United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

June 20, 1989

To the user of Open File Report 89-180

This report represents the results of a collaborative effort in 1983 between the U.S. Geological Survey (USGS) and the People's Republic of China. The final report provided by the Chinese to the USGS is in two forms: one copy is in Chinese and forms the appendix of the Open-File Report; one copy was translated by them into English and this constitutes the body of the Open-File Report.

The purpose of this Open-File Report is to make the documents available in their original Chinese and translated versions; no attempt has been made to correct grammar, spelling or typographical errors in the translated version.

Given the recent circumstances in the People's Republic of China it will be impossible to either pursue further improvements in the report nor to obtain better reproducible copy.

We hope that you will find the report 'usable' in its present form.

Henry Spall
Associate Chief
Office of Scientific Publications

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Sedimentary environments and coal-forming mechanism of the Jurassic Yan'an Formation, Huangling mining area, Ordos Basin, China

By

Tian Ming, Mao Bangzhuo, Liu Shu, Zhang Yonglin, and Han Changlin

Geological Bureau of the Ministry of Coal Industry,

People's Republic of China

and

B.H. Kent, R.G. Hobbs, E.A. Johnson, and W.S. Sigleo

U.S. Geological Survey

Open-File Report 89-180

1989

Prefatory Statement

During the fall of 1983, three geologists and one geophysicist from the U.S. Geological Survey visited the People's Republic of China as participants in a scientific exchange program. This program, known as Project Six and entitled Coal Basin Exploration and Analysis, was part of an earth-science protocol established by the two countries. The purpose of this part of the exchange was to conduct joint research on the depositional environments of coal-bearing sequences within a sedimentary basin in each of the two countries as a way of comparing methodologies. The part of the exchange that occurred in China focused on the Jurassic Yan'an Formation along the southeastern edge of Ordos Basin in the north-central part of the country. This basin was selected by the team because of its structural similarity with the Powder River Basin of Wyoming and Montana, the U.S. study basin, and because the Chinese geologists had a large data base for this area. Geoscientists from both countries conducted field work, examined data, and developed a depositional model for the coal occurrence.

Following the visit, the Chinese geoscientists wrote the report summarizing the conclusions reached by the binational team. The report was forwarded to the U.S. Geological Survey in two forms: one copy in Chinese that forms the appendix of this Open-file Report, and one copy translated into English by the Chinese that constitutes the body of the report. The purpose of this Open-file Report is to make these documents available to the public in their original form, hence, no attempt was made to correct the grammar, spelling, or typographic errors in the translated version.

Contents

SEDIMENTARY ENVIRONMENT AND COAL-FORMING MECHANISM OF JURASSIC YAN'AN FORMATION, HUANGLING MINING AREA, ORDOS BASIN

—— A COOPERATIVE RESEARCH PROJECT WITH THE U.S. GEOLOGICAL SURVEY

BY

Tian Ming, Mao Bangzhuo , Liu Shu,
Zhang Yonglin and Han Changlin

Geological Bureau of the Ministry of Coal Industry,

The People's Republic of China.

AND

B. H. Kent, R.H.Hobbs, E.J.Johnson and W.S.Sigleo.

U.S. Geological Survey.

CONTENTS

Sedimentary Environment and Coal-forming Mechanism of Jurassic Yan'an Formation, Huangling Mining Area, Ordos Basin

Part 1. ABSTRACT

The Yan'an formation is one of the most important Mesozoic coal-bearing strata in northern China. From the detailed analysis of associated relationship between lithology, electric property and lithofacies, the deposit of coal-bearing Yan'an formation in Huangling study area can be grouped into four sedimentary systems, ascendingly, they are: fluvial-lacustrine swamp, lacustrine swamp, lake delta and continental lake. The planimetric combination of associated systems probably reflects the differentiation of the lateral distribution of subenvironment during that time, while the characteristics of vertical variation of these systems and their association, are probably directly related to the process of evolution of sedimentary environments of which local fluvial deposits at the very begining of early Yan'an time were transformed into the lakeshore settlings and deterioration of the lake was represented by active filling of fluvial channel, this process resulted the construction of deltaic system at middle age of Yan'an formation, and the lacustrine sediments were settled during the late-Yan'an period. Peat swamp deposits were obviously a result of swamplization in lakeshore and delta plain districts.

The tectonic background of overall subsidence is the predominant prerequisite for continuous accumulation of coal in the study area, which is represented by the palaeoerosional landform such as palaeouplifts and palaeodepressions. The Post-Indo-China movement palaeotopography

basically controlled the regional distribution and variation of thickness of main coal beds. The palaeodepressions were the most favourable areas for peat accumulation, the coal beds here were thicker, more continuous and were deposited earlier than other parts,on the other hand, coal seams on the palaeotopographic high were relatively thin, and discontinuous. These phenomena suggested that oscillation of earth crust during the time of forming of the peat swamp and differential compaction as well as differential compensation of coal-forming materials were the primary factors which affected the accumulation, texture, spacing, splitting and merging of main coals, so that the coal beds in Yan'an formation appeared rather complex.

Part 2. INTRODUCTION

1. Objectives of Investigation

The main objective of "Project 6" of the Sino-U.S. protocol in earth sciences cooperation for coal basin exploration and analysis is to select one or two coal-bearing basins in the People's Republic of China and the United States to study stratigraphy, coal beds, coal quality, coal petrology, paleontology, structure and geochemical and geophysical exploration techniques in both countries; and to evaluate and summarize coal-forming environments of coal basin and coal resource exploration and assessment methods by computerized data systems. The general objectives of the project are: to study mutual problems in coal basin exploration and analysis; to observe the concepts, approaches and techniques used by counter part scientists; and to participate in joint endeavors to solve typical common problems.

The Powder River Basin in western U.S. and the Ordos Basin in China had been selected as study areas of first round of the joint research program. Chinese geologists and geophysicists were scheduled firstly to do geological investigation and field research work in Powder River Basin from September to November, 1982. The Chinese scientists also observed the coal field geological work both in eastern and western part of the United States, and carried on detailed correlation and the evaluation of coal resources of Felix coal deposits of Powder River Basin in Wyoming and Montana. From September to November, 1983, the geologists and geophysicists from U.S. Geological Survey took part in geological investigation in the Huangling study area in Ordos Basin, the People's Republic of China. All field research programs were focused on the depositional environment and coal-forming control factors of Yan'an formation. They also visited the Tertiary Fushun Coal field, Permo-Carboniferous Xishan coal field in Taiyuan, Shanxi Province, Jurassic Fuxin Coal field in Liaoning Province, and Datong Coal field in Shanxi Province. All these are most typical and representative coal fields during different geological periods.

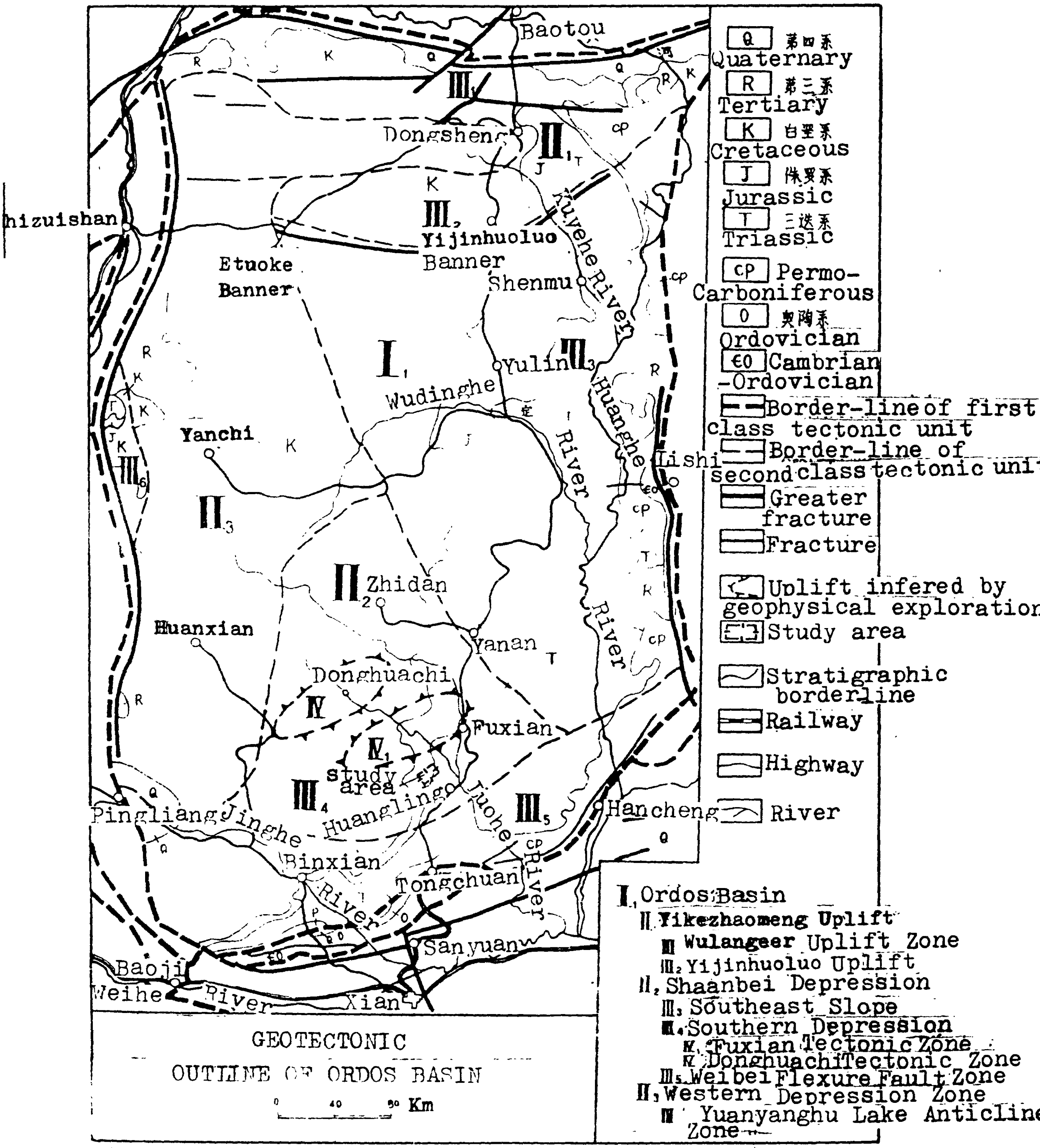
They visited Xian Branch of Coal Science Institute, Xian Aerophotogrammetric Center, Weinan Coal Mining Equipment Factory as well, the geologists of U.S. Geological Survey comparatively understood the metering methods, instruments and prospecting equipments etc.. By discussing and exchanging techniques, the two sides completed the first round of the cooperative plan.

