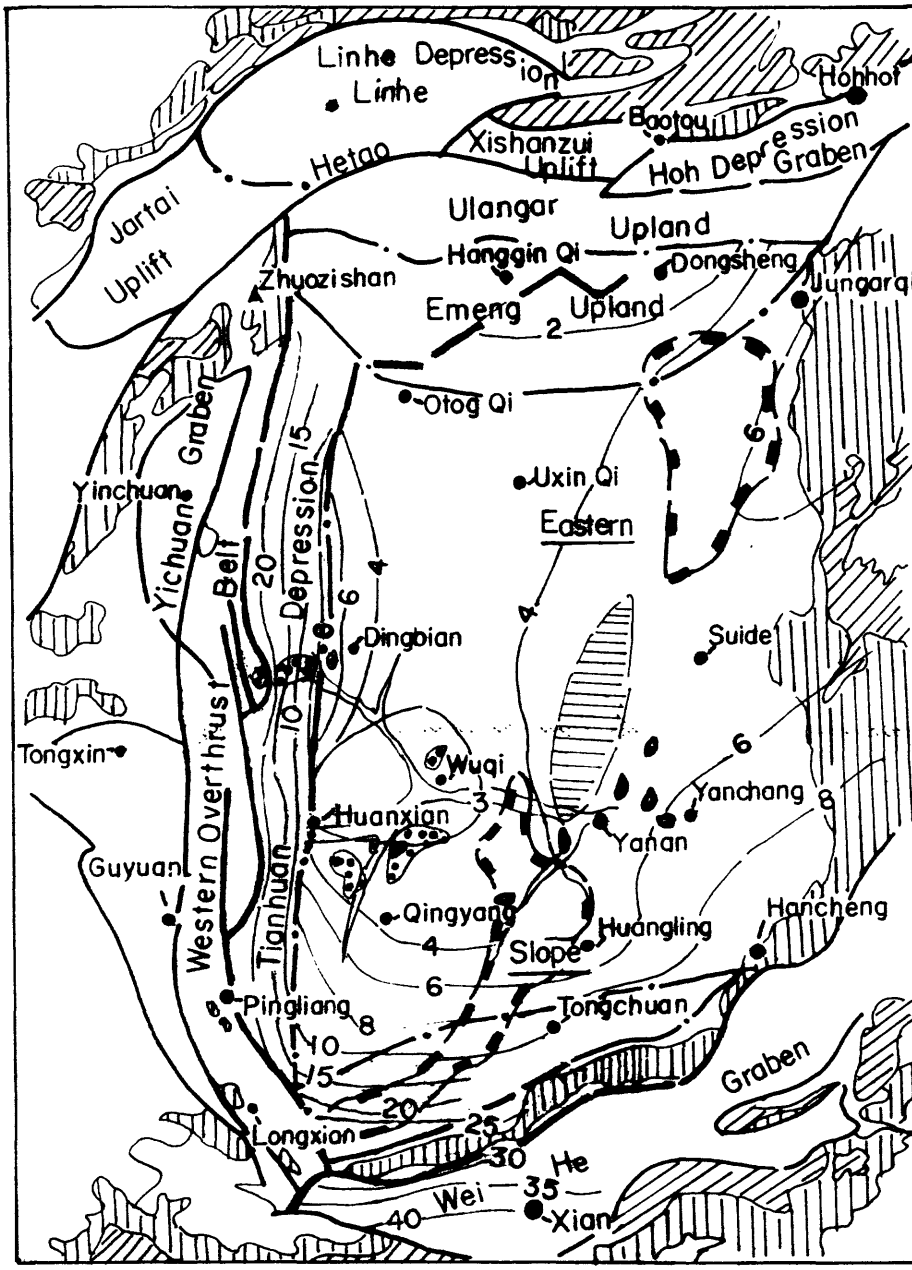


Figure 2. Sketch map of the Shaanganning (Ordos) basin (modified after Institute of Geology, Chinese Academy of Geological Sciences, 1980; Figure 1, v. 1, p. 3).

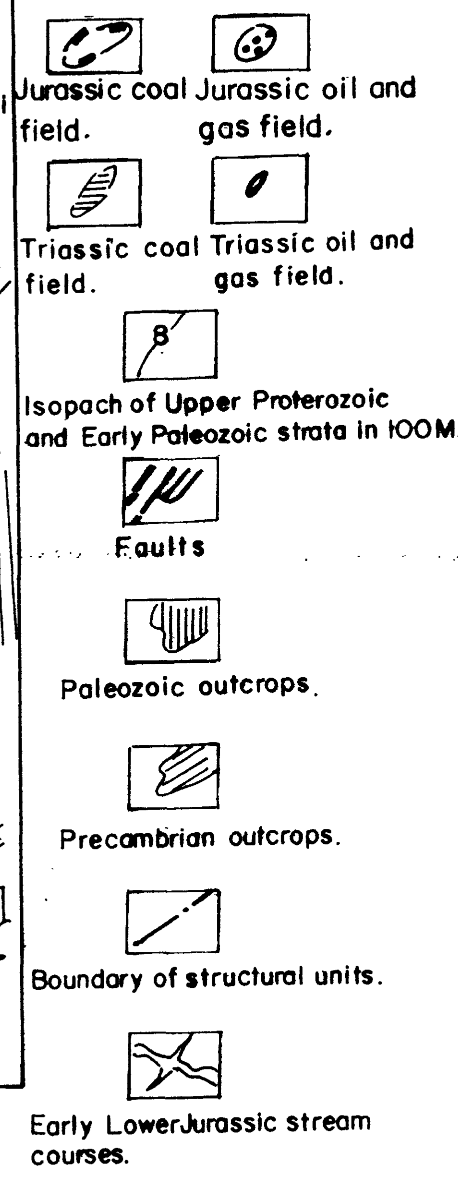
page 7 follows

Table 2.—Orogenic cycles of China (After Huang and others, 1980, table 4, p. 106).

Geologic chronology		Isotopic age (m.y.)		Orogenic cycles
Cenozoic	Quaternary		H_2	Himalayan (H)
		1.5		
	Tertiary		H_1	
		67		
Mesozoic	Cretaceous		Y_3	Yanshanian (Yenshanian) (Y)
		137		
	Jurassic		Y_2	
		190	Y_1	
	Triassic		I	Indosinian (I)
		230		
Paleozoic	Permian		V_4	Variscan (V)
		280		
	Carboniferous		V_3	
		350	V_2	
	Devonian		V_1	
		405		
	Silurian			Caledonian (C)
		440	C_2	
	Ordovician			
		550	C_1	
	Cambrian			
		570		Xingkaiian (Hsingkaiian)
Proterozoic	Sinian	770		
	Qingbaikou			Yangziian (Yangtzeian)
		1100		
	Jixian			?
		1400		
	Nankou			Wulingian
		1700		
	Changcheng Hutuo			Zhongtiaoian (Chungtiaoian)
		1950		
	Wutai			Wutaiian
		2500		
Archean	Fuping			Fupingian



Explanation



Scale

0 50 100 150 KM

Figure 4. Structural units and principal coal and petroleum fields in the Shaanganning (Ordos) basin (modified after Wang and others, 1983; Figure 4-9-45, p. 283; Zhang, 1982; Figure 1, p. 305; and Han and Yang, 1980; Figures 5-28, p. 271, & 5-36 and 5-37, p. 284).

STRATIGRAPHY

General Statement

The stratigraphy of the Ordos basin includes the Late Carboniferous, Permian, and Mesozoic sedimentary sequences. Most of the Late Carboniferous and Permian strata, however, are located beneath the Mesozoic sedimentary cover; therefore, the stratigraphic section of this report is concentrated on the Mesozoic stratigraphy as discussed below.

On the basis of paleontologic studies, the Mesozoic stratigraphy of Ordos basin consists of continental sequences of Triassic, Jurassic, and Cretaceous sedimentary rocks (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 2, 30, and 39). Generally, the Triassic strata are well exposed in the eastern part of the basin along the side of the Yellow River; the Jurassic strata are well exposed in the central portion of the basin; and the Cretaceous rocks are widely distributed and exposed throughout the basin and disconformably overlie the Jurassic and older rocks (figs. 1, 2, 3; table 1).

Triassic

General Statement

The Triassic system in the Ordos basin consists of, in ascending order, the Early, Middle, and Late Triassic (fig. 3; table 1). Excellent exposures of this system occur at places in eastern Shaanxi Province: Shichuanhe, Yaoxian; Qishuihe, Tongchuan; Xuefengchuan, Hancheng; Dalihe, Suide; Kuyehe, Shenmu; Gushanchuan, Fugu; Xilougou, Gucheng; Mazhen, Halazhai; and the vicinity of Yanchuan, Wubao, and Jiaxian. Outcrops are also well exposed along Sanchaunhe, Lishi, and Lanyihe, Xingxian, in western Shanxi Province; and at Zhungeerqi in southwestern Neimeng (Inner Mongolian) Autonomous Region (figs. 1 and 2) (Measured sections).

Stratigraphic units

Early Triassic

The Early Triassic is represented, in ascending order, by the Liujiagou Formation and the Heshanggou Formation. The Liujiagou Formation, 160 to 400 m thick, contains grayish-white, purplish-red, and grayish-purple thick sandstone with conglomerate, locally containing marine fauna in the southern part of the basin (Zhang, 1982, table 1, p. 307). The Heshanggou Formation, 110 to 131 m thick, consists of brick-red or orange-red mudstone and sandy mudstone intercalated with small amounts of sandstone and grayish-green mudstone lenses (fig. 3; table 1).

Middle Triassic

The Middle Triassic consists of, in ascending order, the Ermaying Formation and the Tongchuan Formation. The Ermaying Formation consists of interlayers of grayish-green to yellowish-green and purplish-gray sandstone and purplish-red to dull purplish-red mudstone. In the southeastern part of the basin, the Ermaying contains coarse-grained detritus and black shale. Generally, the sediments of the Ermaying Formation are coarse-grained in the lower part and fine-grained in the upper part. The thickness of this formation ranges from 350 to 813 m. The thickest beds of the Ermaying occur in the southern part of the basin, whereas the thinnest beds are found in the north.

The Tongchuan Formation is subdivided into two members. The lower member is made up chiefly of grayish-green, yellowish- and pinkish-red, blocky fine-grained mudstone, intercalated with shale, siltstone, and mudstone in the upper part. The upper member consists of interlayers of grayish-green, yellowish- and pinkish-red fine-grained mudstone, sandstone, and siltstone, and grayish-black shale, containing oil shale in the southeastern part of the basin. The Tongchuan is 100 to 596 m thick.

Late Triassic

The Late Triassic is represented by the Yanchang Formation. This formation is subdivided into the lower, middle, and upper members. The lower member is mostly gray, grayish-green, thick-bedded, blocky, medium-grained sandstone and siltstone, containing mudstone and locally thin coal. This member is 210 to 325 m thick. The middle member, 95 to 200 m thick, consists of interlayers of grayish-green to yellowish-green, thick-bedded, fine-grained sandstone, siltstone, and mudstone. Locally it contains thin coal beds. The upper member is made up of interlayers of yellowish-green, grayish-black mudstone with sandstone, siltstone, and shale, which contain principal coal beds and oil shale locally in the upper part. This member ranges from 0 to 228 m in thickness.

Six detailed sections of the Triassic system are listed under the heading "Measured Sections" and include the following: I. Qishuihe, Tongchuan; II. Shichuanhe, Yaoxian; III. Kuyehe, Shenmu; IV. Lanyihe, Xingxian; V. Gucheng-gongshe-Xilougou, Fuguxian; and VI. Laocaogou-Wuziwangongshe, Zhungeerqi.

Stratigraphic relation with adjacent units

Throughout the basin, the Late Permian Shiqianfeng Formation is conformable with the overlying Early Triassic Liujiagou Formation. However, the contact between the Late Triassic Yanchang Formation and the Early Jurassic Fuxian Formation is generally disconformable (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 25-27).

Jurassic

General Statement

The Jurassic System of the Ordos basin is subdivided, in ascending order, into the Early, Middle, and Late Jurassic (fig. 3; tables 1 and 3). Late Jurassic is generally absent throughout the basin (Institute of Geology, Chinese Academy of Geological Sciences, 1980, table 4). These sedimentary rocks are well exposed along the banks of the Luohe, Huluhe, Xixingzihe, and

Table 3.--Jurassic stratigraphic correlation of the Shaanganning (Ordos) Basin (adapted after Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 31, table 6).

Age	Stratigraphic Unit / Region	South (South of Jushui)	Central (Huluhe-Dalihe)		Northeast: Shenmu-Zhungeerqi	Northeast: Dongsheng area
	K_1	Zhidan Group	Zhidan Group		Cretaceous (K_1)	Cretaceous (K_1)
	J_3	(hiatus)	(hiatus)		(hiatus)	(hiatus)
	J_2	?	Anding Formation		Third Formation (Anding Formation)	Third Formation (Anding Formation)
		Zhiluo Formation	Zhiluo Formation		Second Formation (Zhiluo Formation)	Second Formation (Zhiluo Formation)
		Yanan Formation	Yanan Formation	Zaoyuan Member	First Formation (Yanan Formation)	First Formation (Yanan Formation)
				Baotashan Sandstone Member		
	J_1	Fuxian Formation(?)	Fuxian Formation		Fuxian Formation	(hiatus)
	T_3	Yanchang Formation	Yanchang Formation		Yanchang Formation / Ermaying Formation	Yanchang Formation(?) / Ermaying Formation

Dalihe streams in the central part of the basin; along the banks of the Kuyehe and Gushanchuan streams in the southern part of the basin, Shaanxi Province; in the vicinity of Dongsheng in the northeastern part of the basin, Neimeng Autonomous Region; and along the basin margin in the southern and southwestern parts of the basin. Because this system contains rich energy-mineral resources, systematic studies of Jurassic stratigraphy in the basin have been conducted during the past two decades.

Stratigraphic units

The Early Jurassic is represented by the Fuxian Formation; the Middle Jurassic consists of, in ascending order, the Yanan, Zhiluo, and Anding Formations (tables 1 and 3) (Institute of Geology, Chinese Academy of Geological Sciences, 1980, table 4).

Fuxian Formation

The Fuxian Formation is named for the exposures of purplish-red mudstone intercalated with small amounts of sandstone and marl in the vicinity of Fuxian, Shaanxi province.

Distribution.--The Fuxian Formation is well exposed in the region of Fuxian on the south and Yanan on the north in the central part of the basin. Other excellent exposures are in the regions of Shenmu on the south and Zhungeerqi on the north in the northeastern part of the basin, as well as in the vicinity of Qingyang in the western part of the basin. This formation is probably absent south of Jushui in the southern part of the basin.

Lithology.--This unit consists chiefly of purplish-red mudstone intercalated with sandstone and small amounts of marl and calcareous concretions, which grade upward into grayish-green sandstone and shale interlayers at the type locality, Dashenhaogou, Fuxian. However, the lower part of the Fuxian Formation consists of conglomeratic sandstone and sandstone-conglomerate at Nanniwan due east of Ganquan, Shaanxi Province.

At Dashenhaogou, Fuxian, samples from the upper part of the Fuxian Formation contain 64 to 89 percent of Pteridespermae spores and only 11 to 36 percent of Gymnospermae pollen. Plant fossils at Daozhen, Ganquan are as follows: *Coniopteris hymenophylloides*, *Cladophlebis fangtzuensis*, *Baiera guilhaumati* Zeiller, *Baiera sp.*, and *Podozamites distans* (Presl) Bauer; and along Luohe, *Coniopteris sp.*, *Pityophyllum sp.*, and *Stenorachis sp*. These fossils occur only near the top of the formation.

Stratigraphic relation and thickness.--The contact of the Fuxian Formation with the underlying Yanchang Formation is disconformable and is generally conformable with the overlying Yanan Formation, such as the Baotashan Sandstone of the lower part of Yanan Formation, but it is disconformable locally. There is an angular unconformity between the Fuxian Formation and the Yanchang Formation in the northeastern part of the basin at Dianerwan, Fuguxian. The Fuxian is probably missing in the Dongsheng area.

The Fuxian Formation ranges in thickness from several meters to more than 100 meters in the central part of the basin. This thickness is variable in the northeastern part of the basin. At Shihekou, north of Shenmu, the Fuxian is more than 100 m thick. It is about 15 m thick along the highway cuts 300 m east of Gushenzhen, Fugu. It reaches a thickness of approximately 100 m in the Halazhai area, located between Fugu and Zhungeerqi.

Yanan Formation

The Yanan Formation is named after the excellent exposures of sedimentary rock along the Xixingzihe stream, Yanan County, and is subdivided into the lower Baotashan Sandstone Member, formerly called "Yanan Sandstone Member," and the upper Zaoyuan Member (fig. 3; tables 1 and 3).

Distribution.--The Yanan Formation underlies most of the central portion of the basin and is well exposed along the banks of the Xixingzihe, Dalihe, Huluhe, and Luohe. The Yanan is probably equivalent to the First Formation in the northeastern part of the basin (table 3) and is distributed extensively in the areas of Fugu, Shenmu, and Zhungeerqi. In the southern part of the basin, the Yanan is exposed sporadically in the areas of Jiaoping and Yaoxian (table 3).

Lithology.--The Baotashan Sandstone Member consists chiefly of grayish-white, yellowish-gray, and yellowish-pink, blocky, fine- to coarse-grained sandstone with a basal conglomerate and intercalated with grayish-black, clayey siltstone and shale in the upper part. Locally, the Baotashan Sandstone contains coal beds and oil shale. Plant fossils in the Xixingzihe profile include: Coniopteris hymenophylloides, C. tatungersis, Baiera furcata, Ginkgoites obrutschewi, and sphenobaiera cf. pulchella.

The Zaoyuan Member consists of a series of gray to grayish-green sandstone, interbedded with grayish-black to dark gray shale, mudstone, and oil shale. Locally, the Zaoyuan contains mineable coal beds. The fossil assemblages of the Zaoyuan consist of plant fossils and lamellibranchia fauna, which were collected and identified by the Institute of Geology of the Chinese Academy of Geological Sciences (1980) from the stratigraphic profiles along the Xixingzihe, Luohe, Huluhe, and Dalihe. The fossil plants are the Coniopteris hymenophylloides Brongniart, C. tatungensis Sze, Cladophlebis sp., Raphaelia sp., Nilssonia cf. moserayi, Stock et Math, Baiera manchurica, Yabe et Oishi, B. munsteriana, Sphenobaiera sp., and Phoenicopsis argustifolia. The faunal pelecypods consist of Sibireconcha extensa, S. anodontoides, S. golovae, Ferganoconcha carta, F. curta, F. sibirica, F. minor, F. elongata, F. estheraeformis, F. subcentialis, F. sibirica sublata, Tutuella crassa, T. balbinensis, T. formosa, Yananoconcha sinensis, Y. zaoyuanensis, Y. hengshanensis, Shensiconcha sp., Unio ganquanensis, U. cf. jenissejensis, U. cf. mirabilis, U. ansaiensis, U. cf. uralensis, Margaritifera cf. isfarensis, and Cuneopsis sp.