The "Project 6" was jointly sponsored by the U.S.G.S./Branch of Coal Resources and Chinese Geological Bureau of the Ministry of Coal Industry, the representives from United States included:

B. H. Kent - geologist of U.S.G.S.
R.H. Hobbs - Geophsicist of U.S.G.S.
E. J. Johnson - Geologist of U.S.G.S.
W. S. Sigleo - geologist of U.S.G.S.

China is rich in coal resources. The characteristics of coal-depositional situation are notable for its vast distribution, very rich coal resources, early and multi-stage coal-forming in geological history, and variform basin structures and types. The initial assignment was designed to a short-term research project which would provide the scientists from the U.S. Geological Survey with opportunity to investigate and promote understanding of the coal geological features and the outline on coal resources as well as resources assessment methodology in China.

A project for analysis of sedimentary environment and coal-controlling function of coal-bearing Yan'an formation in Huangling Study area of Ordos Basin was selected because Ordos Basin is a most important and typical Mesozoic coal-bearing depression, and also because the process of geological investigation and prospecting of Yan'an formation in this area at 1 : 50,000 scale was carried on by a lot of basic geological works during more than twenty years. A detailed depositional modal of Yan'an formation may have applicability for further prospecting and developing coal reserves, so scientists of U.S.G.S. could immediately observe and familiarize themselves with the way for prospecting and studying and the exploration and techniques of Chinese geologists used in dealing with coal basin analysis and the way they thinking. On the basis of first round joint research of sedimentary environment on the Yan'an formation in Huangling Mining area, we envisaged that not only we can go on the full science exchanges to further understand the concepts, methodology and technique used for both sides, but we can accumulate information and experience for second round cooperative research program after finishing our schedule of first round work in Ordos Basin. A final solution of Huangling Research project, however, is to submit a joint geological report.



Baotou
Dongsheng
hizuishan
Etuoke Banner
Yijinhuoluo Banner
Shenmu
Kuyehe River
Yulin
Wudinghe
Yanchi
Huanghe River
Lishi
Zhidan
Huanxian
Yanan
Donghuachi
Fuxian
study area
Huangling
Luohe River
Hancheng
Pingliang
Jinghe River
Binxian
Tongchuan
Sanyuan
Baoji
Weihe River
Xian
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permo-Carboniferous
Ordovician
Cambrian-Ordovician
Border-line of first class tectonic unit
Border-line of second class tectonic unit
Greater fracture
Fracture
Uplift infered by geophysical exploration
Study area
Stratigraphic borderline
Railway
Highway
River
I1 Ordos Basin
II Yikezhaomeng Uplift
Wulangeer Uplift Zone
III2 Yijinhuoluo Uplift
II2 Shaanbei Depression
III3 Southeast Slope
Southern Depression
Fuxian Tectonic Zone
Donghuachi Tectonic Zone
III5 Weibei Flexure Fault Zone
II3 Western Depression Zone
Yuanyanghu Lake Anticline Zone
GEOTECTONIC
OUTLINE OF ORDOS BASIN
0 40 80 Km

Fig.1.

2. Location of the Huangling Study Area.

As shown in Fig.1 located in the Huangling County, Shaanxi Province, the middle of China, included the south part of Huluhe River and north part of Yaoping-Hongshansi-liang-line, Huangling Mine Area is about 2,600 square kilometres, elongate to near north-south across gently east-dipping lopes, according the geographical regionalization, which belong to the southern Shaanbei loess plateau.

Topographically, ranges and mounts as well as monticules are formed intertonguing distribution by erosion and dissection, and shaped the loess canyon, the terrace scarpe and the loess karst on this erosional structural relief. There is also a river called Zhushuihe in the area flowing down eastward or southeastward into the Luohe River. The distance between Huangling city and the study area is about 28 kilometers, 200 km to Yan'an City on north, and 250 km to Xian City on south. The railway line is not to be finished so far.

3. Brief Introduction of Previous Coal Field Geological Work.

The focal point of the coal field geological work was centred on the Permo-Carbaniferous coal field on the south flank of the Ordos Basin when the Shaanxi Company of coal field geology was first established in 1953. The geological investigation for Mesozoic coal resources, however, was primarily carried on in 1957. So, the geological research and prospecting work can probably been divided into three stages according to the nature and purpose of exploration works.

Geological survey included mapping at 1 : 50,000 scale and general exploration before 1960, the purpose of this stage is reconnaissance survey and the task, however, is to outline the boundary of the coal-bearing areas, to analyze the physiographic conditions, to position the "dominated drilling-holes" for coal exploration, to outline the features of quaternary geology and topography, and to roughly determine the depth, continuity and stratigraphic contact of coal-bearing strata. The coal quality and structural modal were probably defined in this stage, and to give a preliminary estimate of coal resources, meanwhile, to identify the industrical uliligation of coal by means of chemical analysis of coal samples, and pehographic studies. Those priviously geological work were summerized in geological reports, such as "Summary of Geological Exploration Survey of Linyou-Yijun Coal Field" and "Geological Reconnaissance Report of Huangling-Qilizhen Coal Field".

The assignment of the second stage of geological investigation in the study area during 1960's to early 1970's was the further understand the characteristics of geology which might deal with not only the remaining problems of first stage, but we must also ascertain the hydrogeological conditions and engineering geological conditions for mining activities to culminate in a geological report which should be included a certain number of utilizable geological coal resources for industry. All technique (exploration method) used in this phase are such as core-drilling exploration, geophysical log and detailed geological surface measurement. Recounaisence and detailed prospecting reports on the geological characteristics of Huangling area studied have been worked out which would assist in the joint study of depositional environment except that in a few of the areas the geological prospecting still goes on. Also, a lot of theses and papers discussed the law of distribution and variation in thickness of coal deposits in view of situation of peat accumulation are focused on the prediction of coal field and the depositional features of Jurrasic Yan'an coal reserve.

So we can conclude that the cooperative research program "Project 6" selected for the analysis of sedimentary environment and control factors of Yan'an coal-bearing formation would probably play a very important part in the third stage of coal field exploration, and also help to promote further development of prospecting methods and understanding of geological concepts.

4. Prospecting Methods

The process of geological works of Chinese side could be divided into three steps: collection of information, field work, analysis and sorting out the data in laboratory. The information collected from joint study area including data of strata, sedimentary structure, coal beds plaleontology and lithology, lithofacies of coal-bearing formation as well as drill logs stratigraphical correlation and mapping units. Because the field work is a basic work phase we could never lack, Huangling studu area nevertheless had been mapped at 1 : 50,000 scale, we still emphsized detailed descrition for lithology, texture and contributing factors of Yan'an formation, surface section and outcrop was the fundamental daily routine. Our study also consists of 19 geological trenches, the total amount of earthwork was 2882 cubic meters, and hundreds of coal or rock samples and fossils collected from measured surface section.

Geophysicists from both sides took part in field geophysical logging in Diantou as well as the investigation of geological section. Indoor analyses had been done by various statistical data to reflect the geometry of deposit or topographic depressions and coal-forming situation on the basis of collected information and field work . Positive results in this joint research are reflected in chapters concerned of this reports including the depositional cycles of Yan'an formation by means of gamma-ray and resistivity logging, some of analytical maps and sections such as: the sedimentary facies sections, the structural maps, the isopach maps of various deposits, the lithofacies and paleogeographic maps, the stratigraphic and coal seam correlation sections and electrical logging curve are also enclosed.

Part 3. THE BACKGROUND OF REGIONAL GEOLOGY

Ordos basin as part of the North China platform is in concordant with the Pre-Mesozoic stratigraphic sequence in the rest part of North China. So that the upper Ordovician, Silurian, Devonian and lower carboniferous deposition are also absent. The basement of Ordos basin is the Pre-Sinian metamorphic clastic rocks overlain mainly by the limestone-dominated facies of marine sediments from Sinian to Ordovician system. Carboniferous system is mainly alternating marine and terrestrial deposits, while the Permian system is terrestrial clastic sediments. The interior-basin deposits were settled after Triassic period which are difference from the platform facies before this period.

Ordos basin is noted for its huge interior basin sedimentation of Mesozoic-Cenozoic strata in round distribution and surrounded by old mountains. The Huangling study area, which is located on the south-east ridge, consists stratigraphically Yongping formation of upper Triassic system; Fuxian formation of lower Jurassic system; Yan'an, Zhiluo and Anding formations of middle Jurassic and Zhidan group of lower Cretaceous system arrange in order from east to west (Fig.2).