At Ganquan, the Yanan Formation contains fossil assemblages of Neocalamites sp., Cladophlebis sp., Coniopteris hymenophylloides Brongniart, C. cf. burejensis, Sphenobaiera sp., Czekanowskia rigida Heer, Pityophyllum sp., and Podozamites sp.

In the northeastern part of the basin, the Yanan Formation consists chiefly of gray, grayish-white, light yellow sandstone, clay-rich sandstone, mudstone, and shale, intercalated with coal beds. The basal conglomeratic sandstone of this formation occurs in the Dongsheng area, Neimeng Autonomous Region. In the southern part of the basin, the Yanan is represented by a series of gray to grayish-green sandstone and shale interlayers, which contain coal beds. The Baotashan Sandstone Member is missing. The Zaoyuan Member is probably present and called the Yisicun Coal Series.

Stratigraphic relation and thickness.--The contact of the Yanan Formation with the overlying Zhiluo Formation is conformable. In the northeastern part of the basin, the Middle Jurassic strata are conformable with the underlying Early Jurassic Fuxian Formation in the region from Shenmu via Fugu to Zhungeerqi but disconformable with underlying older strata at Hantaichuan and Hashilachuan, Dongsheng, Neimeng Autonomous Region.

The Yanan Formation is generally between 200 to 300 m thick in the central part of the basin. For example, it is 250 m thick along the banks of the Xixingzihe, 220 m thick along the Dalihe, and 147 m thick along the Huluhe. In the northeastern part of the basin, the Middle Jurassic has not been clearly defined and ranges from more than 100 m to about 200 m in thickness.

Zhiluo Formation

This unit is named for the exposure of yellowish-green to grayish-green sandstone and bluish-gray to grayish-purple mudstone, clay-rich siltstone, and sandstone, which contain a basal layer of blocky sandstone in the vicinity of Zhiluo, Shaanxi Province (fig. 3; table 1).

Distribution.--The Zhiluo Formation underlies most of the central part of the basin, and excellent outcrops occur in the vicinity of Yanan and along the banks of Xixingjihe stream. This formation is present in the northeastern part of the basin and is probably equivalent to the Second Formation (table 3). Outcrops of this formation are also found at Jiaoping, Jushui, and Qilizhen in the southern part of the basin.

Lithology.--The Zhiluo Formation consists of a basal conglomeratic sandstone, grading upward into coarse- to medium-grained sandstone, yellowish-green, grayish-green, and dark-purple mudstone, and silty mudstone interlayers, which grade up into yellowish-green and yellowish-gray, fine- to medium-grained feldspathic sandstone and interlayers of yellowish-green, grayish-green, and purplish-red mudstone and siltstone. Mudstone fragments and pyritized wood commonly occur in the sandstone (Han and Yang, 1980, p. 280). Fossil pollen and spores are the *Quadresculina*, *Pinuspollenites*, *Piceaepollenites*, *Podocarpidites*, *Classopollis*, *Deltoidospoia*, *Cyathidites*, *Concavissimisporites*, and *Klukisporites*. Plant fossils from the Xixingzihe profile are *Coniopteris hymenophylloides* Brongniart, *Equisteites* sp., and *Pagiophyllum* sp. Faunal pelecypods from the same section consist of *Sibireconcha* sp. and *Shensiconcha* sp.

In the northeastern part of the basin, the Zhiluo Formation is represented by part of a grayish-white, gray, or light yellow sandstone, clay-rich sandstone, mudstone, and shale interbeds. In the southern part of the basin, the Zhiluo consists of the thick-bedded Qilizhen Sandstone in the lower part and sandstone intercalated with clay-rich shale in the upper part. At Jiaoping, it is represented by a layer of conglomeratic sandstone.

Stratigraphic relation and thickness.--The contact of the Zhiluo Formation with the overlying Middle Jurassic Anding Formation is conformable. In the northeastern part of the basin, the Zhiluo equivalent beds are conformable with the overlying Third Formation. In the southern part of the basin, this formation is unconformable with overlying Cretaceous strata and underlying Late Triassic sedimentary rocks (Han and Yang, 1980, p. 280; Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 38) (table 3).

The thickness of the Zhiluo Formation increases from east to west in the basin. Generally it is 90 to 140 m thick in the east, 150 to 260 m thick in the area from the east toward the city of Qingyang, and about 250 m thick at Zhiluo. In the southwestern part of the basin, it is 223 m thick at Huating. In the northwestern part of the basin, it ranges from 270 to 500 m in thickness in the region of Lingwu and Yanchi, Ningxia Autonomous Region, to Dingbian, Shaanxi Province.

Anding Formation

This unit is named for the excellent exposures of black to grayish-black oil shale, shale, calcareous sandstone, and grayish-yellow to pink marl in the vicinity of Anding, Shaanxi Province (tables 1 and 3).

Distribution.--The Anding Formation underlies most of the central part of the basin, and excellent exposures occur along the sides of the Luohe, Huluhe, Xixingzihe, Qingjianhe, and Dalihe. This formation is present at Shenmu, Fugu, and Zhungeerqi in the northeastern part of the basin and is probably equivalent to the Third Formation (table 3). It is missing near the southern margin of the basin.

Lithology.--The Anding Formation generally consists of black to grayish-black oil shale, shale, and calcareous sandstone interlayers containing scattered hyacinth bean-shaped pyrite in the middle and lower parts; and grayish-yellow, pink marl in the upper part. Regionally, the lithology of this formation changes considerably. In the eastern part of the basin, the Anding contains blocky mudstone and sandstone in the lower part, marl in the middle part, and variegated mudstone in the upper part. In the area from Huangling to Fuxian in the southern part of the basin, it consists of yellow, gray, grayish-black mudstone and oil shale, intercalated with dolomitic marl and yellow, calcareous mudstone in the lower part, and dark-purple marl, dolomitic marl and mudstone in the upper part. Generally the clastic grain sizes in the formation become much coarser from south to north in the basin. For instance, from the Huluhe and Xixingzihe northward to the Dalihe, limestone and shale decrease relatively, whereas the siltstone and sandstone increase. Fossil assemblages from the profiles along the Dalihe, Xixingjihe, Luohe, and Huluhe include: vertebrate-*Baleiichys antingensis*; pelecypods-*Psilunio suni*, *Unio ansaiensis*; ostracodes-*Darwinula sarytirmenensis*, *D.*

magna, D. impudica, Timiriasevia shensiensis, T. mackerrowi, T. humilis, T. bella, T. aimeniacumiformis; and pollen and spores-Classopollis, Quadraeculina, Cycadopites, Cerebropollenites, Cyathidites, Verrucosisporites, Concavissimisporites, and Densoioporites.

In the northeastern part of the basin, the Anding Formation is represented by a sedimentary sequence of grayish-white, gray, light-yellow sandstone, clay-rich sandstone, mudstone and shale interbeds.

Stratigraphic relation and thickness.--The contact of the Anding Formation with the overlying Cretaceous Zhidan Group is disconformable in the central part of the basin. In the northeastern part of the basin, the Anding equivalent strata of the Third Formation are disconformable with the overlying Cretaceous sedimentary rocks (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 35 and 37) (table 3).

The Anding Formation varies from 52 to 91 m in thickness in the central part of the basin, 48 to 142 m in the eastern part of the basin, and 0 to 54 m (generally 20 to 40 m) in the area of Huangling and Fuxian in the southern part of the basin (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 35; Han and Yang, 1980, v. 2, p. 281).

Cretaceous

General Statement

The Cretaceous System is widespread in the Ordos basin. During the 1960s, detailed stratigraphic studies were conducted in the basin, and Cretaceous sedimentary rocks were defined in Early and Late Cretaceous age. The Early Cretaceous is well developed in the northern part of the basin, and the Late Cretaceous occurs only in the northwestern part of the basin (fig. 3, table 1).

Stratigraphic units

The Zhidan Group represents the Early Cretaceous and is subdivided into seven members. The Tegaimiao Formation represents the Late Cretaceous in the northwestern part of the basin.

Early Cretaceous

The Zhidan Group is named for the exposures of conglomerate, sandstone, mudstone, limestone and siltstone, containing thin coal beds in the upper part, in the vicinity of Zhidan, Shaanxi Province. This Group is subdivided, in ascending order, into members one through seven (table 1) and is well distributed in the northern part of the basin (fig. 3).

The first member of Zhidan Group is made up chiefly of purplish-gray conglomerate and occurs only along the banks of Jushui stream and in a region from Yijun via Binxian to Qianyang in the southern part of the basin. This member is missing in the northern part of the basin. The member is from 0 to 65 m thick.

The second member of Zhidan Group consists of fluvial interlayers of dark-red to purplish-red mudstone, sandstone, conglomeratic sandstone, and conglomerate, which contain detrital pyroclastic rocks. The type locality of this member is in the Duguijiahan-Bulunmiao area, which is located in a region between Etuokeqi and Hangjinqi, Neimeng Autonomous Region (fig. 2). Generally, this member consists of lower interlayers of silty mudstone, siltstone, and medium- to fine-grained sandstones containing detrital pyroclastic rocks; and upper interlayers of purplish-red conglomerate intercalated with mudstone and containing pollen, spores, and conchostracan fossils. This member is well exposed and distributed throughout a vast region in the northern part of the basin. The member attains a maximum thickness of 392 m.

The third and fourth members of the Zhidan Group are undifferentiated and consist of yellowish-green to grayish-green, feldspathic sandstone intercalated with dark brown mudstone and detrital pyroclastic rocks. Fossils of this unit are *Cladophlebis cf. C. dunkeri, C. cf. C. browniana,* and *Sinamia sp.* The type section is also located in the Duguijiahan-Bulunmiao area in the northern part of the basin. Maximum thickness of these two members is 933 m.

The fifth member of the Zhidan Group in the lower and middle parts consists of purplish-red, orange-red, orange-yellow, cross-bedded, and feldspathic sandstone; and in the upper part, purplish-red mudstone and sandy mudstone intercalated with sandstone. Fossils found in the lower and middle parts of this member are: reptiles-*Psittacosaurus sp., Eotomistoma multideutata,* and ostracodes-*Cypridea koskulensis, Lycopterocypris infantilis, Djungarica stolida, Rinocypris foveata,* and *Darwinula simplus*. An excellent complete profile is in the Duguijiahan-Bulunmiao area and also along the eastern front of Zhuojishan. Generally this member has limited distribution, but good exposures commonly occur south of the Wulangeer upland. Maximum thickness is as much as 376 m.

The sixth member of the Zhidan Group in the lower part consists of green and yellowish-green breccia, conglomerate, and feldspathic sandstone, which are well exposed along the eastern front of Zhuojishan; and in the upper part this member is made up of interlayers of variegated, sandy mudstone, sandstone, and conglomeratic sandstone, containing pseudo-oolitic limestone, and limestone. The limestone occurs in an area east of Dongsheng. The following fossils were collected from the limestone: *Brachyphyllum obesum; Psittacosaurus youngi; Sinoestheria tsaidamensis?, Ordosestheria wujiamiaoensis, Yanjiesthoria cf. sinensis, Y. cf. Y. yumenensis, Xibeiestheria pora, X. yanchiensis, X. ovata;* and *Cypridea koskulensis, Lycopterocypris infantilis, Djungarica stolida, Clinocypris scolia, Cypridea unicostata, Rhinocypris cirrita, Lycopterocypris circulata, Darwinula simplus, Cyridea wujiamiaonensis, Djungarica wujiamiaonensis, Timiriasevia? cyclina, Lycopterocypris eggeri*. This member is distributed extensively in the northern and western parts of the basin. The lower sequence is 234 m thick and the upper sequence is 305 m thick.

The seventh member of the Zhidan Group consists chiefly of interlayers of grayish-white, yellowish-green, blocky, dense, and feldspathic sandstone, and reddish-brown, dark-gray, lenticular, and silty mudstone intercalated with thin coal. Fossil plants reported in the mudstone include: Coniopteris onychioides, Elatocladus cf. E. manchuricus, E. cf. obtusifolis, Sphenolepidium sp., and Brachyphyllum cf. B. japanicum. This member has limited distribution along the banks of the Yellow River (Huanghe) in the northeastern part of the basin. The thickness is 226 m at Lamawan, Qingshuihexian, Neimeng Autonomous Region, but the upper part of this member is not exposed.

Late Cretaceous

The Tegaimiao Formation occurs only in the vicinity of Tegaimiao and Hangjinqi, Neimeng Autonomous Region. The lower part of the Tegaimiao consists of orange-red, yellowish-pink, feldspathic, coarse-grained sandstone; and the upper part is primarily of the orange-red, orange-brown, silty mudstone and light-orange-red siltstone interbeds. Vertebrate fauna includes Protoceratops sp. Thickness is not available.

The stratigraphic contact of the Zhidan Group with the underlying Jurassic strata is unconformable throughout the basin. The stratigraphic contact has yet to be defined between the Zhidan Group and the Tegaimiao Formation as well as between the Tegaimiao Formation and the overlying Tertiary strata.

The second member of Zhidan Group generally is disconformable with the underlying Middle Jurassic Anding Formation. The sixth member of the Zhidan is generally disconformable with the overlying Tertiary strata but conformable with the underlying strata. The seventh member of the Zhidan is unconformable with the overlying Tertiary Pliocene sedimentary strata in the northern part of the basin.

TECTONICS AND EVOLUTION OF THE ORDOS BASIN

The Ordos basin developed in the west-central part of the Sino-Korean platform in North China. This platform formed during the Zhontiaoshan (Chungtiaoian) orogeny about 1,950 m.y. B.P. (Huang and others, 1980, p. 33 to 35) (table 2), an orogeny formerly called the Luliang Movement. The platform is bounded on the south by the North Qin ling (Tsinling) fold system, on the southwest by the Qilian (Nanshan) fold system, on the west by the Alaskan stable block, on the north by the Neimeng-Daxinganling (Inner Mongolian Great Khingan) fold system and the Ji-Hei (Kirin-Heilungkiang) fold system, and on the east by the Yangzi (Yangtze) platform (Huang and others, 1980, p. 29-66). The basement rocks of the Sino-Korean platform consist of pre-Sinian metamorphic rocks, overlain by the Sinian, Cambrian, and Early and Middle Ordovician sedimentary covers, subsequently intruded by igneous rocks (Huang and others, 1980, p. 33 to 35).

From Late Cambrian to the end of Silurian, the Ordos basin emerged as a landmass during the Caledonian Movement. Throughout the basin, the Late Ordovician to Early Carboniferous sedimentary strata are missing, but the marginal troughs on the west and the southwest margins of the Ordos locally contain transitional lithofacies indicating an Early and Late Paleozoic age.

In the period from Early Carboniferous to Permian, the Sino-Korean platform was a relatively stable yet slowly subsiding landmass because of the development of marginal tectonic systems during the Variscan orogeny. As the process of mountain building proceeded, a favorable depositional environment was formed for the accumulation of the richest Late Carboniferous and Early Permian coal deposits in North China. Meanwhile, the initial depositional framework of the Ordos basin was taking shape with the development of the north-south fold systems of Helan shan-Liupan shan on the west and the Alashan Uplift to the northwest.

When the Permian sea retreated from the southern and southwestern parts of Ordos basin, the basin was a relatively emergent landmass. At the end of the Heshanggou Formation in latest Early Triassic time, the first phase of the Indosinian orogeny occurred extensively throughout China. This movement rejuvenated the folding of the Qin ling geosyncline to the south. Subsequently, during late Middle Triassic and early Late Triassic, a second phase of the Indosinian orogeny occurred and was followed by the final Indosinian movement during the end of Late Triassic and the beginning of Early Jurassic (Huang and others, 1980, p. 26). Although the Ordos basin was a relatively low land, it encountered intensive denudation. The depositional framework of Ordos basin, however, had been developed into a closed basin type during the Taihang-Wuling-Xuefengshan uplift to the east in Late Triassic (Han and Yang, 1980, p. 241).

As the Ordos basin continued to subside it received fluvial sediments from the north in Late Triassic. The Jurassic coal-bearing sedimentary rocks disconformably overlie the erosion surface on the Late Triassic sedimentary rocks. During the Yanshanian (Yenshanian) movement from Late Early Jurassic to early Late Cretaceous, the Ordos was affected by active tectonic movements. Especially in the period from the end of Late Jurassic to the beginning of Early Cretaceous, the Ordos was tilted westerly and synkinematically was overthrust northeasterly along the western border. In the basin, the sedimentary rocks were folded into a north-northeasterly trending asymmetrical, broad synclinorium in which the western limb is much steeper than the eastern limb. The synclinal axis is in the west of the basin center along a line from Tianchi to Huanxian. The dip of the coal-bearing strata near the eastern basin margin ranges from 5° to 10°, whereas in the basin center, the angles are generally about 1°. Faults with relatively small amounts of displacement are scattered throughout the basin (Han and Yang, 1980, p. 279).

During the Tertiary Himalayan orogeny, the Ordos basin was affected further by active tectonic movements accompanied by a distinct northeast-southwest graben fault system along the sides of Weihe in the southern part of the basin and a north-south trending recumbent overthrust fault system with reactivation of the Yanshanian overthrusts along the western basin border, as well as by extensive basaltic eruptions to the northeast of the basin (figs. 3 and 4).