1. Yongping Formation of Triassic System.

Occurred on the east flank of study area and nearby Diantou Chechun and as Yaoping along the Jushuihe river

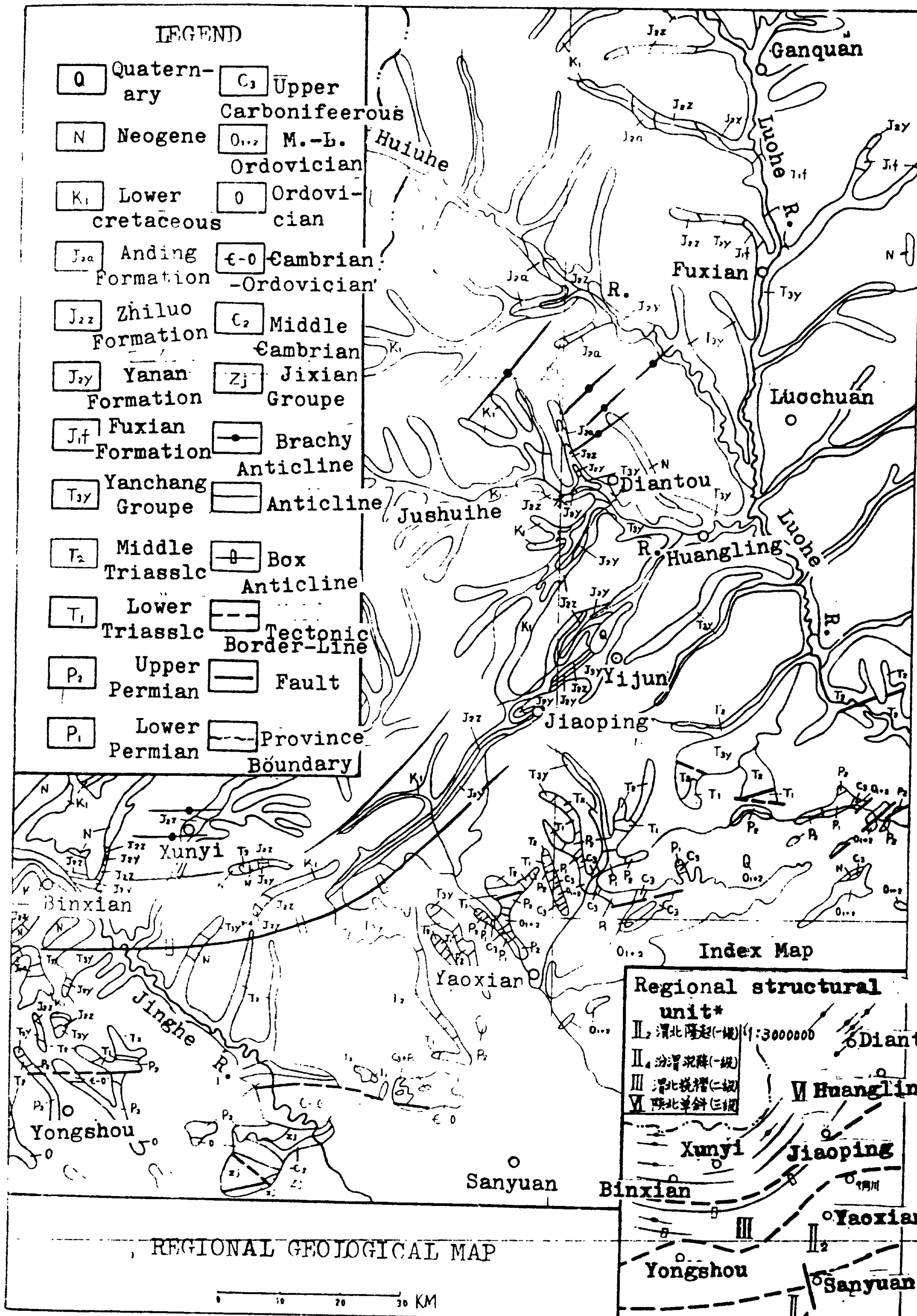


Fig.2

*see fig. 4.

and Nanchuan valley, varies from yellowish green to green, fine to medium-grained sandstone interbeded with grayish green, dark-green mudstone and shed coals. Plant fossils found in this formation are:

Danaeopsis fecunda,
Cladophlebis shensiensis,
Bernoullia zeilleri,
Glossophyllum shensiensis.

2. Fuxian formation of lower Jurassic Period

Crop out in the northern part of Niujiazhuang-Nanhezhai-Lizhanghe-line, Fuxian formation consists the following rocks: grayish-white conglomeratic sandstone and conglomerate at the base, mottled mudstone, siltstone intercalated with thin beded fine sandstone and medium-grained sandstone in middle part, interbeded grayish green mudstone,fine grained sandstone, spotted mudstone, oolitic siderite beds in the upper part.

The lithology and thickness controlled by the palaeotopography are variable, generally speaking, rangs from 10 meters to 78.7 meters in thickness, still more only about 1 meter to the south part. The lithologic character varies from purple to grayish purple mudstone and aluminous mudstone.

3. Yan'an formation of middle Jurassic system.

The Yan'an formation, deceptive conformably overlying the Fuxian formation, are characterized by its terrestrial clastic coal measure, lithologic character varies from mudstone, siltstone, medium-fine sandstone and coal beds in lower part to the thin marl which contain some pelecypoda fossils in middle and upper part, range from 0 to 180 meters in thickness. It is controlled by paleo-topographical features that is relatively thicker in northeast depressions and thiner in southeast palaeouplifts.

The Yan'an formation can be divided into 5 sedimentary cycles on the basis of their lithology, lithofacies and interior texture. The variation trend is that: vary from very fine-coarse - fine grain-size ascendingly and, opposite to the mudstone, sandstone content decreasing from east to west along the dip-direction. As illustrated in Fig.3, minable coal seams occured in lower part of Yan'an formation which are widespread, and showed poor coal-bearing degree in the upper part, whereas coal is concentrated in the lower part of Yan'an formation, plant fossils in Yan'an formation as following:

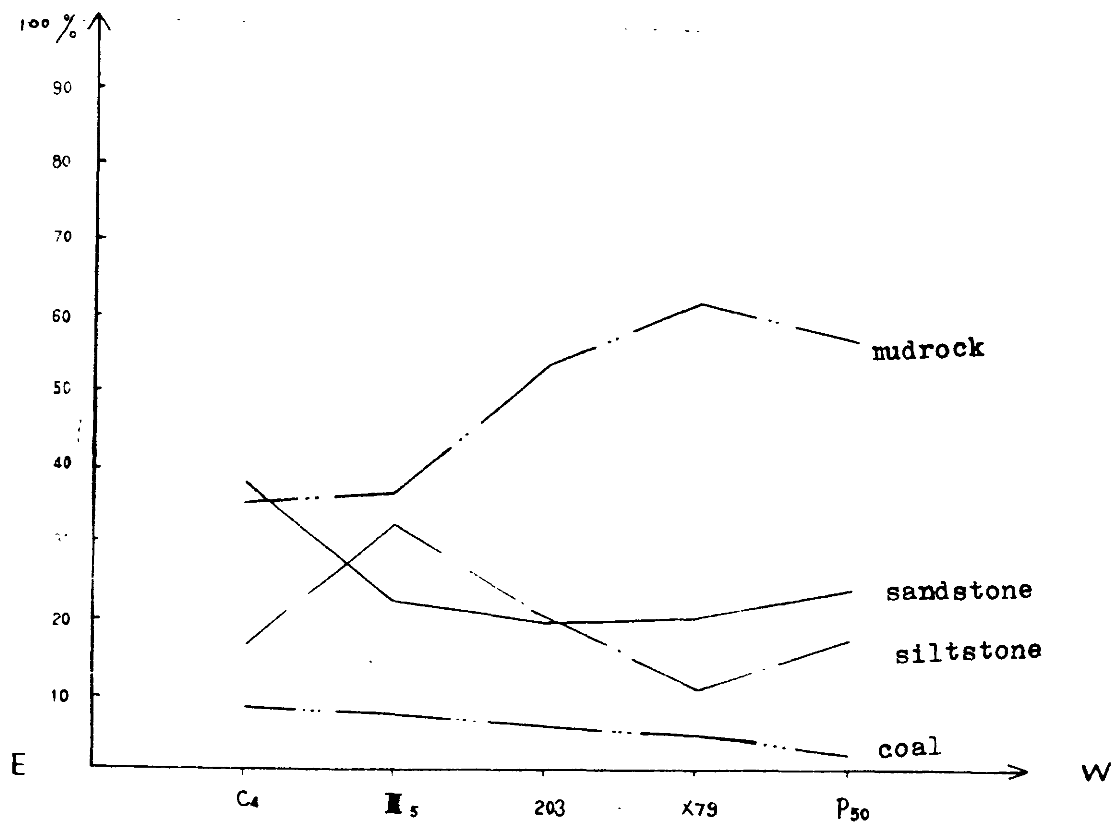


图3 延安组各类岩石含量变化曲线图(傾向)

Fig 3 Diagram showing variation of various rocks content in yan'an Fm

Member I :

Coniopteris hymenophylloides
C. tatungensis Sze
Eboracia lobifolia
Hausmannia leeiana Sze
Todites williamsoni
Czekanowskia rigida Heer
Pityophyllum langifolium
Podozamitea lanceolatus
Nilssonia cf Sinensis
Pagiophyllum ? sp.
Ginkgoites sp.

Member II :

Cladophlebis (todites) cf denticulata
Coniopteris sp.
Elatocladus sp.

Member III and member IV :

Tutuella ? sp.
Ferganoconcha sibirica Cherny.
F. cf sibirica Cherny.

4. Zhiluo formation of middle Jurassic system

This formation is characterized by semiarid climatic terrestrical clastic sediments, ranging from 70 to 200 meters in thickness, which is commonly considered of two grain-size cycles according to their color, lithology and vertical sequence of grain-size.

The color varies from grayish green, yellowish green, grayish white in the basal part to the purple red, brown purple at the top; the lithology ranges from medium-coarse feldspathic arenite to mudstone, arenaceous shale parting with siltstone to fine sandstone. The internal structure are also varied from linear crossbeds feldspathic arenites that are commonly cementad by mudmatrix to unbeded musrock. The rhythmic succession in lower part is very obvious and scattered by ironstone, shed coal, vitrinite belts, mud enclourse and large ironized woods, erosional surface in basal horizon are easily been identified so that the delineation of marker bed can be used for a regional correlation.

The contact relationship between Zhiluo and Yan'an is paraun-comformity and Zhiluo formation is overlying immeditely on the Yongping formation nearly Yaoping in the southern study area. The fossils in this formation includ:

Coniopteris hymenophylloides,
Podozamites lanceolatus.

5. Anding formation of Jurassic System.

Overlying conformably on the Zhiluo formation, the Anding is characterized by it's lacustrine deposition, and distributed to the north of upper reaches of Lizhanghe creak, the color varies from black to grayish purple, light yellow, the lithology ranges from shale, oil shale to mudrock intercalated pink dolomitic mudstone, caleareous siltstone in middle part. The upper part of this formation showed horizontal and irregular ripple laminations with the fossil fragments of ostracoda, fish bones, fish scale and Psilunio cf Suni (Chow), P. sp. as well, ranges from 0 to 54 meters in thickness.

6. Zhidan group of lower Cretaceous system.

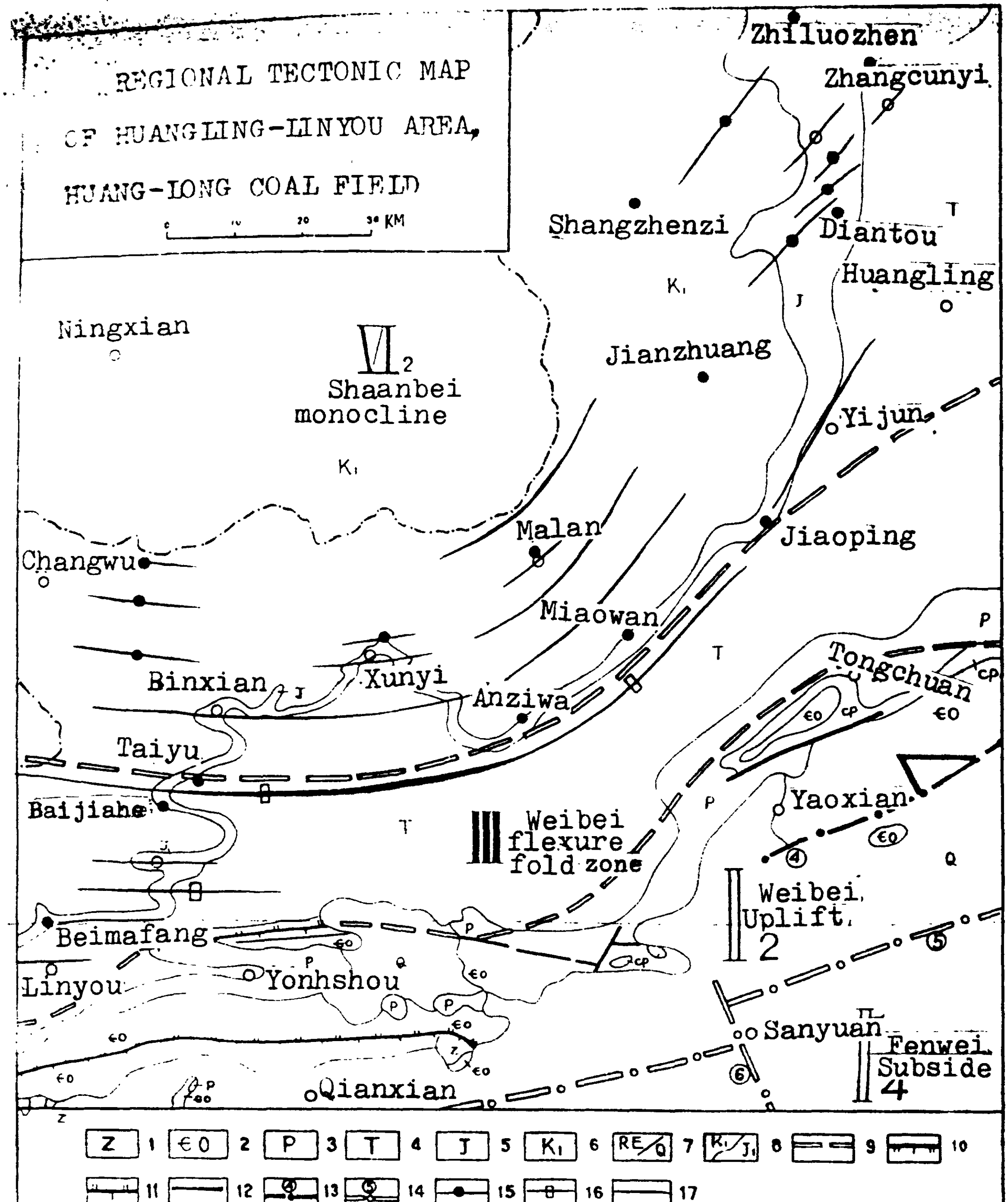
Overlying parallel unconformably on the Jurassic system, Zhidan group is characterized by fluvial-dominated, fluvial-lake-dominated facies, and eolian sediments. It consists of the following four formations arranged in lower to upper order: Yijun, Luohe, Huachi-Huanhe and Jinchuan formations except that the Yijin and Jinchuan formations are absent in the Huangling study area, Luohe formation is marked for it's thick orange, brick red, well-sorted and medium-grained sandstone intercalated with lense-shaped mudrock. The sandstones are commonly poor cemented and show large-scale cross-beds with the thickness of 200 meters.

The Huachi-Huanhe formation crops out in local area and shows characteristics different from Anding formation by the grayish-purple, grayish-green siltstone interbeded with fine-grain sandstone and mudrock. The vertical sequence of internal structures consists of horizontal ripple laminations cemented by calcareous rock with the thickness of 156 meters.

Tertiary system, crops out scatteredly in the Taipingcun of northern study area, ranges from 0 to 60 meters thick marked by light red sandy clay rock and are shown unconformably with underlying strata.

The characteristics of Quaternary System are indicative of lower loess with on 200 meters in thickness, and upper modern channel deposits with generally about 10 meters in thickness.

Ordos platform is a typical interior syneclise with fantastic stability and large-scale gentle folds system except for the edge of the basin which are based on pre-Sinian hypo-metamorphic crystalline rocks. The orientation of basin edge structures of Ordos platform is coincident with basin delineation in a north-south direction, which outline showed basically west-dipping monocline called Shaanbei declivity. As shown in Fig.4, on the western edge of Ordos basin is Tianhuan syncline and Weibei fold belt nearby the Fenwei graben-like basin (Fig.4). Located on the east flank of Shaanbei declivity, Huangling study area shows basically monoclinals oriented in the west-northeast- dip direction. It's proximate grade wide and gently dipping folds with 3,000 to 4,000 meters in width in northeast orientation, which is close related with the distribution of Yan'an coal-bearing formation and the structural deformation is gradually changed weaken from basin edge to centre.



1 - Atsen tectonic strata. 2 - Caledomian tectonic strata

3 - Hercynian tectonic strata.

4 - Indo-Chinese sub-tectonic strata.

5 - Early-Yanshan sub-tectonic strata.

6. -Later-Yanshan sub-tectonic strata.

7 - Xishan tectonic strata

8 - stratigraphic border-line.

9 - Tectonic unit border-line..

10 - Normal fault. 11 - Thrust fault.

12 - Fault unidentified 13 -Great fracture.

14 - Great fracture found by geophysical exploration.

15 - Brachy anticline. 16 - Box anticline.

17 - **Anticline.**

*4 - Hongdong-Yaoxian great fracture.

5 - Fengxiang-Linyi great fracture.

6 - Sanyuan great fracture.

Fig.4.

rdos platform had been undergoing tectogenesis many times during the development of long historical period including the pre-Sinian (Precambrian) lüliang movement which resulted in tectonic tamorphism of pre-Sinian system so that the harden clastic rocks overlain unconformably by the Sinian to Ordovician shallow marine strata.

The platform uplifted after mid-Ordovician Caledomian movement which changed the marine environment into continental so that the sediments from upper Ordovician to lower Carboniferous system are absent, and the middle or upper Carboniferous system are overlying parallel unconformably on mid-Ordovician system regionally. Upper palaeozoic Hercynian movement is characterized by regional subsidence so that the middle to upper carboniferous deposits are alternating terrestrial and marine and terrestrial clastic rocks.