COAL DEPOSITS

General statement

The coal deposits in the Ordos basin occur chiefly in the Late Carboniferous and Early Permian and the Late Triassic and Early to Middle Jurassic rocks. The coal deposits of the Late Carboniferous and Early Permian occur south of the Ulangar upland in the northern part of the basin at depths in excess of 2,000 m (Zhang, 1982, p. 313) (fig. 4). According to Wood and others (1983), coal from such burial depths is not suitable for mining, but it has been found to have a high potential for natural gas resources (Wang and others, 1983, p. 339). Near the Ordos basin border in the Yinchuan area, extensive mining of Late Paleozoic coal beds has continued; mining activity also occurs in the Jungarqi area in the northeastern part of the basin and in the Hancheng area north of the Wei He in the south part of the basin. This report provides general geologic background on the coal deposits. The Mesozoic mineable coal beds are confined generally to the top part of the Late Triassic and Middle Jurassic sedimentary strata. The Mesozoic stratigraphic nomenclature of the basin varies somewhat in the definitions of individual formations due to detailed studies in the basin during the past several decades; however, the stratigraphic nomenclature of the coal-bearing Late Triassic sedimentary sequences is herein defined after descriptions by Han and Yang (1980, p. 267-272). The stratigraphy of the Early to Middle Jurassic coal-bearing formations is discussed generally in accordance with the nomenclature given by Han and Yang (1980, p. 275-285) and by the Department of Coal Teaching and Researches, Wuhan College of Geology (1980, p. 115-121). Table 1 shows the correlation and nomenclature used in this report.

Triassic Coal Deposits

General statement

The Triassic coal deposits, designated as the Yanchang Group by Han and Yang (1980, p. 267) (table 1), occur in the Late Triassic sedimentary sequences of the Ordos basin. This group is divided, in ascending order, into the Tongchuan, Hujiacun, Yongping, and Wayaobao Formations (Han and Yang, 1980, p. 267) (table 1). Based on lithologic and palaeontologic criteria, the Institute of Geology (Chinese Academy of Geological Sciences, 1980, p. 22-27) has redefined the Tongchuan to be of upper Middle Triassic age and the Yanchang into formation status and has subdivided it into lower, middle, and upper members (table 1). The lower member is probably correlated with the Hujiacun Formation, the middle with the Yongping Formation, and the upper with the Wayaobao Formation (table 1).

Tongchuan Formation

The Tongchuan Formation is distributed extensively throughout the basin but is absent north of Fugu in the northern part of the basin. This formation consists of a lower member of fluvial deposits of feldspathic sandstone intercalated with sandy mudstone and siltstone, and an upper member of lacustrine deposits of sandy mudstone and mudstone containing 1 to 3 m of thick oil shale and black mudstone near the top. Locally the oil shale attains a thickness of more than 30 m. Thin coal beds are present in both the lower and upper members in the northern and southwestern parts of the basin. The thickness of the Tongchuan ranges from 100 to 447 m, as given by Han and Yang (1980, p. 267) (table 1).

Hujiacun Formation

The Hujiacun Formation is widely distributed in the basin, but it is locally absent in the southwestern part of the basin due to erosion. This formation consists chiefly of fluvial and lacustrine deposits of interlayers of mudstone and siltstone (fig. 5). Several thin coal beds are exposed in the southern part of the basin. The formation is from 172 to 383 m thick.

Yongping Formation

The Yongping Formation is widespread throughout the basin but is missing in the southern and southwestern parts of the basin due to erosion. It consists of fluvial deposits of sandstone intercalated with siltstone, mudstone, and thin coal. The thickness of the Yongping ranges from 95 to 183 m.

Wayaobao Formation

The Wayaobao is the principal Late Triassic coal-bearing formation. Outcrops of this formation are confined to the region from Wudinghe on the north to Tougchuan on the south and Ansai on the west to Yongping on the east. Han and Yang (1980, p. 268-269) divided this formation into lower, middle, and upper members (fig. 6). This formation ranges in thickness from 90 to 410 m.

The lower member of the Wayaobao Formation consists of gray to grayish-black, medium- to fine-grained sandstone intercalated with mudstone and silty mudstone which contain pyrite-rich concretions, plant fossils, and mineable coal beds (fig. 6). The thin coal beds range from several centimeters to about 20 centimeters in thickness. This member ranges from 120 to 160 m thick (Han and Yang, 1980; p. 268).

The middle member of the Wayaobao Formation consists of interlayers of gray, medium- to fine-grained sandstone, siltstone, and dark gray to gray sandy mudstone and mudstone. Its thickness ranges from 90 to 120 m. This member contains about 20 thin coal beds with coal traces. The thickness of the coal varies from 2 to 25 cm, and locally is more than 1.7 m thick. The No. 3 coal zone of the Wayaobao can be mined locally (fig. 6).

The upper member is the principal coal-bearing member of the Wayaobao Formation and consists of interlayers of black mudstone, grayish-black siltstone, and fine-grained sandstone. In the upper part of the member is a sequence of oil shale 4 to 14 m thick, with grayish-white clay layers and more than 20 coal beds and coal traces, of which the No. 1 coal zone can be mined commercially (fig. 6). The maximum thickness of this member is 130 m.

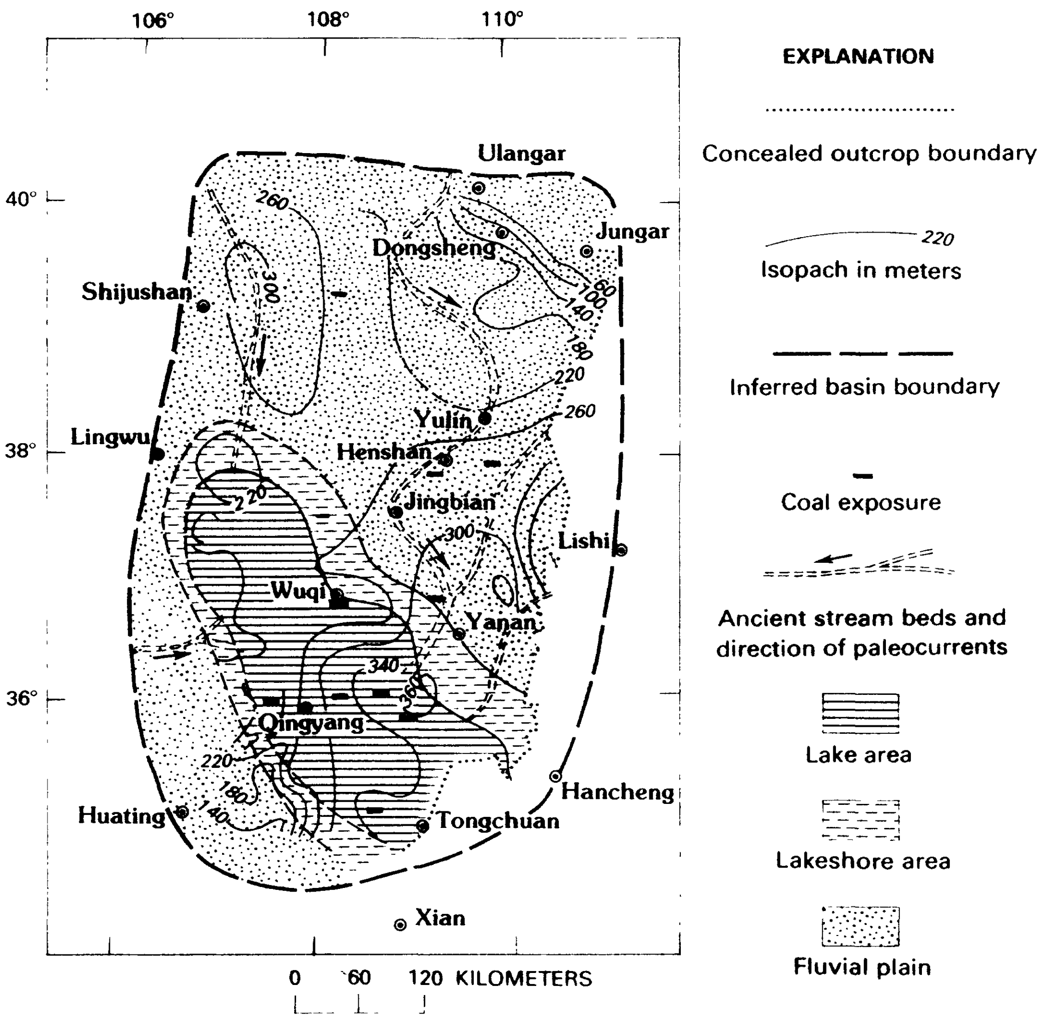


Figure 5. Depositional environments of the Late Triassic Hujiacun Formation in the Shcanganning (Ordos) basin (after Han and Yang, 1980; Figure 5-24, P. 269).

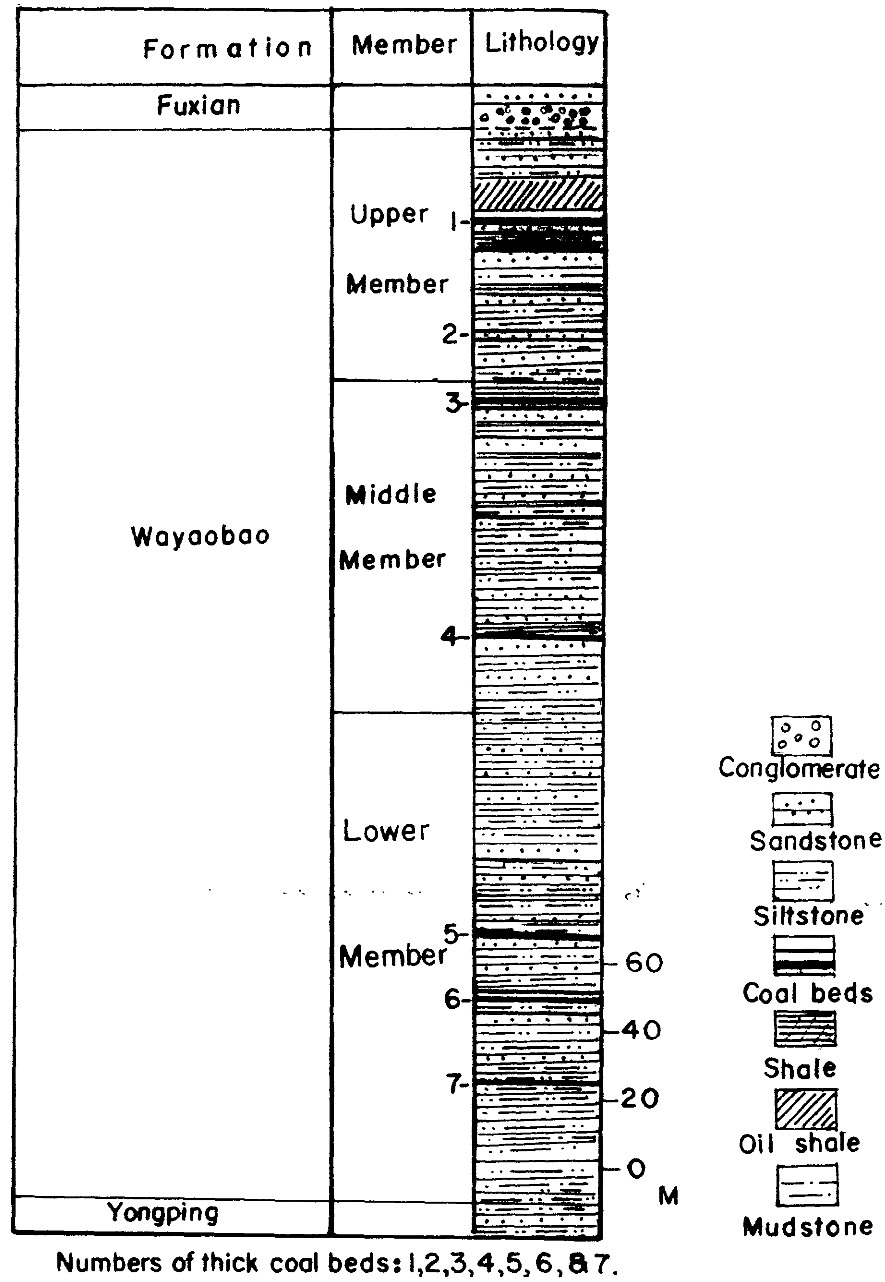


Figure 6. Stratigraphic columnar section of the Late Triassic Wayaobao Formation in the Yanan-Zichang area of the Shaanganning (Ordos) basin (modified after Han Yang, 1980; Figure 5-23, p. 269).

The Wayaobao Formation generally contains seven coal zones, which are made up of more than 50 beds most of which can not be mined commercially. The No. 1 coal zone has an average thickness of 1.5 m, and the structure of the coal zone has been complicated by intercalating with 5 to 9 layers of rock partings. The No. 2 coal zone is generally less than 0.2 m thick and can be mined only locally. The No. 3 coal zone has a maximum thickness of 1.73 m, which contains 0 to 5 layers of rock partings; the mineable coal is generally low in sulfur and ash.

Depositional Framework

The Late Triassic coal-bearing sedimentary rocks of the Ordos basin were deposited in fluvial and lacustrine environments associated with active diastrophism (Han and Yang, 1980, p. 268-272) (table 1). During the period from Tongchuan to Yongping times, the depositional center of the basin was situated in the southwestern part of the basin, probably under arid to semi-arid climatic conditions. The early stage of Tongchuan sedimentation is indicated by a relatively smaller lake area than that of the later depositional stage of Tongchuan time, during which extensive lacustrine and deltaic deposits occurred throughout the basin. Later, during Hujiacun time, the lake area decreased about one-third. This depositional stage is characterized by the presence of peat deposits and scattered coal beds up to several centimeters thick, and coal traces in the lake, lake margin, and associated fluvial plain. Coal beds from individual drilling cores of this formation amount totally to 3 m in thickness. During Yongping time, the lake area became considerably smaller than during the preceding time and was confined to the area from Wuqi on the north via Huachi to Qingyang on the south.

From Tongchuan to Yongping times, the influxes of fluvial detritus were transported by the ancestral Helaigou and Liugou streams from the north. These streams played major roles during the deposition of the Wayaobao Formation in the late stage of Late Triassic time. In the northern part of the Ordos basin, the fluvial plain deposits of sandstone were widely distributed and graded southward into the fluvial deltaic and lacustrine deposits in the southern part of the basin.

During the deposition of the Wayaobao Formation, the depositional center of the Ordos basin generally shifted toward the southern and central parts of the basin. The lithofacies of the lower member of the Wayaobao is chiefly of fluvial plain and nearshore lacustrine deposits of sandstone, siltstone-sandstone, sandstone-siltstone, mudstone-sandstone, siltstone-mudstone-sandstone, sandstone-mudstone, and siltstone-mudstone. The lacustrine deposits of this member are confined to the southern part of the basin. Data from drilling cores show 96 percent sandstone at Qinshen 1, 50 percent each, sandstone and conglomerate, at Hongjiannao, 94 percent sandstone at Wuyu 2, and 85 percent sandstone at Dao 2 in the northern part of the basin.

The middle and upper members of the Wayaobao consist chiefly of lacustrine lithofacies of mudstone, siltstone, fine-grained sandstone, and coal. The coal thickness generally trends in parallel alignment with the areas of siltstone and mudstone. The sandstone and siltstone of the units are lenticular, cross-laminated, ripple bedded, and contain plant remains. These sediments were deposited in lakes, lake margin deltas, and in overbank floodplain environments.

A finely laminated oil-shale bed, 4 to 15 m thick, commonly occurs in the upper member of the Wayaobao Formation and contains disseminated or banded pyrite and fossils. This shale was deposited in a deep lake-water environment.

Jurassic Coal Deposits

General Statement

The Jurassic coal deposits are represented by the Early and Middle Jurassic coal-bearing formations in the Ordos basin, which consist of the Early Jurassic Fuxian Formation and the Middle Jurassic Yanan, Zhilao, and Anding Formations (Institute of Geology, Chinese Academy of Geological Sciences, 1980; p. 30-38) (table 1)(figs. 7 and 8). However, Han and Yang (1980, p. 279) report the Yanan Formation to be Early to Middle Jurassic in age.

Fuxian Formation

The Fuxian sedimentary rocks were deposited on an erosion surface of Upper Triassic rocks in the southern and northeastern parts of the Ordos basin. This formation consists of fluvial sandstone and lacustrine siltstone and mudstone containing thin coal and oil shale (fig. 8). The thickness of the Fuxian ranges from 15 to 140 m.

Yanan Formation

The Yanan Formation is the principal coal-bearing formation in the Ordos basin. Han and Yang (1980, p. 279-280) subdivided this formation, in ascending order, into four members except in the southwestern part of the basin where the Yanan is divided into three members. Tentatively, the first member of the Yanan is equivalent to the Baotashan sandstone member, and the second through the fourth members are probably equivalent to the Zaoyuan member (table 1). The thickness of the Yanan ranges from 150 to 296 m (fig. 9).

The first member of the Yanan consists of the lower fluvial Baotashan sandstone and an upper lacustrine mudstone and siltstone intercalated with thin sandstone, which contains 1 to 3 mineable coal beds and 2 to 3 layers of oil shale. The Baotashan sandstone belt extends about 200 km from east to west and is about 100 km wide in the eastern part of the basin. The coal beds in the upper part of this member are well developed at Shenmu and Dingbian.

The second member of the Yanan is made up of fine detritus intercalated with 4 mineable coal zones. Generally coal beds are poorly developed to the east of the basin center.