From the beginning of Jurassic period, the basin was changed into interior-basin-type, The process of basin development consists three stages: forming; stable development and enclosed three steps. Initial stage of Ordos basin development was begun in Triassic Period and the subsidence centre are concentrated on the southwest of Ordos basin, whereas basin was uplifted and tilted westward at the end of the late-Triassic Indo-China movement and dissected by erosion marked by the erosional surface at the top of Triassic system which representated by a number of palaeo-uplifts and palaeodepression. As the outline in Fig.5, lower Jurassic Fuxian formation accumulated in palaeodepressions was uplifted by the post-Fuxian tectonic oscillation movement and parallel conformably overlain on the Yan'an formation.

The stable development stage is indicated by the Yan'an deposits when basin subsidence after the settling of Yan'an formation. The extensively uplift movement resulted in parallel conformably between Zhilao and Yan'an

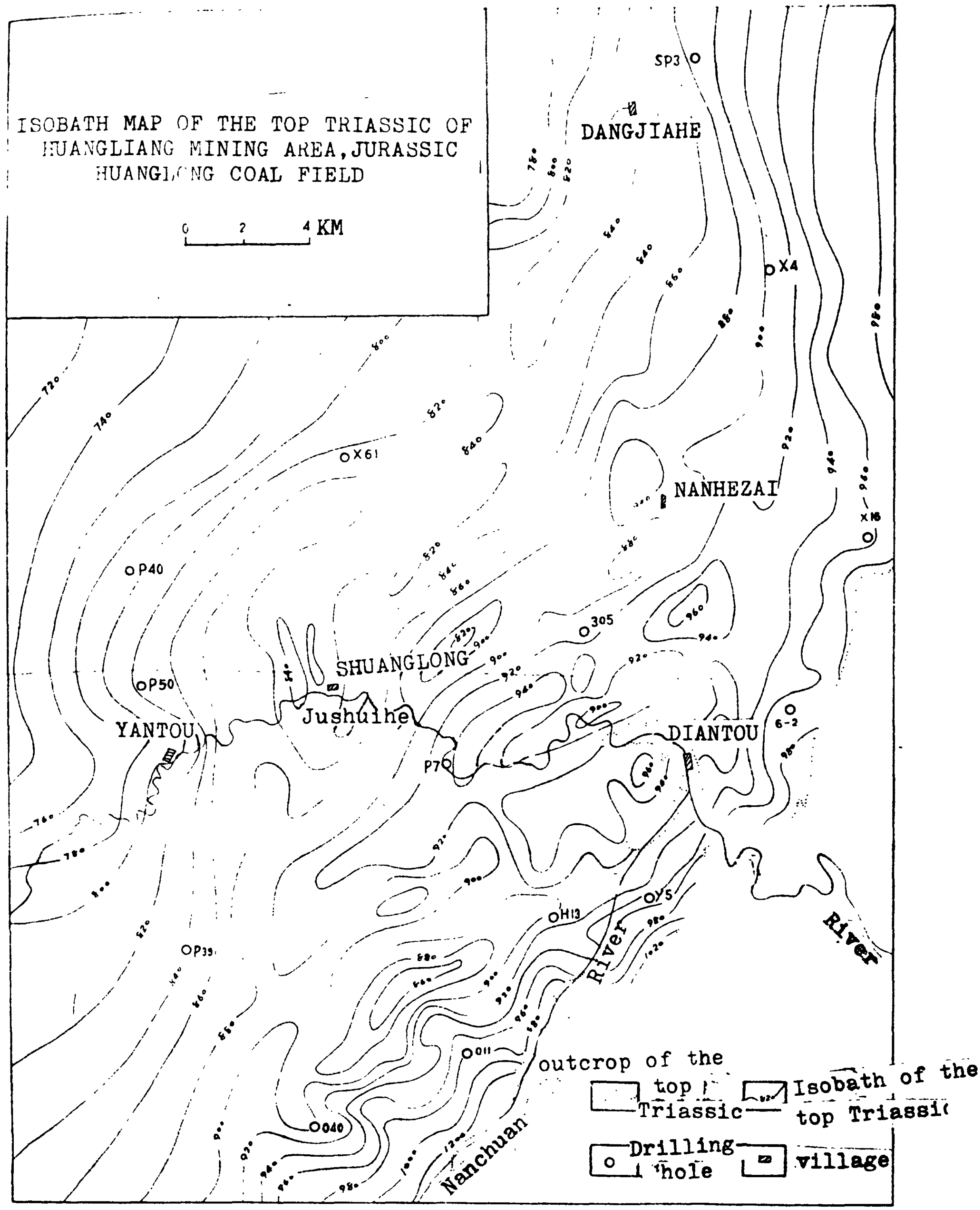

ISOBATH MAP OF THE TOP TRIASSIC OF
HUANGLIANG MINING AREA, JURASSIC
HUANGLONG COAL FIELD
0 2 4 KM
SP3
DANGJIAHE
X4
X61
NANHEZAI
X16
P40
305
SHUANGLONG
P50
Jushuihe
YANTOU
DIANTOU
6-2
P7
Y5
H13
P39
River
River
011
040
Nanchuan
outcrop of the top Triassic
Isobath of the top Triassic
Drilling hole
village

FIG.5

formation and was truncated by the erosion in a different degree in the upper part. Phase A of extensively Yanshan movement, which began after Zhilao and Anding formation, was deposited, is characterized by the folded mountain-building movement on the platform edges, which caused the unconformably contact between Jurassic and cretaeous systems, whereas uplift-subsidence movement occured in the platform proper to form parallel conformably contact between lower cretaceous and Jurassic. Phase B of Yanshan movement entirely uplifted the Ordos basin, exposed over the water-level and dissected by erosion, so the Tertiary system overlying unconformably on the underlain strata, modern geomorphic features resulted probably by the Himalayan movement on the basin of truncated by erosion during upper Tertiary period, thus coming to the close of sedimentary history of Ordos basin.

The frequently tectonic movements in the study area are mainly noted for the uplift-subsidence movement in brief, especially from Mesozoic Period. Comparing with earlier tectonic movement, the later is characterized by frequent and heritage on the paleouplifts and palaeodepressions to form the north-south trend anticlines which obviously controlled the sedimentation of Yan'an formation, especially the deposits and thickness of first and second member of the formation.

Part 4.

ANALYSIS OF DEPOSITIONAL ENVIRONMENT OF COAL-BEARING YAN'AN FORMATION

1. Lithologic Characters.

The Yan'an formation consists mainly of mudstone, siltstone, medium fine-grained sandstone, carbonaceous shale and coal deposits including five members on the basis of their lithologic characters and sedimentary cycles. As shown in Fig.6, Member I of Yan'an formation is characterized by their darkgray mudstone, siltstone intercalated with thin fine-grained sandstone, carbonaceous shale and No.2 seam group except have some local grayish white medium-fine feldspathic quartzite arenites at the base. This member ranges from 1 to 30 meters with average 15 meters in thickness which reflects the differential compaction caused by paleotopography, so the thicker on the centre of depression and thiner on the uplift (topographic high).

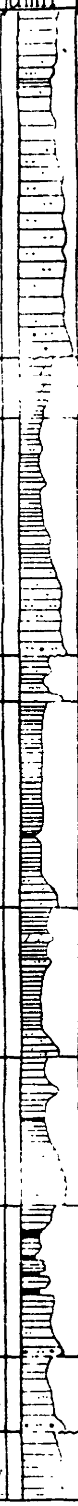
Member II ranges from 20 to 30 meters with as much as 22.4 meters nearby the Diantou study area with lithologic character of gray medium-fine quartzite sandstone, siltstone intercalated with thin mudstone and coal beds and gradually change laterally into fine-grain siltstone interbeded with mudrock.

The characteristics of Member III of Yan'an formation are represented by its stable thickness ranging from 20 to 30 meters varying from gray mudstone, fine-grain sandstone and calcareous siltstone, mudstone as well as lens-shaped siderites.

The Member IV of Yan'an formation in the study area ranges from 35 to 50 meters in thickness, which consists of dark gray siltstone, gray fine sandstone with local thin coal beds in lower part and mainly dark gray mudrock interbeded with siltstone, contains freshwater pelecypoda fossils.

FIG.6

GENERALIZED STRITIGRAPHIC COLUMN SECTION OF THE HUANGLING(DIANTTOU)MINING AREA



Strata		Column	Thickness (m)	major lithologic character
LOWER CRETACEOUS	K_1		133~156	upper part is interbed of light purple grey and mottled siltstone and fine- grained sandstone.the bed contain thin mudrock.lower part are brick and **brown red** middle-fine grained sandstones.lowest part is **conglomerate generally.**
			[illegible]	major part consists of **marls** and calo-mudrocks. lower part include dark grey.brownish purple or black oil shale.
ZHILUO FM.	J_{2z}		31~164 / 45~120	upper mainly consists of greyish green,purple red mudrock , sandy mudrock and siltstone,lower consists of greyish white-green block or thick bed middle to fine grained sandstone .lowest is fine sandstone usually.
YANAN FM.	$J_{2}y^{5}$		0~22 / 7	yellow-greyish green siltstone with mudrock.
	$J_{2}y^{4}$		1~49 / 40	sediments mainly consists of mudrock whick contains siltstone and include thin coal bed(No.).lowest is middle-fine grained sandstone.
	$J_{2}y^{3}$		4~45 / 20~25	lower part is middle grained sandstone.upper part contains a large suit dark grey mudrock or silty mudrock and include thin beds of **marls** and calc-siltstone
	$J_{2}y^{2}$		0~40 / 20~[illegible]	lower part is thick middle-fine grained sandstone,the upper mainly are mudrock,silty mudrock in which contain sandstone and thin coal bed(No.1).
	$J_{2}y^{1}$		0~30 / 7~15	mudrock and siltstone.with coal.lower part is sandstone.lowest part occasionally fine **conglomerate** .all four coal beds are 2^{-4}, 2^{-3}, 2^{-2}, 2^{-1}, from lower to upper.
*F. FM.	$J_{1}f$		0~78 / 5~20	northern mainly consits of sandstone,mudrock and siltstone interbedding;southern are "spotted mudrock".
Y.GP.	$J_{3}y$		not base	yellow-greyish green fine-grained sandstone with mudrock