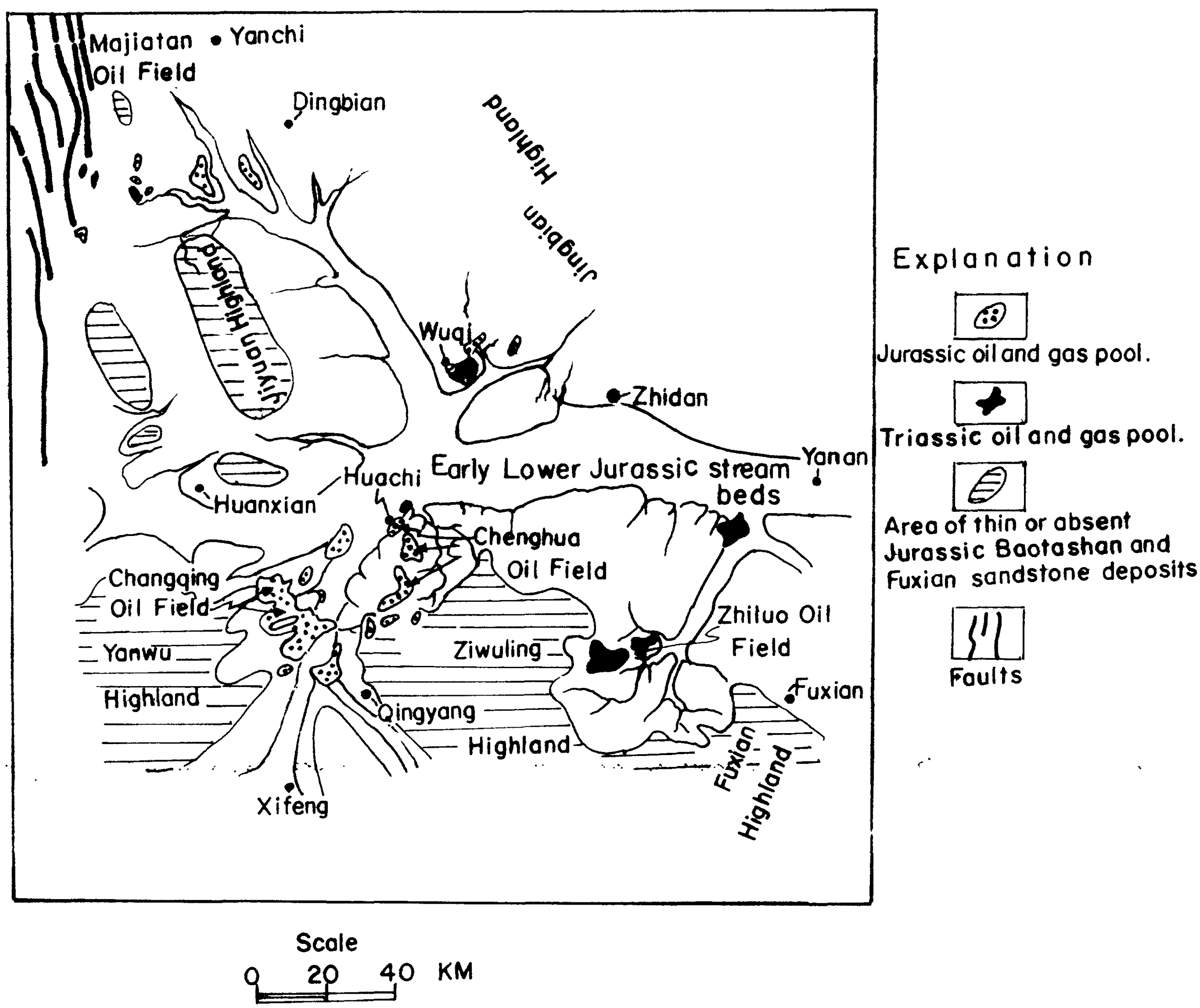


Figure 7. Paleogeomorphic features of the post-Indosinian movement and principal petroliferous areas in the Shaanganning (Ordos) basin (modified after Huang and others, 1981; Figure 2, p. 5).

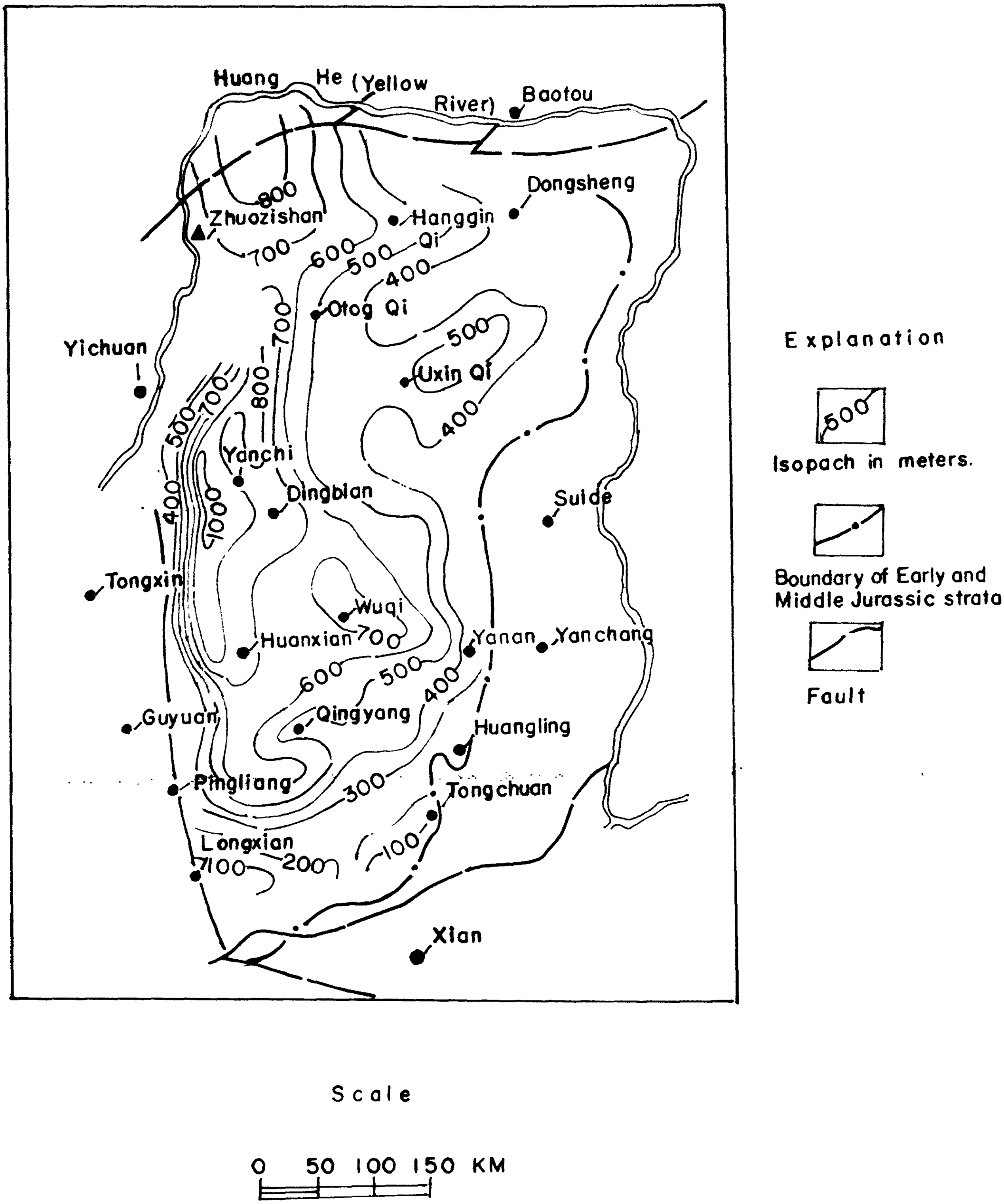


Figure 8. Isopachs of the Early and Middle Jurassic strata in the Shaanganning (Ordos) basin (modified after Department of Coal Teaching and Researches, Wuhan College of Geology, 1980; Figure III - 101, p. 117).

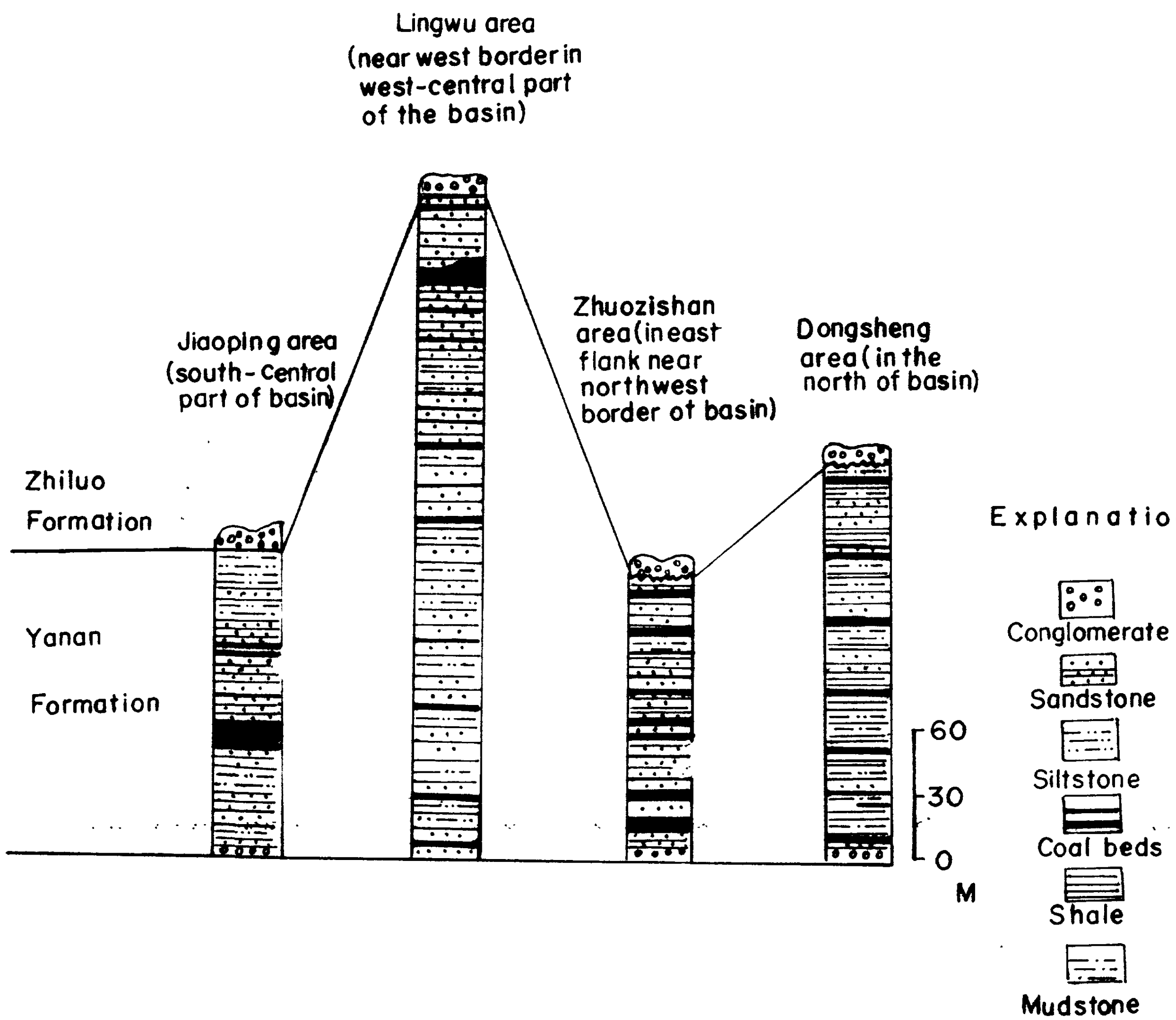


Figure 9. Stratigraphic columnar sections of the Early to Middle Jurassic Yanan Formation in the Shaanganning (Ordos) basin (after Han and Yang, 1980; Figure 5-33, p. 279; and Department of Coal Teaching and Researches, Wuhan College of Geology, 1980; Figure III - 106, p. 121).

The third member of the Yanan consists of a lower lacustrine gypsum-bearing siltstone and an upper mudstone and siltstone intercalated with carbonaceous mudstone and devoid of coal beds in the eastern part of the basin. In the area of Lingwu, Yanchi, and Dingbian in the western part of the basin and the Shengmu-Dongsheng area in the northeastern part of the basin, the fluvial sandstone contains the thick mineable coal zones. Deep-water lacustrine facies of oil shale, sandy limestone, sandy mudstone, mudstone, and thin coal occur in the area of Yulin, Hengshan and Tiebeancheng.

The fourth member of the Yanan is made up of lacustrine and lake-margin facies of mudstone, siltstone, and fine-grained, feldspathic sandstone. This member contains a thick mineable coal zone in which one coal bed is mined south of Chenmu and in the vicinity of Dingbian.

In the southwestern part of the basin, the base of the Yanan Formation commonly consists of a residual ferruginous and alumina-bearing mudstone and is locally conglomerate. The upper part of this formation is incomplete due to erosion. In this region, the Yanan consists of three members. The lower member is represented by the Baotashan sandstone generally 25 m thick but ranging from 0 to 116 m, with some thin coal beds. The middle member, the so-called Xiaojie member, consists of conglomeratic sandstone and sandstone with interlayers of siltstone and medium- to fine-grained sandstone, which contain two coal zones that are locally mineable. The middle member is generally 40 to 50 m thick but ranges from 6 to 135 m. The upper member is made up of sandstone intercalated with siltstone and mudstone and coal traces. Generally the upper member is 30 to 40 m thick but ranges from 4 to 90 m. Lacustrine facies of the upper member occur in the vicinity of Diantou. The thickest deposits of the Yanan in this region are located in the Huating area where three mineable coal beds occur in a sedimentary sequence of a thickness of 150 to 296 m. In the east at Jiaoping, the distribution of rich coal zones is shown in figure 9.

Thick coal beds of the Yanan also occur in the northern part of the Ordos basin. Mineable coal beds of from 6 to 7 beds to more than 10 beds exist, and the total thickness of the coal beds amounts to about 20 m (fig. 9).

Good quality coal of the Yanan also occurs in the western part of the Ordos where the total thickness of the coal beds ranges from 10 to about 20 m (fig. 9).

Zhiluo Formation

The Zhiluo Formation consists chiefly of fluvial sandstone and, locally, of lacustrine silty mudstone. This formation contains scattered coal beds which are generally not mineable. However, portions of the Zhiluo are mined locally in the northwestern part of the basin in the Neimeng Autonomous Region (table 1).

Anding Formation

The Anding Formation consists of inland lacustrine deposits of mudstone and marl in the eastern part of the basin and mudstone or oil shale intercalated with dolomitic marl and calcareous marl in the area from Huangling to Fuxian in the southern part of the basin. Coal deposits are not reported (table 1).

Depositional Framework

The Early and Middle Jurassic coal-bearing sedimentary rocks of the Ordos basin were deposited in a post-Triassic, eroded, land-form environment (fig. 7). During the early depositional stage of the Fuxian Formation, the southerly flowing drainage systems in the northern part of the basin and the easterly flowing streams in the south-central part of the basin played major roles in the extensive deposition of continental sedimentary rocks throughout the basin (fig. 7). The Ordos was covered by a flood plain in the north and by shallow lakes in the central and southern parts of the basin. Because of active diastrophic movements and the western margin faulting from Pingliang to Yinchuan, the lake areas expanded and formed a large inland lake during Yanan time under rather humid climatic conditions. This basin received a considerable amount of detritus from adjacent highlands, particularly near the western basin margin, which contains the most important coal deposits of Jurassic age (figs. 7, 8, and 9).

During the deposition of the Yanan third member, the inland lake expanded to its fullest extent. The depositional center shifted toward the south of the basin, and coal was deposited extensively throughout the basin. Thin coal beds were deposited in the area south of Suide, north of Zhiluo, and east of Wuqi in the east-central part of the basin. Thick Yanan coal beds, however, were deposited in the stream overbank and lakeside marshes and swamps. The mineable Yanan coal deposits were clearly confined to the following areas. In the area from Yulin and Shenmu to Zhungeer and Dongsheng in the northern part of the basin, nine mineable coal beds were deposited along the sides of ancient stream beds (fig. 7). Some single coal beds are up to 8 m thick. In the areas of Lingwu, Yanchi, Dingbian, and Maling, Chenghao and Jiyuan of Qingyang, as well as Tianshuibao of Huanxian in the western part of the basin, the Yanan coal is a better quality coal and usually has eight mineable coal beds. In the areas from Diantou of Huangling, Jiaoping and Yishicun of Yijun westward to Zhaojin of Xunyi, Binxian, Linyou, and Longxian, and then northwestward to Ankou and Huating of Gansu Province in the southern part of the basin, the Yanan coal deposits are also well developed. Here the so-called Yishicun Coal Series contains one to three mineable coal beds, and locally as many as eight. The thickest coal bed at Yishicun is, however, up to more than 30 m thick. In the strip mining areas at Jiaoping, the coal beds are totally more than 20 m thick. The coal beds in both the Jiaoping and Yishicun areas are lenticular.

During Zhiluo and Anding times, the paleoclimate gradually changed from moist to semi-arid and arid conditions, as indicated by the presence of late Middle Jurassic black mudstone, dolomitic marl, and variegated mudstone. This climatic change caused the coal accumulation to decrease in magnitude throughout the Ordos basin.

Cretaceous Coal Deposits

Thin coal beds and coal traces occur in the seventh member of the Cretaceous Zhidan Group along the banks of the Huanghe (Yellow River) in the northeastern part of the Ordos basin, Neimeng Autonomous Region (table 1).

Carboniferous and Permian Coal Deposits

General Statement

The Carboniferous and Permian coal deposits of the Ordos basin are represented by the Late Carboniferous Taiyuan Formation and the Early Permian Shanxi Formation (table 4) (Han and Yang, 1980, figs. 4-9, p. 104-105) (fig. 10). The Taiyuan and Shanxi coal beds are reported to be mined in the area between the city of Hancheng on the north and the Wei He River on the south near the southern basin border, and also in the vicinity of Jungarqi along the southern flank of the Ulangar upland near the northern basin border (Han and Yang, 1980, p. 101-125). Generally these coal beds are buried at depths in excess of 2,000 m elsewhere throughout the basin (Zhang, 1982, p. 313).

Taiyuan Formation

The Taiyuan Formation of the Ordos basin consists chiefly of brown fine- to medium-grained sandstone, siltstone, gray to carbonaceous shale and mudstone intercalated with gray limestone, coal beds, and fire-clay and siderite layers. These sedimentary rocks were deposited in shallow-sea shoreline, swamp-marsh, deltaic, and fluvial environments. In the Hancheng area, the Taiyuan coal beds are from 0.5 to 4 m thick, but in the vicinity of Jungarqi, they reach a thickness of more than 9 m (Han and Yang, 1980, figs. 4-9, p. 105) (fig. 10). The thickness of the Taiyuan is about 60 m in the Hancheng area and about 65 m in the Jungarqi vicinity (Han and Yang, 1980, figs. 4-9, p. 105).

Shanxi Formation

The Shanxi Formation conformably overlies the Taiyuan Formation, and the flourishing stage of the coal accumulation proceeded into the Early Permian. This formation is made up of light-gray and brown fine- to coarse-grained sandstone, siltstone, grayish-green and blackish-gray shale interclated with thick coal beds, fire-clay layers, and siderite concertions. These detrital sedimentary rocks were deposited chiefly in fluvial, overbank, lacustrine, marsh, and swamp environments and locally with lagoonal and nearshore deltaic facies present. Thickness of the Shanxi coal beds amounts to more than 7 m in the Hancheng area and about 7 m in the Jungarqi vicinity (fig. 10) (Han and Yang, 1980, figs. 4-9, p. 105). This formation is about 120 m thick in the Hancheng area and about 95 m in the vicinity of Jungarqi (Han and Yang, 1980, figs. 4-9, p. 105).

Table 4.--Permian and Carboniferous stratigraphy of the Ordos basin (modified after Department of Coal Teaching and Researches, Wuhan College of Geology, 1981, v. 2, Table III-8, p. 49; Han and Yang, 1980, v. 2, p. 101-152).

System	Series	Formation	Remarks
Permian	Late Permian	Shiqianfeng	Continental red beds
		Upper Shihezi	Chiefly continental lithofacies. Regression continued toward south and southeast in Late Permian; fluvial, lake, swamp, and marsh in north; and fluvial-shoreline, lagoonal, and shallow sea in south.
	Early Permian	Lower Shihezi	
		Shanxi	Sea regression. Shoreline, lagoonal, deltaic, fluvial, lake, swamp, and marsh environments.
Carboniferous	Late Carboniferous	Taiyuan	Sea regression and then transgression. Shoreline, lagoonal, deltaic, fluvial, lake, swamp, and marsh environments.
		Benxi	Sea transgression. Shallow sea and shoreline environments.

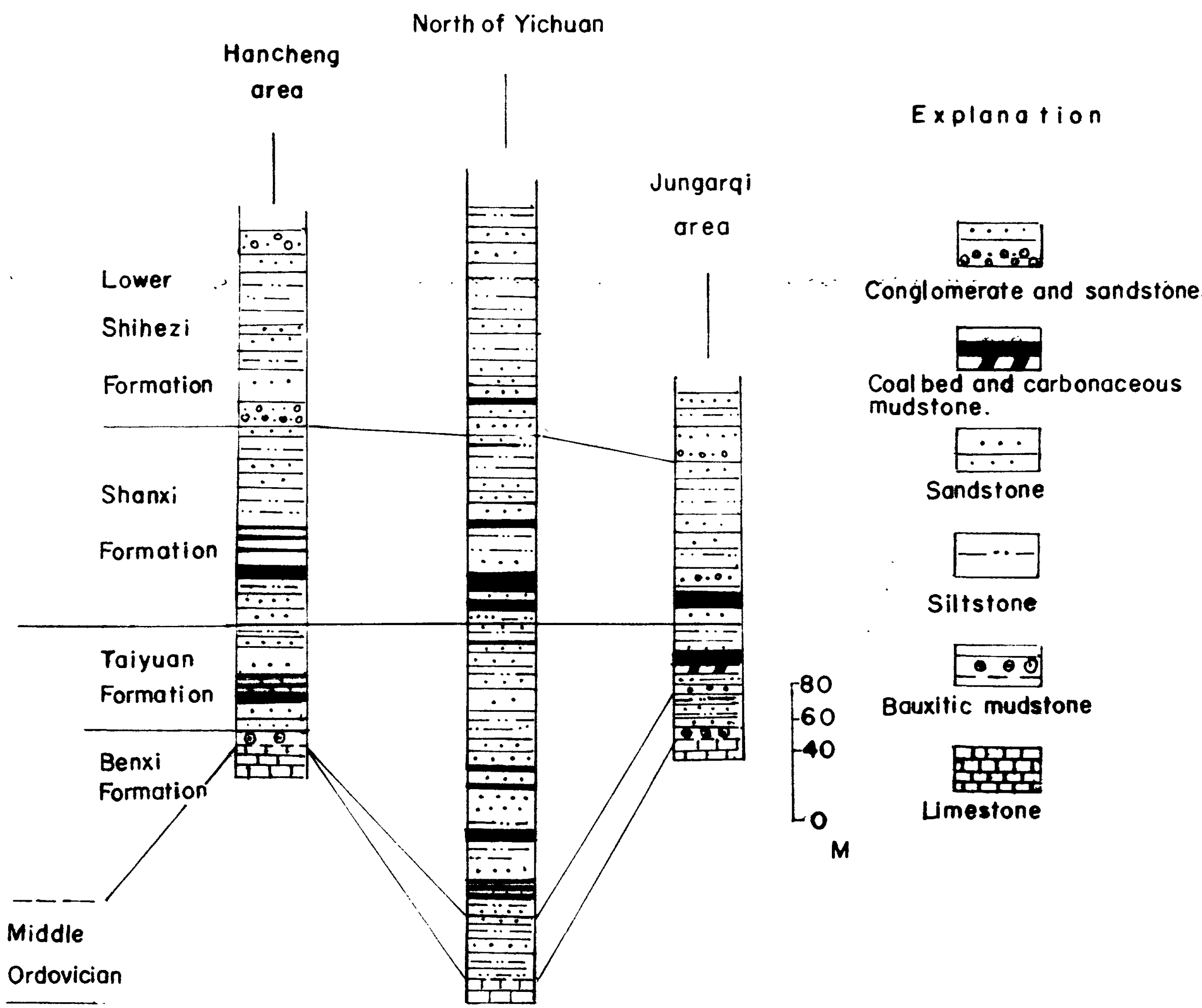


Figure 10. Stratigraphic columnar sections of the Late Carboniferous Taiyuan Formation and Early Permian Shanxi Formation in the Shaanganning (Ordos) basin (modified after Han and Yang, 1980; Figure 4-9, p. 105).

Depositional Framework

During deposition of the Early Late Carboniferous sedimentary rocks, the Ordos basin was covered by platform carbonate rock sequences of the Upper Proterozoic to Middle Ordovician ages (Institute of Geology, Academia Sinica, 1956; table 40, p. 175-187). The basin was bounded on the north by the Precambrian Yin Shan highland, on the south by the Precambrian Qinling-Zhongtiaoshan, on the west by the Helanshan trough, and on the east by lowland areas. At the incursion of the Benxi sea from the east, most of the eastern part of Ordos basin became a swamp and marsh; the incursion of the Qi Lan sea from the southwest caused the western part of the basin to become a shallow sea. The northern part of the basin, however, was in the flood plain and became a deltaic and coastal-plain environment. The central part of the basin was then an upland with a thin Late Paleozoic sedimentary cover (fig. 11). Subsequently, the sea water withdrew from the Ordos during the deposition of the late Taiyuan and Shanxi coal-bearing sedimentary sequences. During this time, the accumulation of coal flourished in fluvial, deltaic, lagoonal, lacustrine, and shoreline deposition environments. From about late Upper Shihezi to the Shiqianfeng, Ordos basin gradually changed into a continental depositional environment (table 4).

Potential

The high quality bituminous coals of the Carboniferous, Permian, Triassic, and Jurassic ages, which are concentrated in most of the Ordos basin, possess the greatest potential for coal resources in the North China region. The Triassic and Jurassic coal beds have been extensively mined in the central and south-central parts of the basin. Because of the deep overburden, most of the Carboniferous and Permian coals are not suitable for mining; however, they are mined locally in the Hancheng, Jungarqi, and Zhuozishan areas near the basin borders (fig. 4). In the northern part of Ordos basin, the Carboniferous Taiyuan and Permian Shanxi beds consist of high-volatile to low-volatile bituminous coal. Outside the basin in the Yichun area, medium volatile bituminous to metamorphic coals are mined (Sun and others, 1983). Nevertheless these Late Paleozoic coal beds have the greatest potential for generating natural gas resources (Liu, 1985; Sun and others, 1983; Zhang, 1982; Zhang and Wu, 1985).

PETROLEUM DEPOSITS

General Statement

Petroleum deposits in the Ordos basin have been studied in detail during the past 20 years. The source rocks evolved from the large inland fresh-water lakes which contained flourishing organisms during the Triassic Yanchang time and the Jurassic Yanan time. Note, however, that information on the location, size, and production of individual oil and gas fields throughout the basin is not available.

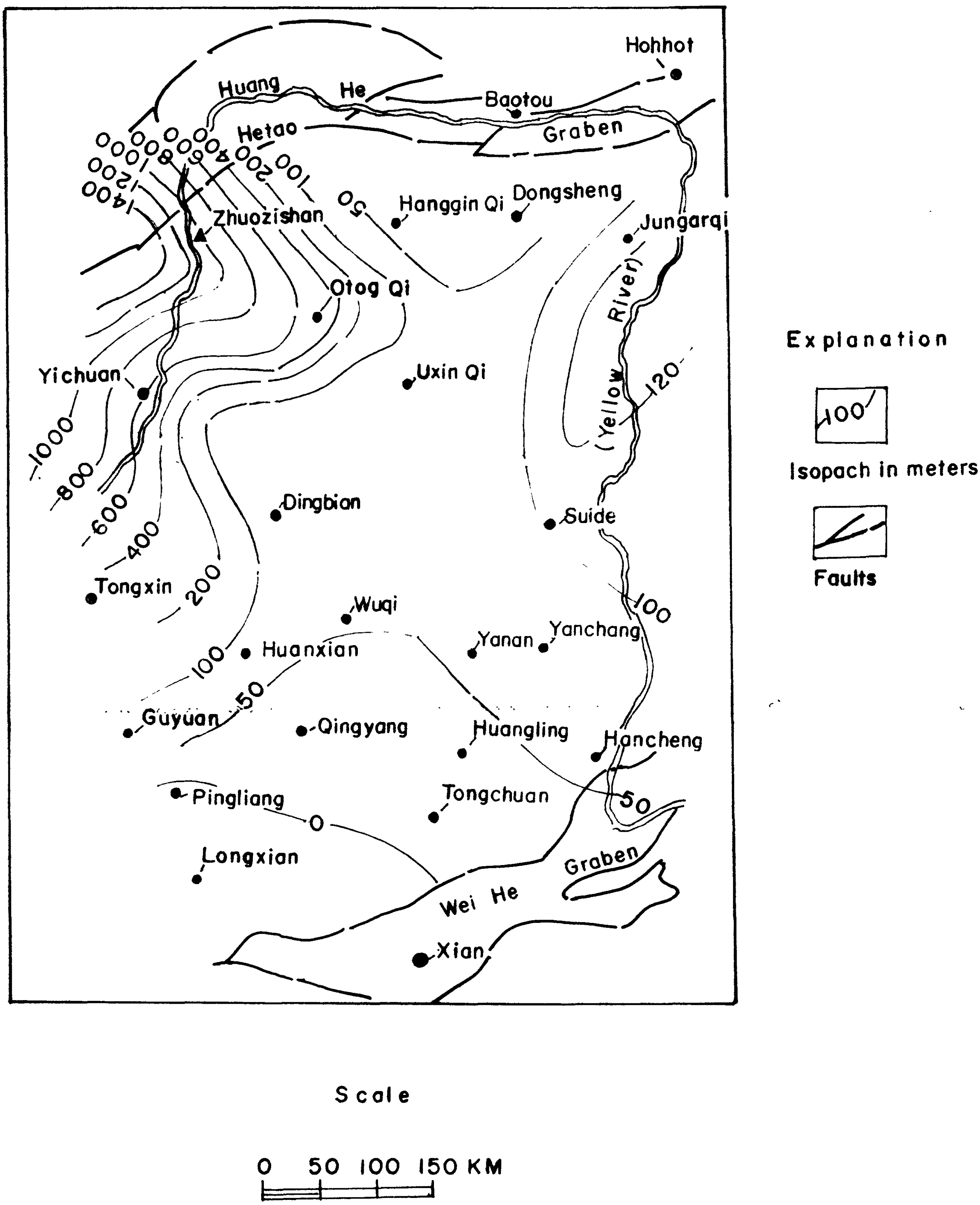


Figure 11. Isopachs of the Late Carboniferous sedimentary sequences in the Shaanganning (Ordos) basin (modified after Wang and others, 1983; Figure 4-9-41, p. 280, and Figure 4-9-45, p. 283).

Through time, due to detailed paleontological studies, the Mesozoic stratigraphic nomenclature regarding the definition of individual formations of the Ordos has been changed considerably. The stratigraphic nomenclature of the Late Triassic and Early to Middle Jurassic oil- and gas-bearing formations is tentatively adopted from Huang, Wang, and Shih (1981, p. 1-3) (table 1). Stratigraphic correlation is approximated on table 1.

Stratigraphy

In the literature of petroleum geology, the name Yanchang Group has been used and subdivided into five members to represent the Late Triassic oil- and gas-bearing stratigraphic units (table 1). The first and second members of the petroleum geologists' Yanchang are probably correlated with the Tongchuan Formation, and the third, fourth, and fifth members are tentatively correlated with the Yanchang Formation (table 1).

The petroleum deposits of the Ordos basin occur in the Late Triassic Yanchang Group and in the Jurassic Fuxian, Yanan, and Zhiluo Formations (Huang, Wang, and Shih, 1981, p. 1-10) (table 1). The distribution of oil and gas deposits is controlled by the paleogeomorphic features and the lithologic and structural characteristics of the country reservoir rocks.

The Yanchang Group is about 1,300 m thick and consists of sedimentary sequences of a lower fluvial coarse sandstone, a middle lacustrine and deltaic unit, and an upper lacustrine Wayaobao coal series.

The Fuxian Formation is 120 to 150 m thick and consists of fluvial deposits of conglomerate, sandstone, and sandy mudstone, which filled the erosion surface on the Yanchang. Later, the Fuxian was covered by the Yanan fluvial deposits of sandstone, siltstone and mudstone. Locally, the Yanan sedimentary rocks disconformably overlie the Fuxian and reach a thickness of 120 m in the buried foothills and about 410 m in the buried valleys (Huang and others, 1981, p. 2). The basal Yanan fluvial Baotashan sandstone is distributed extensively along the sides of an ancient easterly flowing drainage system in the central part of the Ordos and generally thins in the direction of the adjacent ancient highlands. The middle and upper Yanan sedimentary sequences consist of lacustrine coal-bearing rocks, which indicates a climate change from humid to semi-arid. During the deposition of the Zhiluo and Anding Formations, the fluvial and lacustrine deposits reached a thickness of 400 m of varicolored sedimentary rocks, suggesting a rather arid climatic condition.

Source Rocks

The potential source rocks in Ordos basin are confined to the Upper Proterozoic to Middle Ordovician marine carbonate rock sedimentary sequences; the Late Carboniferous and Early Permian shallow sea, shoreline, and lagoonal deposits of limestone, shale, and mudstone; and the Late Triassic and Early to Middle Jurassic continental deep-lake deposits of grayish-green and blackish carbonate shale, oil shale, and mudstone. Of these, the Late Triassic and

Early to Middle Jurasic lacustrine fine-grained detrital sediments are the principal source rocks for generating almost all the oil and gas deposits throughout the basin (table 5). Oil and gas shows from the Late Carboniferous formations, however, are widely indicated by test wells in the northern, western, and eastern parts of the Ordos (Wang and others, 1983, p. 284). The thickness of Late Carboniferous source rocks averages about 500 m in the Yinchuan area (Sun and others, 1983, p. 111-112).

The Late Triassic source rocks are confined to the Yanchang Group (table 1), and the Early to Middle Jurassic source rocks are concentrated in the Yanan Formation (table 1). Based on organic geochemical characteristics of source rocks, the dark-gray, dark mudstone of the third member of the Yanchang Group belongs to the sapropelic to humic transitional type of kerogen and is considered to be favorable for generating petroleum deposits (Wang and others, 1983, p. 84) (table 5). The dark-gray, grayish-black mudstone of the Yanan Formation is the humic type of kerogen, which generally generates the least amount of hydrocarbon as compared with the Yanchang source rocks (table 5). The incipient depth of the hydrocarbon evolution from source rocks of the Yanchang Group is 1,600 m with a geothermal gradient of 58°C; and from the Yanan source rocks it is 1,415 m with a geothermal gradient of 53°C (table 5).

The Late Carboniferous source rocks are confined to the Benxi and Taiyuan Formations, and the Early Permian source rocks occur in the Shanxi Formation (table 4) (figs. 10 and 11). Sun and others (1983, p. 112) mentioned that most of the Late Carboniferous and Early Permian source rocks are the humic type kerogen with low ratios between the hydrocarbon and organic carbon; on the basis of vitrinite reflectance (R° max), most of this type of kerogen reaches a highly mature gas stage in the northern part of the Ordos, except locally in the northwestern part of the basin, the Zhuozishan mining area, where a mature oil stage has been indicated but which has limited areas of distribution.

Source-rock and Oil Correlation

The source-rock identification in Ordos basin was done by Wang and others (1980), Huang, Wang, Fan, Shang, and Cheng (1980), and Huang and Shang (1981). The genetic relationship between petroleum and source rock was established by comparative analyses of sterane and triterpane from crude oil and extracts from source rock. The distribution of the molecular level of triterpane compounds was used by Wang and others (1980) to trace the migration of oil from the source rock to reservoirs. Huang and Shang (1981) and Cheng and Zhang (1981) studied the thermal evolution of the phytone system of the continental humus kerogen with the formation of coal. The presence of Oleancones in oil well Ling-55 shows a match of biological marker-compound from continental plant remains in brown coals. As a result of other studies, the principal source rocks of the Ordos basin have been identified as being in the Triassic Yanchang Group and the Jurassic Yana Formation.

Table 5.--Organic geochemical characteristics of the source rocks in the Ordos basin (modified from Wang and others, 1983; Tables 2-3-3, p. 57; 2-4-4, p. 85, 2-4-10, p. 97; and 2-4-23, p. 121).

Group Formation and Member	Kerogen elemental Atomic ratios		Type of Kerogen	Elements (%)				Group Components (%)				Non-HC+bitumen/Total HC	Remarks
	H/C	O/C		C	H	O	O+S+N	Saturated HC	Aromatic HC	Saturated HC/Aromatic HC	Non-HC+ bitumen		
Yunan Formation	0.64	0.25	III humic	62.97	3.33	20.62	20-29	5-17	10-22	0.5-0.8	60-80	3-4.5	Dark-gray, grayish black mudstone. Relatively deep lake facies. Incipient depth of maturation is 1,415m at 53°C.
Third Member of Yanchang Group	0.79	0.14	II sapropelic -humic transition	69.65	4.60	12.29	13-20	20-40	15-25	1-1.6	40-60	1-3	Dark gray, dark mudstone, about 300-500 m thick. Deep lake facies (Song,1984 p.3-4). Incipient depth of maturation is 1,600 m at 58°C. (Huang and others, 1984, fig. 4, p. 23).