*A Anding * F Fuxian *Y Yanchang

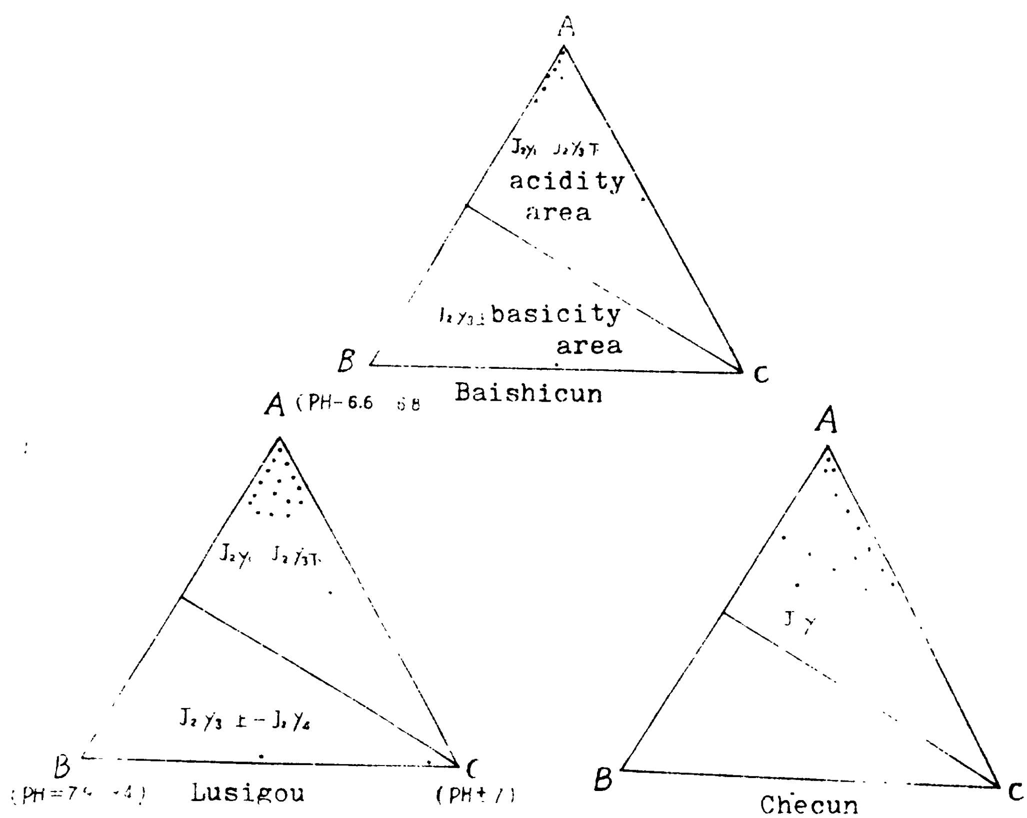
The Member V is characterized by it's grayish green, light gray siltstone, mudrock and sandstone with the purple mottled mudrock and siltstone at the top distributed in the northern study area. The remanent thickness is less than 10 meters, the maximum thickness is 22 meters.

The clastic component of Yan'an sandstone consists of following parts arranged in a descending order of abundance: quartz (88.3 to 91%), feldspar (3.6 to 7.2%), rock fragments (0 to 2%) and micas etc. (Table 1)

Cont. % Mb / Comp.	Member I	Member II	Member III	Member IV
quartz	88.25	87.08	91.00	88.30
fildspar	6.25	5.18	3.63	7.17
biotite	1.±	<1.00	0.90	0.50
muscovite	2.00	2.00	3.00	2.00
ditritus	2.00	2.00	0	0.50±

Table 1 showing composition of sandstone fregments content slices of quartz grains show mostly a single crystal grain and undulatory extinction which are usually microcline, orthoclase and limited amount of albite. Detritus is mainly composed of mud rock fregments, heavy minerals consists dominantly of zircon, tourmaline and rutile, the sandstone of Yan'an formation is poor to medium sorted with commonly cemented by muddy and iron material in lower part and calcareous cements in upper part with pored to contacted cementing.

The composition of clay minerals in Yan'an formation consists of kaolinite (mostly) and illite (secondly) in total member I, II and lower part of Member III. So, the project-points of composition are well located in acid area of the trangle-diagrams; however, the composition of the upper part of Member III and Member IV, V are dominately montmorillonite and illite, siderite sulfoferrite and other self-generated minerals. The project-points, of course, are all on the basic area (Fig.7). As above-mentioned, those characteristics suggest that palaeoclimate was probably warm humid, in addition, water medium apparently acid and oxidation reaction during early Yan'an formation; lately, the palaeoclimate was graduate changed into hot and water shows basicity and weakly reduction reaction, these matters have a controlling bearing on the accumulation of coal deposits.



FIG,7 TRANGLE--DIAGRAMS SHOWING CONTENTS OF CLAY MINERAL IN MUDROCK OF YANAN FM.
A--KAOLINITE, QUARTZE; B--MONTMORILLONITE,SIDERITE,SULF FERRITE
C--ILLITE;

2. The Features of Geophysical Log.

Geophysical exploration is one of necessary means for coal field prospecting with responsibilities as follows: to ascertain depth, thickness and texture of coal deposits; to find out the occurrence of radioactive minerals; and to determine the declination and temperature of drill holes by means of spontaneous potential (SP) and resistivity, gamma ray and gamma-gamma logs etc..

Comprehensive interpretations have been carried on from the qualitative analysis and coal seam determination and drilling-holes geological section by combination of resistivity log, gamma ray and gamma-gamma ray at 1:200 scale. The depth, thickness and texture of coal deposits are determined by gamma-gamma, resistivity log and ground resistance gradient log at 1:50 scale.

The geophysical characteristics of stratigraphic interval in Huangling study area were interpreated according to the statistical inference of field-log information as following (Fig.8).

Upper Triassic Yong-Ping formation consists mainly of siltstone and fine-grain sandstone, the value of apparent resistibility varies from 20 to 80Ω.M., which is a little higher than Fuxian formation and lower Yan'an deposits and a little lower than Fuxian and lower Yan'an formation in gamma ray log.

Lower Jurassic Fuxian deposits contained basal conglomeratic sandstone and conglomerates, however, is characterized by the lower resistance and lower density, which is a little higher than uppermost strata of Yangping formation.

The characteristics of middle Jurassic coal-bearing Yan'an formation are indicated by lower resistivity, moderate-density and high radioactive content of mudrock and siltstone except coal deposits, medium-fine grain sandstone and calcareous siltstones.