Reservoir Rocks

In the Ordos basin, potential reservoir rocks of petroleum deposits are the Cretaceous, Jurassic, Triassic, and Permian to Carboniferous sandstone and conglomeratic sandstone; and the Ordovician to Cambrian as well as the Upper Proterozoic carbonate rocks. At present, principal producing reservoir rocks are the Early to Middle Jurassic Fuxian, Yanan, and Zhiluo sandstone and the Late Triassic Yanchang sandstone (table 1) (Song, 1984; Wang and others, 1983; Petroconsultants S.A., 1978). The porosity of these sandstones averages 10 to 15 percent, and the permeability ranges from 1 to 6 md (Petroconsultants S.A., 1978). The petroleum deposits are generally trapped by faulted anticlines, stratigraphic onlapping and overlapping, or updip pinchouts (figs. 12 and 13). Nevertheless, the rich hydrocarbon deposits in the Jurassic sandstone sequences accumulated in sandstone bodies deposited as fluvial channel fills, point bars, levees, and sedimentary cover over dissected pre-Jurassic low-hill belts. Thus, the pre-Jurassic landforms were the principal factors in controlling the distribution of petroleum throughout Ordos basin (Song, 1984; Huang, Wang, and Shih, 1981).

During the Indosinian movement, Ordos basin was uplifted and rapid erosion occurred. During the Late Early Jurassic, the regional relief within the basin reached more than 300 m by the early stage of the Yanshanian movement. Subsequently, a relatively rugged erosion surface was covered by the sedimentary rocks of the Fuxian and Yanan Formations. As stated by Huang, Wang, and Shih (1981, p. 5-6), in the central part of Ordos basin, the easterly-flowing drainage system consisted of a main stream, tributaries, and gullies, which eroded the landscape into three geomorphic terrains. The first and highest terrain was the highland areas with relief of about 200 m and peaks over 300 m high. The Fuxian sandstone is absent in most of these areas. The second terrain was the foothills along the front of the highland areas, and relief was about 120 to 200 m with a rapidly decreasing slope from the highland peaks to the stream valleys. Here the Fuxian sandstone is absent or very thin, but the Yanan sandstone is commonly present because a further subsidence of the basin occurred during the early episode of the Yanshanian movement. Most of the oil fields in the Ordos are associated with relief of less than 120 m. These valleys were filled with Fuxian fluvial detritus.

During the Late Jurassic Yanshanian movement, the formation of the sandstone reservoirs within the basin, in association with favorable reservoir-rock properties, led to oil and gas migration from the Late Triassic source beds and accumulation in the Jurassic sandstone reservoir throughout the central part of Ordos basin. Generally after the deposition of the Jurassic Fuxian, Yanan, and Zhiluo dendritic sandstone bodies, the source beds of the Late Triassic sedimentary sequences were buried to an incipient depth of maturation of 1,600 m with a geothermal gradient of 58°C, resulting in the conversion of organic matter to oil and gas (Huang and others, 1984).

Potential

The Ordos basin covers about 320,000 km^2 and has a sedimentary fill of about 576,000 km^3 (Wang and others, 1983; Table 4-10-2, p. 327). During the sedimentation of the Mesozoic sedimentary sequences, the depocenter of

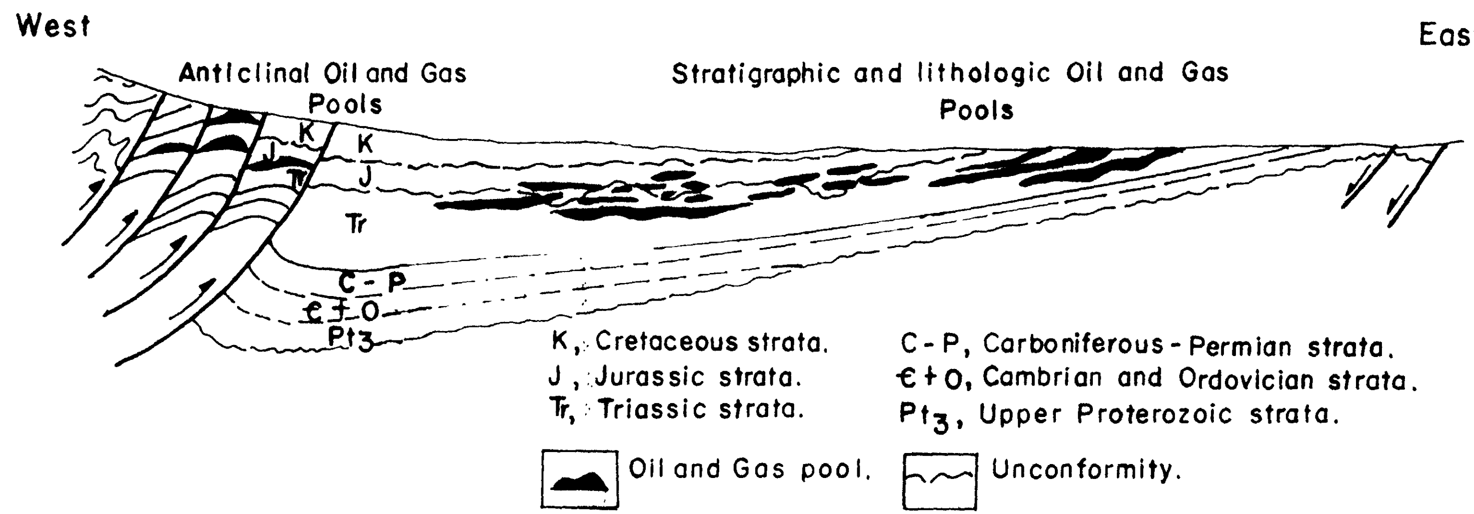
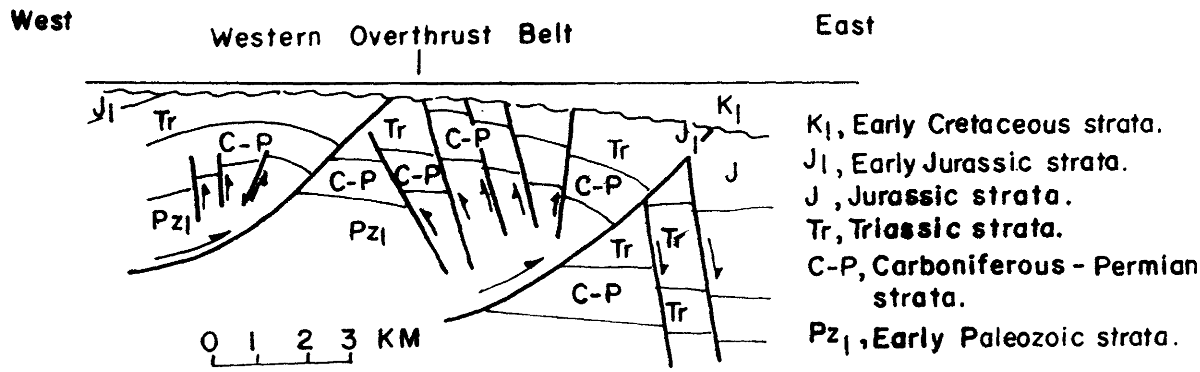
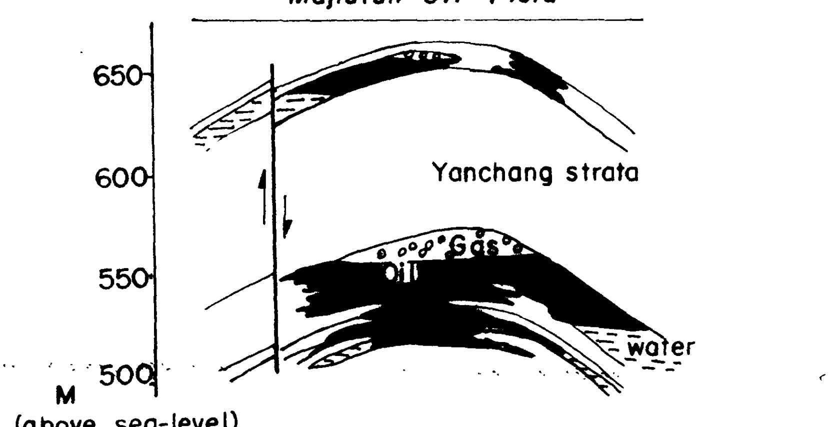


Figure 12. Schematic structural cross section showing petroleum occurrence in the Shaanganning (Ordos) basin (after Wang and others, 1983; Figure 4-10-15, p. 340).



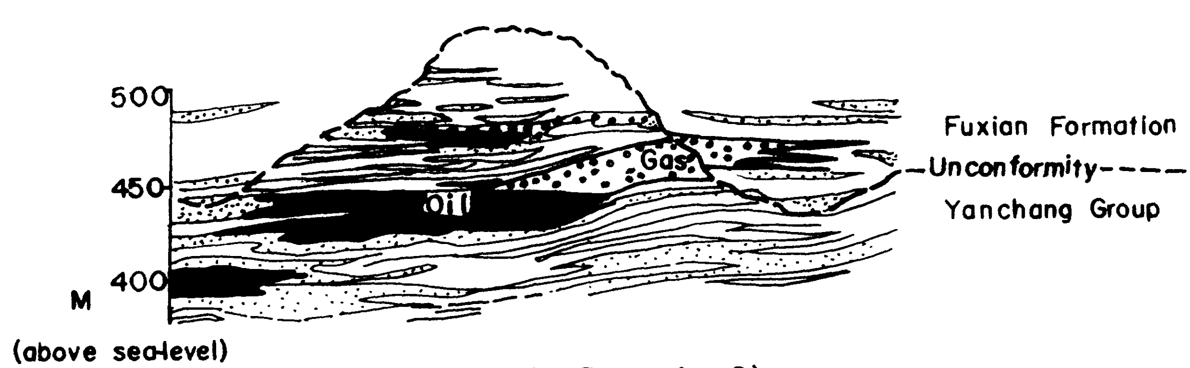
Seismic profile showing pre-Cretaceous structural features in the Western Overthrust Belt near the west-central border of the basin (after Wang and others, 1983; Figure 4-8-28, p. 234).

Majiatan Oil Field



(after Wang and others, 1983; Figure 3-7-6, p. 182).

Zhiluo Oil Field



(after Huang and others, 1981; Figure 4, p. 8).

Figure 13. Schematic cross sections showing structural features in the Western Overthrust Belt and the petroleum occurrence in the Majiatan and Zhiluo oil fields of the Shaanganning (Ordos) basin.

the Late Triassic Yanchang source rocks was located in the Huanxian-Tongchuan area in the southwestern part of the Ordos; as Jurassic time approached, the depocenter of the Jurassic Yanan source rocks shifted to the vicinity of Yanan in the south-central part of the basin. Total thickness of the Mesozoic source beds is estimated by the author to be about 1,000 m, of which the sapropelic-humic transitional type kerogen is dominant and favorable for generating petroleum deposits. The source rocks of Late Carboniferous Taiyuan and Early Permian Shanxi Formations is believed to be widely distributed within the basin (figs. 10 and 11) and favorable for generating large amounts of natural gas. There appear to be adequate quantities of rich source beds present within Ordos basin as well as outside the western basin border. For this type of basin a normal amount of recoverable petroleum is expected. As shown at the Maling oil field (Song, 1984, p. 19), output per well averages about 140 tons per day. It is expected that future new discoveries will be in the thrusting fault belt near the western basin border and along the southern flank of the Ulangar upland in the northern part of the basin.

SUMMARY AND CONCLUSION

The Ordos basin is situated in the west-central part of the Sino-Korean platform in North China. The depositional framework of the basin developed during the Taihang-Wuling-Xuefengshan uplift to the east in Late Triassic. When the Permian sea retreated from the Ordos basin during Early Triassic, the Ordos gradually became a large inland fresh-water lake and received continental detritus chiefly from the western and northern highlands.

During the Yanshanian movement from the end of Late Jurassic to the beginning of Early Cretaceous, the sedimentary rocks in the Ordos basin were folded into a north-northeasterly trending synclinorium with a gently dipping eastern limb and a more steeply dipping western limb. Synkinematically north-easterly overthrust faulting occurred along the west basin border and caused the migration of oil and gas from the source rocks to the reservoirs throughout the basin. It is believed that this process continued during the Cenozoic Himalayan movement.

Commercial coal deposits of the Ordos occur locally in the upper member (Wayaobao Coal Series) of the Late Triassic Yanchang sedimentary sequences and in the Middle Jurassic Yanan Formation, and were deposited in fluvial marshes and swamps associated with stream overbank and lakeside areas under relatively moist climatic conditions. These coal beds are found mostly in the central and southern parts of the basin. Thick Permian-Carboniferous coal beds are mined near the basin borders in the northern and southern parts of the basin.

Petroleum deposits occur in the Triassic Tongchuan and Yanchang Formations and in the Jurassic Fuxian, Yanan and Zhiluo Formations. The distribution of the Jurassic sandstone reservoirs in the basin was controlled by the relief on the Triassic Yanchang erosional surface. The principal oil fields are associated with the buried foothills in front of ancient highland areas, as well as with the buried rolling hills adjacent to paleochannels. Chemical analyses of sterane and triterpane compounds from crude oil and extracts from source rock indicate that the principal source rocks are in the Triassic Tongchuan and Yanchang Formations and the Jurassic Yanan Formation. New discoveries can be expected in the overthrust fault belt near the western part of the basin and along the southern flank of the Ulangar upland in the north.

MEASURED SECTIONS

Section I.--Qishuihe, Tongchuan, Shaanxi Province (Institute of Geology, Chinese Academy of Geological Sciences, 1980; v. 1, p. 2-9). [Section of the Triassic system including the Ermaying, Tongchuan, and Yanchang Formations. Measured from Zhifangzhen, Tongchuan, up along the Qishuihe (highway from Tongchuan to Jiaoping) to a cableway across the river at Jiaoping].

Triassic system (incomplete)
Late Triassic
Yanching Formation
Upper member
Overlying strata - Jurassic system
-------------disconformity--------------

		Thickness (in meters)
373.	Quartzose sandstone, yellowish-gray, grayish-yellow, fine grained, feldspathic, thick-bedded and blocky---------	6.0
372.	Mudstone, dark gray, yellowish-green; containing brownish-black, carbonaceous shale and coal traces with plant fossils: *Bernoullia zeilleri*, *Taeniopteris sp.*------	5.6
371.	Siltstone, yellowish-green, clayey; containing mudstone----	4.0
370.	Mudstone, grayish-green, dark gray, grayish-black, sandy; containing grayish-black shale and clayey siltstone. Abundant plant fossils in upper yellowish-green mudstone: *Neocalamites carcinoides*, *N. carrei*, *Danaeopsis fecunda*, *Bernoullia sp.*, *Cladophlebis gigantea*, *Cl. grabauiana*, *Cl. raciborskii*, *Cl. undata*, *Todites shensionsis*, *Sphenopteris chowkiawanensis*, *Thinnfeldia nordenskioldi*, *T. cf. rigida*, *Pterophyllum sp.*, *Nilssonia cf. N. orientalis*, *N. pterophylloides*, *Anomozamites*, *Sphenozamites Changi*, *Glossophyllum (?) shensiense*, *Sagenopteris ginkgoides* *S. lanceolatus*, *Taeniopteris sp.*--------------------------	7.8
369.	Mudstone, dark gray, grayish-green, silty; containing coal traces in basal part and plant fossils: *Equisetites acanthodon*, *E. sthenodon*, *Danaeopsis fecunda*, *Todites shensiensis*, *Cladophlebis kaoiana*, *Cl. raciborskii*, *Cl. undata*, *Protoblechnum hughesi*, *Aipteris shensiensis*, *Baiera cf. gracilis*, *Glossophyllum? shensiense*, *Stenorachis lepida*, *Swedenborgia cryptomerioides*, *Sagenopteris sp.*-----	5.8
368. to 366.	Sandstone, siltstone, and mudstone, yellowish-green, yellowish-gray, median thickbedded; rather abundant iron concretions in mudstone------------------------------------	16.0
365. to 364.	Mudstone, yellowish-green, silty; basal siltstone and coarse-grained sandstone, containing coal traces; plant fossils: *Annulariopsis annularioides*, *A. lobatannularioides*, *Todites shensiensis*, *Bernoullia zeilleri*, *Desmiophyllum sp.*, *Sagenopteris sp.*-----------------------	5.4

		Thickness (in meters)
363.	Mudstone, grayish-green, yellowish-green, silty; containing siltstone and coal traces; plant fossils: *Equisetites cf. brevidentatus*, *E. deltodon*, *Neocalamites carreri*, *N. cf. rugosus*, *Danaeopsis fecunda*, *Todites cf. T. shensiensis*, *Cladophlebis gigantea*, *Protoblechnum hughesi*, *Aipteris shensiensis*, *Ginkgoites sp.*, *Baiera cf. B. gracilis*, *Glossophyllum? shensiense*, *Stenorachis cf. lepida*, *Swedenborgia cryptomerioides*, *Sagenopteris ginkgoides*, *S. lanceolatus* --	11.8
362. to 360.	Sandstone and siltstone, gray, yellowish-green, thick-bedded; sandstone, fine-grained, containing yellowish-green silty mudstone in the middle part of this sequence----	27.0
359.	Mudstone and siltstone, yellowish-gray, gray, sandy, clayey, interlayered; containing plant fossils: *Annulariopsis annularioides*, *A. lobatannularioides*, *Danaeopsis fecunda*, *Asterotheca? szeiana*, *Todites shensiensis*, *Cladophlebis ichunensis*, *Cl. Kaoiana*, *Cl. gracilis*, *Cl. tenuifolia*, *Sphenozamites changi*, *Glossophyllum sp.*, *Taeniopteris sp.*---	26.0
358-356.	Siltstone and mudstone, yellowish-green, grayish-green, clayey, silty, and interlayered------------------------------	23.0
355.	Siltstone and mudstone, yellowish-green, grayish-green, clayey, silty, interlayered; abundant plant fossils in mudstone: *Neocalamites carcinoides*, *Danaeopsis fecunda*, *Bernoullia zeilleri*, *Todites shensiensis*, *Cladophlebis grabauiana*, *Cl. gracilis*, *Cl. Kaoiana*, *Cl. raciborskii*, *Sphenozamites changi*--	12.0
354. to 352.	Siltstone and sandstone. Siltstone, yellowish-green, clayey. Sandstone, yellowish-gray, light yellowish-green fine grained. Both form interbedded layers-----------------	10.0
351.	Mudstone, yellowish-green, grayish-green; intercalated with clayey siltstone and coal traces, contains fossils: Conchostracan (crustacean) - *Euestheria shensiensis (sp. nov.)*; Ostracodes - *Tungchuania aurita* Zhong, *T. agrestata*, *T. houae*, *T. perelegana*, *D. liulingchuanensis*, *D. opinabilis*, *Gomphocythere? pulchra*; and lamellibranchs - *Shaanxiconcha triangulata*, *S. cf. S. triangulata*, *S. dilatata*, *S. mianchiensis*, *S. subrhomboidalis* --------------	3.0
350-348.	Sandstone and mudstone, grayish-yellow, light grayish-green; fine-grained sandstone interbedded with mudstone-----	8.0

Thickness (in meters)

347. Mudstone, yellowish-green, silty, intercalated with siltstone, and coal traces, containing fossils: Conchostracan (crustacean) - Eustheria deformis, and Ostracodes - Tungchuania agrestata, Darwinula liulingchuanensis, D. opinabilis, Lutkevichinella costata, Gomphocythene sp. indet.--- 15.0

346. to 344. Mudstone and sandstone, yellowish-green, grayish-green; mudstone silty; sandstone, fine-grained and median thick-bedded--- 8.0

343. Mudstone, grayish-yellow, yellowish-green, silty; containing plant fossils, Danaeopsis sp.-------------------------- 2.5

342. Sandstone, grayish-yellow, greenish-yellow, thick-bedded, and fine-grained; intercalated with thin-bedded siltstone and silty mudstone; contains pelecypod, Shaanxiconcha triangulata --- 2.6

341. Mudstone, grayish-green, yellowish-green, silty; intercalated with siltstone, coal traces, and black shale. Mudstone and shale contain fossils: Ostracodes - Tungchuania perelegana, T. aurita, T. agrestata, Darwinula liulingchuanensis, D. gerdae; pelecypods - Shaanxiconcha triangulata, S. dilatata, Unio cf. U. xuefengchuanensis ------------------- 17.0

340-339. Mudstone, yellowish-green, grayish-green, silty, and grayish-black, carbonaceous shale in upper part-------------- 7.0

Middle member

338. Sandstone, light gray, yellowish-gray, yellowish-green, fine-grained, thick-bedded; changing into sandstone and mudstone interlayers near top of this sequence. Plant fossils in middle part: Danaeopsis fecunda, Asterotheca? szeiana, Cladeoplebis ichunensis, Glossophyllum? shensiense, Podozamites lanceolatus, Stenorachis sp., and Ostracodes near the top: Darwinula liulingchuanensis, Lutkevichinella costata, Gomphocythere sp. indet.------------ 7.0

337. to 336. Mudstone, grayish-green, yellowish-green, silty, fine-grained sandstone in basal part; contains ostracodes: Tungchuania agrestata, T. aurita, T. houae, D. scheideri --- 7.5

335. Mudstone, grayish-green, yellowish-green, silty; contains conchostracan: Euestheria brodieana; ostracodes: Tungchuania cf. T. houae, Lutkevichinella ornatusa, Darwinula liulingchuanensis and pelecypods: Shaanxiconcha triangulata, S. cf. S. triangulata, S. longa, S. dilatata ------------------------------------ 2.8

		Thickness (in meters)
334. to 332.	Sandstone, yellowish-gray, yellowish-green, fine-grained, median thick-bedded; intercalated with clayey shale in middle part; contains pelecypods, ostracodes, and conchostracans: Shensiconcha dilatata, S. longa, Unio cf. U. xuefengchuanensis, Tungchuania perelegana, T. houae, Darwinula liulingchuanensis, Gomphocythere pulchra, Euestheria multireticulata, E. cf. E. hausmanni-------------	14.0
331. to 329.	Mudstone, siltstone, and sandstone; dark-green silty mudstone in upper part; grayish-green siltstone and fine-grained sandstone in middle and lower parts. Fossils are pelecypods, ostracodes, and conchostracans: Darwinula alta, D. liulingchuanensis, D. gerdae, Tungchuania agrestata, T. houae, T. aurita, Neocalamites carcinoides---	9.0
328. to 315.	Sandstone, siltstone, and mudstone; yellowish-green, grayish-green, fine-grained sandstone, siltstone, and silty mudstone are interbedded------------------------------	59.0
	Lower member	
314.	Shale, light yellow, dark-gray; contains Tungchuania sp. indet.--	10.0
313-301.	Siltstone, yellowish-green, clayey siltstone and siltstone interbedded--	98.0
300-282.	Mudstone and shale, yellowish-green, silty mudstone and shale, containing fine-grained sandstone-------------------	145.0
281.	Sandstone, yellowish-green, fine-grained, thick-bedded; contains plant fossils: Bernoullia zeilleri, Cladophlebis ichunensis---	3.0
280. to 267.	Mudstone and sandstone, grayish-green, yellowish-green silty mudstone, and grayish-yellow, yellowish-green fine-grained, median thick-bedded sandstone interbedded-------------------	66.0
Middle Triassic		
	Tongchuan Formation	
	Upper member	
266.	Shale, black-gray, light yellow; contains oil shale---------	10.7
265. to 264.	Siltstone, shale, and mudstone, yellowish-green, grayish-green, median thick-bedded siltstone interbedded with shale and mudstone---------------------------------------	35.0

		Thickness (in meters)
263.	Oil shale, containing fossil fish scales-------------------	27.0
262-253.	Siltstone, browinish-gray, grayish-green, yellowish-green, clayey; contains oil shale and fine-grained sandstone-------	58.0
252.	Shale, grayish-black; contains ostracodes: *Tungchuania houae*, *T. aurita* --	0.4
251-249.	Mudstone, yellowish-green, silty; interbedded with siltstone and fine-grained sandstone---------------------------	9.0
248.	Siltstone and sandstone, light gray. greenish-gray, median thick-bedded, intercalated with mudstone; contains plant, pelecypods, conchostracans fossils: *Pleuromeia labiata (sp. nov.)*, *P. tongchuanensis*, *Neocalamites carcinoides*, *N. carrerei*, *Danaeopsis magnifolia*, *Beinoullia zeilleri*, *Cladophlebis roesserti*, *Thinnfeldia sp.*, *Glossopteris chinensis*, *Equisetites cf. E. strobili*, *Unio huangbogouensis*, *Tungchuania houae*	6.5
247-240	Mudstone, grayish-green, yellowish-green, silty; interbedded with siltstone and fine-grained sandstone------------	40.0
239-238.	Siltstone, yellowish-green, clayey; interbedded with silty mudstone and siltstone; contains Unio huangbogouensis-------	13.0
237.	Mudstone, yellowish-green, dark grayish-green; contains ostracodes and conchostracans fossils: *Tungchuania houae*, *T. aurita*, *Euestheria tongchuanensis*, *E. gibba*, *E. jinsouguanensis* --	6.5
236. to 232.	Siltstone and sandstone, yellowish-green, clayey siltstone and fine-grained sandstone, interbedded with dark gray, grayish-black shale which contains plant, ostracodes, conchostracans, and fish-scale fossils: *Danaeopsis magnifolia*, *Cladophlebis roesserti*, *Araucarites sp.*, *Tungchuania aurita*, *Darwinula cf. accuminata*, *D. schneideri* ------------	15.0
231.	Shale, yellowish-green, dark grayish-green; contains insect fossils: *Triassoblata phyllopteris* and *Minonymthites orthophlebes*; ostracode: *Tungchuania sp.* indet. conchostracan: *Euestheria celeta* --------------	5.0
230.	Siltstone, yellowish-green, clayey; interbedded with fine-grained sandstone--	2.0
229.	Shale, dark gray, grayish-black; contains insect fossils: *Rhidoblatta lonchopteris* and *Clathrocupes anthilegnotos*, and conchostracan: *Eueshteria sp.*-------------------------	2.6

		Thickness (in meters)
228. to 225.	Sandstone, siltstone, and mudstone, yellowish-green, yellowish-gray, fine-grained sandstone, siltstone, and silty mudstone--	17.0
224.	Mudstone, yellowish-green, silty mudstone interbedded with grayish-green, yellowish-green, median thick-bedded siltstone and fine-grained sandstone; containing plant and pelecypoda fossils: _Equisetites brevidentatus_, _Neocalamites carcinoides_, _Taeniocladopsis rhizomoides_, _Danaeopsis magnfolia_, _D. plana_, _Tongchuanophyllum concinnum_, _T. trigonum_, _Shaanxiconcha sp._ -----------------	8.5
223. to 221.	Mudstone, dark gray, grayish-green; interbedded with siltstone and fine-grained sandstone; containing ostracode: _Darwinula sp._ indet.---------------------------	7.0
220. to 219.	Mudstone and sandstone, grayish-green, yellowish-green silty mudstone in upper part, containing conchostracans fossils; yellowish-green, thick bedded, fine-grained sandstone in lower part------------------------------------	13.0
218.	Mudstone, dark gray, dark green, silty mudstone interbedded with median thick-bedded siltstone; containing bluish-gray shale in middle part, which yields ostracodes: _Tungchuania sp._ indet.------------------------------------	5.6
217- 206.	Mudstone, yellowish-green silty mudstone interbedded with siltstone, fine grained sandstone--------------------------	52.0
	Lower member	
205.	Sandstone, yellowish-green, grayish-green thick-bedded, blocky, and fine-grained------------------------------------	18.0
204.	Siltstone, dark gray, grayish-green siltstone interbedded with clayey siltstone and fine-grained sandstone; Plant fossils in lowest part: _Pleuromeia sp._--------------------	8.7
203. to 195.	Sandstone, siltstone, and mudstone, yellowish-green, thick-bedded and fine-grained sandstone; siltstone; and silty mudstone--	58.0
194.	Mudstone, dark gray, yellowish-green, silty mudstone interbedded with siltstone; containing plant fossils: _Danaeopsis magnifolia_, _D. cf. D. marantacea_-----------------------	n.a.
193.	Siltstone and sandstone, yellowish-green, median thick-bedded and fine-grained sandstone--------------------------	2.0

		Thickness (in meters)
192.	Siltstone, grayish-green, yellowish-green, median thick-bedded siltstone interbedded with silty mudstone; containing iron concretions and fossils: _Equisetites brevidentatus_, _E. sthenodon_, _Neocalamites carcinoides_, _N. carrerei_, _Danaeopsis magnifolia_, _D. cf. D. marantacea_, _Tongchuanophyllum shensiense_ ------------------------------	16.0
191. to 184.	Sandstone, yellowish-green, fine-grained sandstone interbedded with siltstone, silty mudstone; containing a lenticular layer of fine-conglomerate---------------------------	55.0
183.	Siltstone, yellowish-green, median thick-bedded siltstone, interbedded with silty mudstone; containing plant and pelecypoda fossils: _Equisetites sp. (strobilis of Equisetites)_, _Danaeopsis magnifolia_, _Todites shensiensis_-----------------	6.0
182. to 179.	Sandstone, yellowish-gray, yellowish-green, fine-grained sandstone, interbedded with silty mudstone; variation in rock thickness and chiefly sandstone----------------------	28.0
178.	Siltstone, yellowish-green, median thick-bedded, fine-grained siltstone, interbedded with silty mudstone. Plant fossils: _Equisetites tongchuanensis_, _Neocalamites carcinoides_, _Danaeopsis magnifolia_, _D. cf. marantacea_, _Glossopteris cf. angustifolia_, _Tongchuanophyllum shensiense_ ------------------------------	10.0
177-166.	Sandstone, grayish-green, yellowish-green, gine-grained sandstone, siltstone interbedded with silty mudstone-------	48.0
165.	Sandstone, yellowish-green, blocky, fine-grained; contains pelecypod: _Shensiconcha fragilis_, _Unio sp._----------------	11.0
	Ermaying Formation Upper member	
164.	Mudstone, grayish-green, dark grayish-green silty; contains plant fossils: _Equisetites sthenodon_, _Neocalamites carcinoides_, _Taeniocladopsis cf. rhizomoides_, _Danaeopsis sp._-----	7.0
163. to 159.	Sandstone and siltstone, yellowish-green, fine-grained sandstone and siltstone interbedded with grayish-green silty mudstone---	18.0
158.	Siltstone, yellowish-green, median thick-bedded interbedded with silty mudstone; contains Unionidae indet.-------	9.0
157. to 153.	Sandstone and siltstone, yellowish-green, thick-bedded fine-grained sandstone and siltstone, interbedded with silty mudstone---	27.0

		Thickness (in meters)
152.	Mudstone, yellowish-green, silty; intercalated with three layers of coal traces. Contains ostracodes: *Darwinula liulingchuanensis*, *D. accuminata*, *D. cf. D. fragilis*, *D. suovadiformis* --	3.0
151. to 147.	Siltstone and sandstone, grayish-green, yellowish-green, clayey siltstone and fine-grained sandstone containing insect traces---	13.0
146. to 145.	Siltstone, grayish-purple, yellowish-green, clayey siltstone interbedded with purplish-gray, yellowish-gray siltstone; fine-grained sandstone and siltstone at base; contains black carbonaceous shale at top of sequence----------------	10.0
144.	Siltstone, grayish-green, clayey; contains fossils: *Shensinella praecipua*, *Darwinula gerdae*, Unionidae indet.--	5.7
143. to 117.	Mudstone, purplish-red, grayish-green, silty; interbedded with purplish-gray, grayish-green yellowish-green siltstone and fine-grained sandstone. Mudstone contains insect traces and calcareous concretions -----------------	102.0
116.	Shale, dark gray, grayish-green; contains fossils: *Shensinella praecipua*, *S. Gaoyadiensis* Su et Li, Unionidae indet. --	4.0
115. to 112.	Mudstone, siltstone, and sandstone; grayish-green, purplish-red, silty mudstone, fine-grained sandstone intercalated with siltstone -------------------------------	17.0
111.	Mudstone, yellowish-green, intercalated with carbonaceous, thin-bedded shale in middle part; contains fossils: *Darwinula fragilis*, *Shensinella praecipua*, *S. gaoyadiensis* (*sp. nov.*) -----------------------------------	0.56
110. to 94.	Mudstone, purplish-red, dark purplish-red, silty; interbedded with subordinate amount of purplish-gray, grayish-green siltstone and fine-grained sandstone --------	69.0
93.	Mudstone, yellowish-green, red; contains ostracodes: *Darwinula fragilis*, *D. accuminata*, *Lutkevichinella ansulca*, *L. ornatusa*, *L. cf. L. longovata*, *Shensinella gaoyadiensis* Su et Li -------------------------------------	3.4
92. to 85.	Sandstone, mudstone, and shale, yellowish-green, purplish-gray, silty, and fine-grained sandstone; yellowish-green, grayish-green mudstone, and shale --------	20.0

Bed	Description	Thickness (in meters)
84.	Mudstone, dark gray, grayish-green; contains ostracodes and pelecypods at top: *Lutkevichinella ornatusa*, *L. longovata*, *L. brachycostata*, *Darwinula schneideri*, *D. fragilis*, *Shaanxiconcha antiqua* ----------	12.5
83. to 73.	Mudstone, yellowish-green, silty mudstone, interbedded with siltstone and fine-grained sandstone; contains a layer of grayish-green shale near base -----------------	42.0
72.	Shale, dark gray, grayish-green; contains plant fossils pelecypods and ostracodes: *Darwinula schneiderae* *Tungchuania quadratiformis*, *Lutkevichinella minuta*, *L. longovata*, *L. ornatusa*, *Equisetites sp.*, *Neocalamites sp.*, *Todites cf. T. shensiensis*, *Cladophlebis sp.*, *Glossopteris sp.* *Carpolithus sp.* 1, 2, 3 ----------------	8.0
71.	Shale, black; contains *Tungchuania sp.* indet. -----------	1.6
70.	Mudstone, yellowish-green, silty; contains *Zhifangia typica* --	2.3
69. to 37.	Mudstone, dark purplish-red, silty mudstone; interbedded with subordinate amount of clayey siltstone, purplish-gray, grayish-green, fine-grained sandstone; contains *Pseudosuchia*? --------------------------------------	2.4
	Lower member	
36. to 34.	Sandstone, yellowish-green, grayish-green, purplish-gray, thick-bedded, blocky, fine- to medium-grained; intercalated with a layer, about 2 m thick, of purplish-red, silty mudstone --	30.0
33. to 28.	Sandstone, siltstone, and mudstone; purplish-gray, grayish-gray, fine-grained sandstone, siltstone, and dark purplish-red, silty mudstone in upper part; yellowish-green, thick-bedded, blocky, fine-grained sandstone intercalated with fine conglomerate lenses in lower part ---	58.0
27. to 18.	Sandstone, grayish-green, yellowish-green, thick-bedded and fine-grained sandstone, intercalated with dark red, silty mudstone and siltstone containing a basal fine conglomerate --	60.0

Thickness (in meters)

17. to 6.	Conglomerate, yellowish-green, grayish-green, purplish-gray, thick-bedded, and very small to small pebbly conglomerate, intercalated with orange-red shale and grayish-green siltstone, contains a basal layer about 4 m thick of fine conglomerate --------------------	86.0

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Underlying strata: Heshanggou Formation

Total Triassic System 2,055.0

Section II.--Shichuanhe, Yaoxian, Shaanxi Province (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 9-10). [Section of the Permian Shiqianfeng Formation, and the Early Triassic Liujiagou and Heshanggon formations. Measured from Tongjiawei, Anli to Liulinzhen but excluding the Permian Shanxi and Shihezi formations and Middle Triassic and Late Triassic.]