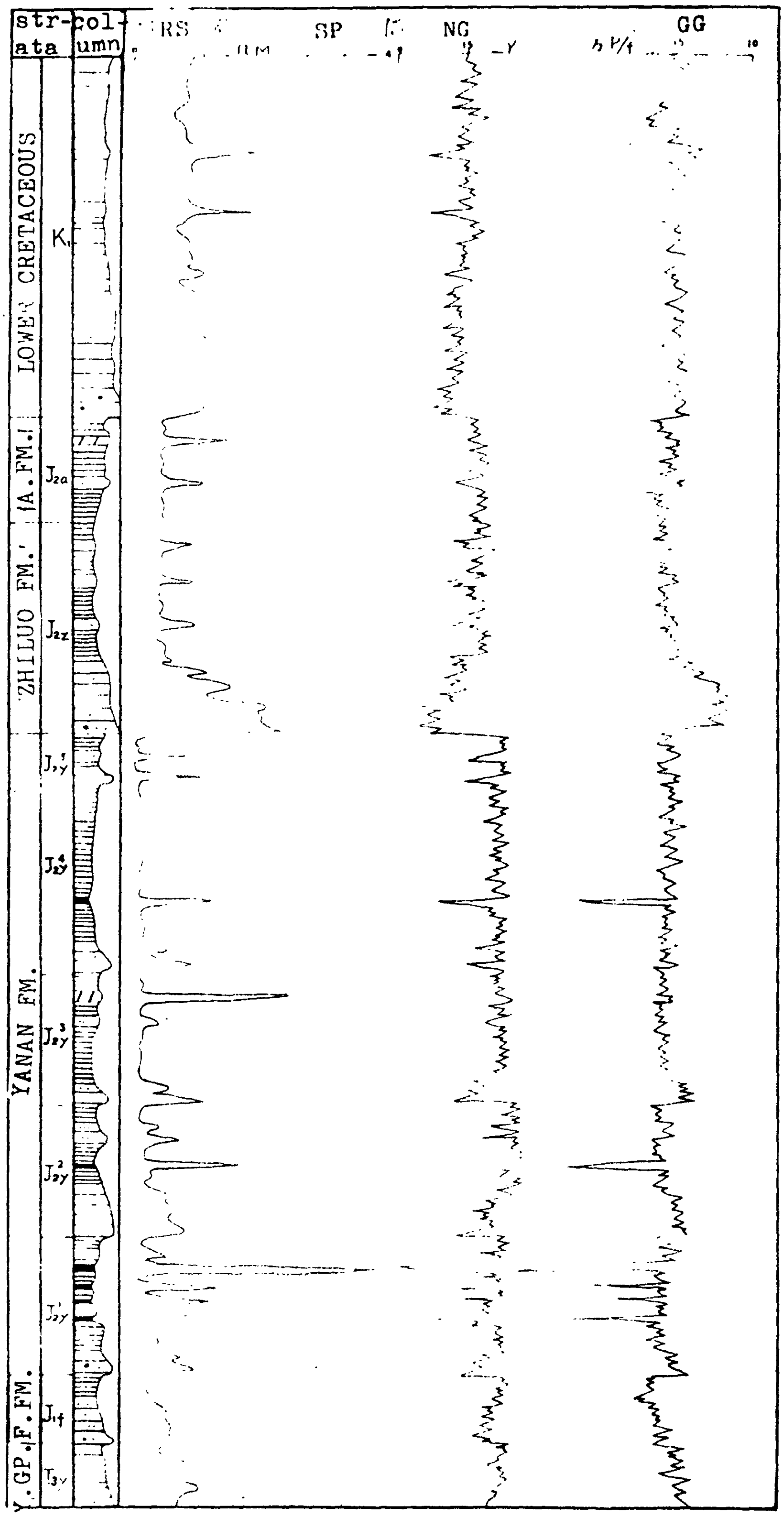


FIG.8 GENERALIZED GEOPHYSICAL LOGS OF THE HUANGLING MINING AREA

The resistivity and density of medium-finegrain sandstones is comparatively high, especially the lower part of Member II medium-sandstone nearby Diantou study area with up to 150Ω. M. apparent resistivity value only less than which of coal beds and calcareous siltstones.

The coal beds are, of course, marked by highest resistivity, smallest density and lowest radioactive elements content throughout whole hole-sections so that the unusual high (appear) value could appear on the resistivity and gamma-gamma ray and easy to find on the gamma ray logs.

The apparent resistivity value of calcareous siltstone is only less than which of coal beds and much more than which of the rest strata.

The above-mentioned geophysical characteristics of Yan'an formation is less changable along the strike and dip directions which suggested the Member III to V of Yan'an formation are very stable and could be correlated extensively.

The parameters of different lithology and geophysical characteristics of coal seams of Yan'an formation is showed on Table 2.

Param. / Lithology	Apparent resistivity (Ω.M)	gamma-gamma ray (p/f)	gamma ray (r)
mudstone	7 -29	50000-100000	18 - 30
siltstone	27 -40	45000-80000	17 - 24
calcareous siltstone	158-283	40000-65000	12 - 26
medium-fine grained sandstone	30-150	40000-65000	15 - 20
coal beds	80-420	7-20(million)	3 - 10

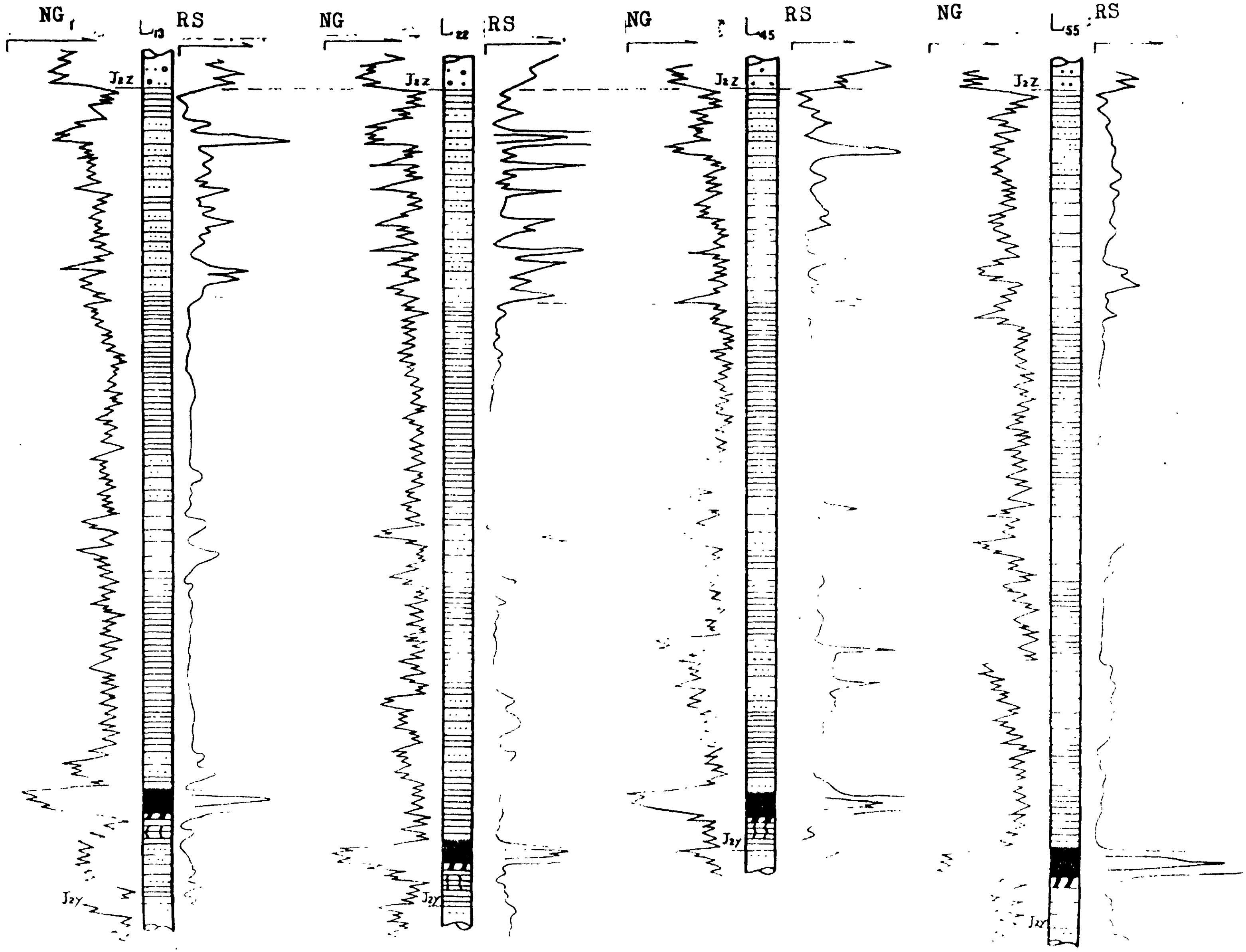


Fig.9. Correlation of geophysical logs along the strike of the Yan'an Formation, Huangling mining area.

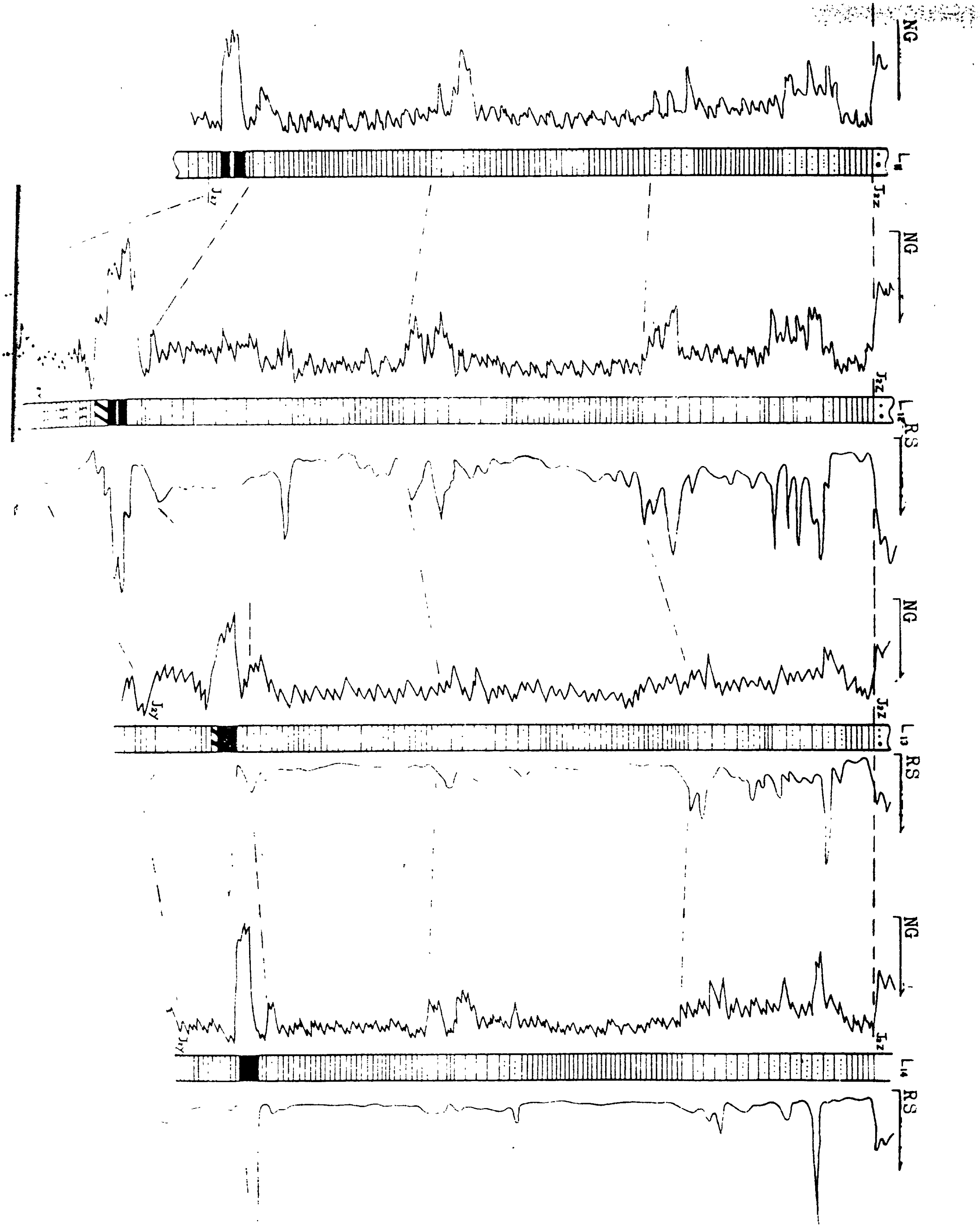

NG
RS

Fig.9 and Fig.10 showing correlation of Yan'an formation.