Triassic System (incomplete)
Early Triassic
Heshanggon Formation

Thickness (in meters)

Overlying strata - Ermaying Formation
------------- conformity ------------

110.	Mudstone, orange-red, purplish-red; containing ostracodes: *Darwinula triassiana*, *D. rotundata*, *D. fragilis* ---	3.8
109-107.	Siltstone and mudstone, orange-red, purplish-red, median thin-bedded siltstone and silty mudstone ----------	5.0
106.	Mudstone, purplish-red and orange-red; intercalated with fine-grained sandstone and siltstone; contains ostracode and conchostracan fossils, ostracode: *Darwinula sp.* indet. -------------------------------------	12.0
105-98.	Mudstone, orange-red, purplish red, silty; intercalated with siltstone ---	21.0

		Thickness (in meters)
	Liujiagou Formation	
97. to 92.	Sandstone, grayish-purple, purplish-gray, median thick-bedded and fine-grained; contains two layers of conglomerate in which rock fragments consist chiefly of sandstone with subordinate amounts of mudstone. Diameter of fragements ranges from 0.5 to 1 cm; some as large as 3 to 5 cm -------------------------	53.0
91. to 79.	Sandstone and siltstone, grayish-purple, median thick-bedded, medium- to coarse-grained sandstone and orange-red siltstone, intercalated with dark purplish-red mudstone ------------------------------------	66.0
78. to 70.	Sandstone and siltstone, light purplish-red, median thick-bedded sandstone and siltstone containing a small amount of mudstone ---------------------------------	40.0
	Total Early Triassic	201.0

--------conformity--------

Permian System (incomplete)
Upper Permian (incomplete)
Shiqianfeng Formation

Upper member

69.	Shale, orange-red, dark purplish-red, and silty ----------	36.0
68.	Mudstone, dark purplish-red, silty; interbedded with grayish-green, grayish-purple, calcareous siltstone ------	6.0
67.	Shale, bluish-green; contains 3-4 layers of thin-bedded marl in which each layer is 5-10 cm thick. Fossils: Abiella sp., Microdontella sp., Lingula sp., Sinolimnadiopsis yaoxianensis ------------------------------------	2.0
66. to 65.	Mudstone, bluish-green, dark purplish-red; contains thin-bedded marl (each layer 0.5-5 cm thick), and bluish-green shale at top of sequence --------------------	4.0
64-56.	Mudstone and shale, dark purplish-red, silty; contains siltstone and thin-bedded marl ------------------	39.0

Lower member

55-54.	Sandstone, purplish-gray, median thick-bedded to blocky; fine-grained -------------------------------------	88.0

		Thickness (in meters)
53. to 39.	Sandstone, bluish-green, grayish-green, median thick-bedded to blocky; fine-grained; contains dark purplish-red silty mudstone ------------------------	136.0
	Total Shiqianfeng Formation	311.0

Section III.--Kuyehe, Shenmu, Shaanxi Province (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 10-12). [Section of the Triassic System including the Tongchuan and the Yanchang formations only. Measured from Shihekou, north of Shenmuxian down along the Kuyey via Shenmuxian, Gaojiata, Shiyaoshang, Yanjiaping, Zaowa, Shibanshang, and Shijueta.]

Triassic System (incomplete)

Late Triassic

Yanchang Formation

Upper member

Overlying strata - Jurassic Fuxian Formation

----------------Disconformity---------------

61-55.	Sandstone, yellowish-gray, light yellow, grayish-green thick-bedded to blocky, medium- to fine-grained ---------	54.0
54.	Shale and mudstone, grayish-green, sandy shale and sandy mudstone; interbedded with clayey siltstone; contains two layers of coal traces, which contain plant fossils at Shihekou: _Cladophlebis undata_ (_sp. nov._), _Cladophlebis ichunensis_, _Cladophlebis gracilis_, _Todites shensiensis_, _Podozamites cf. P. lanceolatus_, _Sphenopteris cf. S. chowkiawanensis_, _Glossophyllum? shensiense_, _Danaeopsis fecunda_, _Equisetites sp._, _Equisetites cf. E. deltodon_, _Asterotheca szeiana_, _Neocalamites carrerei_, _N. cf. N. carcinoides_ ------------	5.5
53.	Sandstone, yellowish-gray and grayish-green, blocky, fine-grained ------------------------------------	28.0
52. to 51.	Shale, grayish-green, sandy shale, interbedded with grayish-white, thin to medium thick-bedded, fine-grained sandstone, and grayish-green, clayey siltstone --	16.0

Middle member

50.	Sandstone, grayish-white, grayish-green, blocky, medium-grained --	24.0

		Thickness (in meters)
49.	Sandstone, grayish-white, gray, thick-bedded, medium-grained; interbedded with grayish-green, clayey siltstone, contains coal traces and black shale --	4.0
48.	Shale, grayish-green, sandy; contains thin-bedded siltstone. Plant fossils collected along hill slope on east bank of stream southeast of Nianlidun: *Todites shansiensis*, *Cladophlebis gigantea*, *Ginkgoidium eretmophylloidium*, *Ginkgoidium longifolium*, *Ginkgoidium turncatum*, *Stenorachis lepida* ----------------	3.0
47. to 44.	Sandstone and siltstone, grayish-green, yellowish-green, yellowish-gray, thick-bedded, blocky, fine-grained sandstone and siltstone interbedded with sandy shale; in lower part, grading into thick-bedded medium-grained sandstone containing weathered "honeycomb" rock surface ----------------------------------	21.0
43.	Sandstone, grayish-green, grayish-yellow, blocky, medium-grained; contains iron concretions. In the equivalent bed at Gaojiata, plant fossils were collected: *Annulariopsis sp.*, *Danaeopsis fecunda*, *Bernoullia zeilleri*, *Todites shensienses*, *Cladophlebis cf. gigantea*, *Cl. gracilis*, *Cl. raciborski*, *Thinnfeldia alethopteriodes*, *Ginkgoites cf. G. hermelini*, *Glossophyllum? shensiense* --------------	43.0
	Lower member	
42. to 36.	Sandstone, yellowish-green, medium to thick-bedded, fine-grained, interbedded with grayish-green, sandy mudstone; contains black mudstone and coal traces --------	41.0
35.	Sandstone, yellowish-green, fine-grained, intercalated with grayish-green silty siltstone; contains coal traces near top. Plant fossils: *Neocalamites carcinoides*, *Desmophyllum sp.*, *Cladophlebis raciborskii* -------	4.0
34. to 26.	Sandstone, yellowish-green, thick-bedded, blocky, medium- to fine-grained; intercalated with grayish-green, silty mudstone and clayey siltstone ---------------	79.0
25.	Mudstone and siltstone, grayish-green, yellowish-green, silty mudstone and clayey siltstone; contains fine-grained sandstone in middle part. Plant fossils collected on hill slope east bank of stream, 1 km SE of Shiyaoshang: *Cladophlebis gracilis*, *Cl. gigantea*, *Cl. grabauiana*, *Danaeopsis*	

Bed	Description	Thickness (in meters)
	sp., *Todites sheniensis*, *sphenopteris chowkiawanensis*, *Thinnfeldia rhomboidalis*, *Thinnfeldia nordenskioldi*, *Nilssonia acuminata*, *N. orientalis*, *Ginkgoites sp.*, *Podozamites lanceolatus* ----------------------------------	7.0
24-18.	Mudstone, grayish-green, yellow, grayish-white, blocky and sandy --	53.0
17.	Mudstone, grayish-green, dark green, thin-bedded, sandy; intercalated with fine-grained sandstone. Abundant plant fossils in mudstone (collected from hill slope east of Yangjiaping): *Todites shensiensis*, *Danaeopsis fecunda*, *Bernoullia zeilleri*, *Astrotheca szeiana*, *Aipteris nerviconfluens*, *A. obovata*, *Cladophlebis gigantea*, *Cl. cf. C. raciborskii*, *Ginkgoites digitata*, *Ginkgoidium longifolium*, *Sphenobaiera sp.*, *Glossophyllum? shensiense* --------------------------	12.5
16.	Sandstone, grayish-green, yellowish-gray, blocky, and medium- to fine-grained -----------------------------	14.0
	Tongchuan Formation	
	Upper member	
15.	Mudstone, silty, interbedded with fine-grained sandstone and some shale. Plant fossils collected from sandy shale near top: *Equisetites sthenodon*, *Noecalamites carcinoides*, *N. carrerei*, *N. cf. N. hoerensis*, *Danaeopsis cf. D. magnifolia* ---	10.0
14. to 13.	Sandstone, mudstone, and siltstone, grayish-green, grayish-yellow, grayish-red, fine-grained sandstone in lower and middle parts; grayish-green, silty mudstone and siltstone in upper part --------------------	16.0
12.	Clay, variegated colors (clayey rock layers) ------------	0.5
11.	Sandstone, light grayish-green, grayish white, fine-grained ---	5.0
10.	Sandstone and mudstone, yellowish-red, grayish-green, fine-grained sandstone, and grayish-green thin-bedded, silty mudstone; contains plant fossils: *Cladophlebis ichunensis*, *Todites shensiensis* ------------------------	5.0
9.	Sandstone, yellowish-pinkish-red, blocky, medium-to fine-grained --	10.0

		Thickness (in meters)
8.	Mudstone, grayish-green, gray, thin-bedded, silty and laterally changes into blackish-gray mudstone. Plant fossils collected from south bank of stream, north of Zaowa: Danaeopsis magnifolia, D. cf. D. marantacea, Neocalamites carcinoides, Tongchuanophyllum trigonum, Todites shensiensis, Cladophlebis cf. C. Ichunensis ---	10.5
7. to 6.	Sandstone and mudstone, yellowish-pinkish-red, blocky sandstone in upper part and grayish-green, thin-bedded, silty mudstone in lower part ---------------	6.0

Lower member

5.	Sandstone, light red, yellowish-red, blocky, feldspathic and quartzose --------------------------------	21.0
4-1.	Sandstone, light red, grayish-green, thick-bedded, blocky, medium-grained; contains silty mudstone ---------	22.0

------------conformity-------------

Underlying strata: Ermaying Formation

Total Traissic System 509.0

Section IV.--Lanyihe, Xingxian, Shanxi Province (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 12). [Section of the Permian Shiqianfeng Formation to the Early and Middle Triassic: Liujiagou, Heshangou, and Ermaying formations. Measured from Maputan, Xingxian via Watang to the bank of the Huanghe (Yellow River)]

Triassic System (incomplete)
Middle Triassic (incomplete)
Ermaying Formation

Overlying strata - Tongchuan Formation
--------------conformity--------------

77. to 70.	Sandstone, yellowish-pinkish-red, medium- to coarse-grained, feldspathic, and quartzose; interbedded with purplish-red, silty mudstone. Two layers within vertebrate faunas ----------------------------------	71.0
69-65.	Sandstone, gray, grayish-green, fine-grained; interbedded with purplish-red, silty mudstone -----------	85.0
64.	Mudstone, purplish-red, silty; contains calcareous banded layers and concretions. Vertebrate faunas -------	8.4

		Thickness (in meters)
63. to 55.	Sandstone, gray, grayish-green, purplish-gray medium-grained; interbedded with subordinate amount of purplish-red, silty mudstone ------------------------	143.0
54.	Mudstone, purplish-red, silty; contains vertebrate faunas ---------------------------------------	9.0
53. to 51.	Sandstone, grayish-green, medium- to fine-grained; contains a 1.5 m thick bed of purplish-red, silty mudstone. Vertebrate faunas: _Parakannemeyeria xinxianensis_ found in purplish-red mudstone of lower part of this formation at Watang, Xingxian. Abundant vertebrate faunas found in purplish-red mudstone of upper part of formation in areas of Peijiachuankou to Luoyukou and Shamao to Hejiachuan: _Kannemeyeridae_ indet., _Sinokannemeyeria sp._, _Parakannemeyeria shenmuensis Shansisuchus shansisuchus_, _S. Kuyeheensis_, _Shansiodon shaanbeiensis_ ----------------	31.0
Early	Triassic Heshanggou Formation	
50. to 45.	Mudstone, purplish-red, brick-red, silty; contains small amounts of fine-grained sandstone. _Ceratodus heshanggonensis_ found in upper sandstone of formation at Gegan, east of Watang, Xingxian ------------	131.0
	Liujiagon Formation	
44-36.	Mudstone, purplish-red, silty; interbedded with gray, medium- to fine-grained sandstone and siltstone ---------	111.0
35-30.	Sandstone, purplish-red, reddish-brown, fine-grained; contains siltstone --------------------------------------	118.0
29. to 20.	Sandstone and siltstone, gray, grayish-white, fine-grained, clayey; contains purplish-red, sandy mudstone --	169.0
	Total Triassic System	876.0

--------conformity--------

Thickness
(in meters)

Permian System (incomplete)

Upper Permian (incomplete)

Shiqianfeng Formation

19.	Mudstone, purplish-red, sandy ----------------------------	22.0
18. to 6.	Mudstone, purplish-red, silty; interbedded with purplish-gray, medium- to fine-grained sandstone. Chiefly sandstone in upper part and mostly sandstone in lower part ------------------------------------	101.0
5. to 2.	Sandstone, purplish-gray, medium- to coarse-grained; interbedded with purplish-red, sandy mudstone --	11.0
1.	Sandstone, yellow, conglomeratic -------------------------	18.0

---------- conformity ----------

Underlying strata - Upper Shiheji Formation

Total Shiqianfeng Formation 152.0

Section V.--Xilougou of the Auchenggonshe, Fuguxian, Shaanxi Province (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 12-13). [Section of Early and Middle Triassic: Upper Liujiagou Heshanggon, and Ermaying formations. Measured from Xiaonangou proper within the Xilougou to the mouth of Xilougou.]

Triassic System (incomplete)
Middle Triassic (incomplete)
Ermaying Formation
Overlying strata - Jurassic
--------- disconformity --------

13.	Sandstone, grayish-white, purplish-gray, thick-bedded to blocky, medium- to coarse-grained; interbedded with purplish-red, sandy mudstone and siltstone --------------	16.0
12.	Mudstone, dark purple, sandy; intercalated with sandstone; pollen and spores found in mudstone ----------	14.0
11.	Sandstone, grayish-white, blocky, medium- to coarse-grained --	12.0

		Thickness (in meters)
10.	Mudstone, purplish-red, sandy; intercalated with two layers of sandstone. Mudstone contains vertebrate fauna	13.0
9.	Sandstone, grayish-white, very thick-bedded, coarse-grained; intercalated with purplish-red sandy mudstone	22.0
8.	Mudstone, purplish-red, sandy; intercalated with thin-bedded (10-20 cm) sandstone; vertebrate fauna	4.0
7.	Sandstone, yellowish-white, grayish-white, very thick-bedded, medium- to coarse-grained; intercalated with purplish-red, silty mudstone; mudstone contains *Shaanbeikannemeyeria xilougouensis*	13.0
6.	Sandstone, yellowish-white, blocky, medium- to coarse-grained	15.0

Early Triassic (incomplete)

Heshanggon Formation

5.	Mudstone, purplish-red, silty	3.0
4.	Sandstone, grayish-white, green, thick-bedded; contains vertebrate faunas	12.0
3.	Mudstone, brick-red, silty; contains conchostracans and abundant pollen and spores in lenticular interlayers of grayish-green, sandy mudstone near top of sequence: *Aquilonoglypta xilougouensis*	2.5
2.	Mudstone, brick-red or orange-red, silty; intercalated with two layers, 1.5 m thick, of sandstone. Grayish-green banded zones and spots in mudstone	30.0
1.	Sandstone, grayish-white, thick-bedded, medium- to fine-grained; interbedded with brick-red, silty mudstone. Sandstone of this sequence increases from upper part to lower part, accompanied by gradual decrease of mudstone; frequently grayish-green, sandy, lenticular mudstone occurs between sandstone and mudstone. This mudstone is 1.5-2 m thick and extends 100-200 m laterally; contains conchostracans	70.0

The equivalent strata at following localities contain fossils: Conchostracan - *Aquilonoglypta clinoquadrata* in the upper part of this formation at Zhaojiagou about 500 m each of Xiaonangou.

Thickness
(in meters)

Conchostracans - Cornia guchengensis, Gabonestheria clinotuberica, G. guchengchuanensis, Diaplexa varidicta, Loxomicrograpta sangerjiagouensis, Palaeolimnadia ovata, P. longovata, Dictyosriaca subcyclata in the grayish-green, green mudstone interlayers of the middle and lower parts of this formation at Songeerjiagou, Guchenggonshe.

Ostracodes - Darwinula gracilis, D. ingrata, D. triassiana in the middle and upper parts of this formation at Sangejiagou.

Ostracodes - Darwinula parva, D. rotundata in the strata of this formation at Xilougou.

---------- conformity ----------

Underlying strata - Liugiagou Formation

Total Lower and Middle Triassic 226.0

Section VI.--Laocaigou of the Wuziwangonshe, Zhungeerqi, Neimeng Autonomous Region. (Institute of Geology, Chinese Academy of Geological Sciences, 1980, v. 1, p. 13-14) [Section of the Middle Triassic Ermaying Formation. Measured along western bank of Halazhaichuan, Laocaigou, which is located between Wuziwangonshe, Zhungeerqi, Neimeng Autonomous Region and Halazhaigonshe, Fuguxian, Shaanxi Province.]

Triassic System (incomplete)
Middle Triassic (incomplete)
Ermaying Formation (incomplete)
Overlying strata - Jurassic Fuxian Formation
-------- disconformity --------

8. Mudstone, dark purplish-red, silty; contains vertebrate faunas: Parakannemeyeria sp., Shansisuchus sp. ---------- 16.8

7. Sandstone, grayish-white, medium-grained in upper part; readily weathering and forming residual sandstone spheroids. Cream-yellow and medium-grained in lower part ----- 4.5

6. Mudstone and siltstone, dark green, dark yellowish-green, sandy mudstone and clayey siltstone. Plant fossils occur in the 0.2 to 0.3 m thick sandy mudstone at base of sequence: Pleuromeia wuxiwanensis, Todites shensiensis, Protoblechnum wongii, Aipteris wuziwanensis, Pachypteris sp., Ginkgoites cf. G. marginatus, Baiera cf. B. gracilis, Glossophyllum? shensiense, Nilssonia grandifolia, Podozamites

		Thickness (in meters)
	lanceolatus, *Pagiophyllum* *sp.*, *Equisetites* *sp.*, *Neocalamites* *sp.*, *Bernoullia* *cf.* *B.* *zeilleri*, *Caldophlebis* *raciborskii*, *Ctenozamites* *sarrani*, *Sinozamites* *sp.*, *Taeniopteris* *abnormis*, *Stenorachis* *sp.*, ------------	1.6
5.	Sandstone, yellow, blocky, medium- to coarse-grained; conglomeratic ----------------------------------	22.0
4.	Mudstone and sandstone, dark purplish-red mudstone and coarse-grained, conglomeratic sandstone -------------	8.0
3.	Sandstone, grayish-white, blocky, coarse-grained and conglomeratic ---------------------------------------	18.0
2.	Mudstone, dark purplish-red, silty ---------------------	4.0
1.	Sandstone, grayish-white, coarse-grained and conglomeratic; intercalated with purplish-red clayey rock lumps and banded layers. Basal part not exposed; exposure is 11 m thick	
	Total Ermaying exposure thickness ------------	86.0

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