Mid-Jurassic Zhiluo formation is characterized by basal thick, medium-coarse sandstone which shows obviously high apparent resistibility and density as a primarily marker beds the curve by contrast to Yan'an formation, middle-upper of Zhiluo formation is noted for the alternate deposits of sandstone with high resistivity and low-resistibility mudstone, so the deformation of resistibility curve pattern is outstanding characteristics for Zhiluo formation.

The characteristics of middle Jurassic Anding formation are basically for its lower-resistibility shale, mudstone and siltstone. The value of resistivity ranges from 15 to 50 . M. with lower and gentle pattern of curve, while mudstone and calcareous sandstone, however, have abnormal high and as much as 300 Ω. M. apparent resistibility for mudstone.

Lower cretaceous Luohe formation is characterized by its very low, smooth curve pattern because of the loose porous cemented sandstone which is full of water. Other parameters curves are also normal (usual).

The apparent resistibility and density of cretaceous Huachi-Huanhe formation are higher than Luohe formation.

The comprehensive interpretation derived from a series of geophysical logs in Huangling study area emphasized that the ulilization of log information to divide the subsurface stratigraphic units and to determine the depth and thickness of coal deposits, and to reconstruct the stratigraphic framework are most available and reliable.

It's also possible to primarily inquire into the sedimentary environment of coal-bearing Yan'an formation by the use of gamma-ray log combined with apparent resistibility curve. As shown in Fig.11, geophysical-log interpretation of thick mudrock for Member III of Yan'an formation should

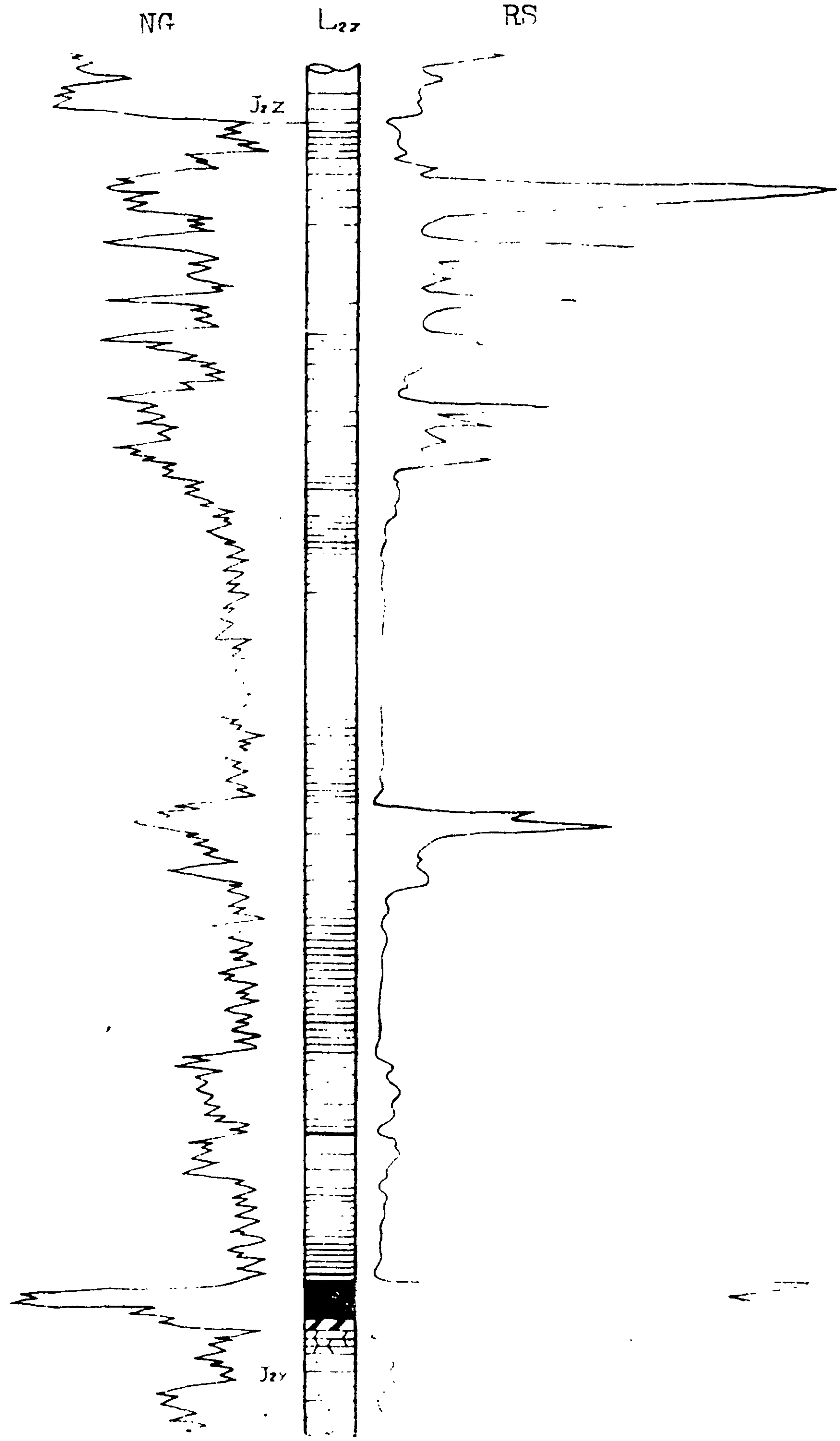


FIG.11. SHOWING GEOPHYSICAL LOGS FOR HOLE L22 OF THE YANAN FM. HUANGLING MINING AREA

therefore reflect (indicate) the quiet stable waterbody deposits which are characterized by high gamma-ray responses and very low apparent resistivity.

The symmetrical pattern of Member IV of Yan'an formation contained thin alternated siltstone and fine-grain sandstone sediment shown obvious changes in nature-gamma and apparent resistivity curve which is indicative of lake beach deposits marked by the frequently alternated process of regressive and transgressive.

Characteristically, the symmetrical pattern of Daitou sandstone of lower Member II of Yan'an formation is proved by stable property of gamma-ray curves.

All we can say is geophysical logs of coal exploratory holes are good for detailed analysis of sedimentary environment and have specific value.

3. Lithofacies Analysis.

Detailed studies of the structures, vertical lithologic changes, mineralogical variation and fossil content of interior basin sediments permit to determine facies of coal-bearing Yan'an formation, which can be grouped into alluvial, swamp, laeustrine-delta and lacustrine lithofacies.

(1) Alluvial Facies.

The accumulation of this facies generated in the early-Middle Jurassic period are locally distributed in Cangcun and northern Cangcun area have a planer belt distribution at the base of Yan'an formation. So that thickness varies to 25 meters in Cangcun area with average within 10 meters. The alluvial facies is differentiated into fluvial channel and over-bank subfacies according to individual characteristics.

The characteristics of fluvial channel subfacies are indicated by their light gray medium-coarse sandstone, local basal conglomerates comprise poor sorted quartze and silex and consists of linear cross-beds and cross bed.

The overbank plain subfacies is associated with fluvial channel subfacies and consists of mainly light gray fine-grained sandstone and siltstone etc..

(2) Swamp Facies.

This facies can be subdivided into closed swamp (poor drainage), open swamp(good-drainage) and peat-swamp subfacies according to the basin's hydrodynamic function and sedimentary characteristics.

Closed swamp subfacies is characterized by their grayish siltstone, mudrock, abundant vertical root fossil content and crumble tecture, which usually pass below the open swamp and peat swamp facies marked for the floor and parting of coal deposits.

The characteristics of open-swamp subfacies are indicated by their horizontal and irregular horizontal stratification consisting of mainly carbonaceous mudrock and siltstone with high carbonaceous content these used to be the roof and parting of coal beds.

Peat-swamp subfacies, was interpreted as the most favorable environments for coal accumulation. There are two kinds of peat-forming swampings: lake beach swamping and local delta plain swamping according to their origin. This difference is probably directly related to the evluation of environment, and the former permitted the continue accumulation of thick peats to form widespread, medium thick coal deposits recongnized as main minable coal beds, which can be demonstrated in variation of thickness and number of coal seams under the affect of palaeotopography.

The peat deposits in the delta-plain swamping are characterized by thin but wide spread coal distribution because the short period of coal accumulation, and which overlapped immediately by lake transgressive deposits, distributed within the delta plain.

(3) Lacustrine-delta Facies

As illutrated on Fig.12, occupying in the Member II of Yan'an formation, lacustrine-delta facies show interfinger toague trendtoward in the orientation of Dianton to northwesv direction, it is constructed from precess of fluvial deposits were washed debouching into lake, and which consists of three-layered texture of delta deposits. That is, predelta on the lower part, delta front facies in the middle, and delta plain in the upper part.

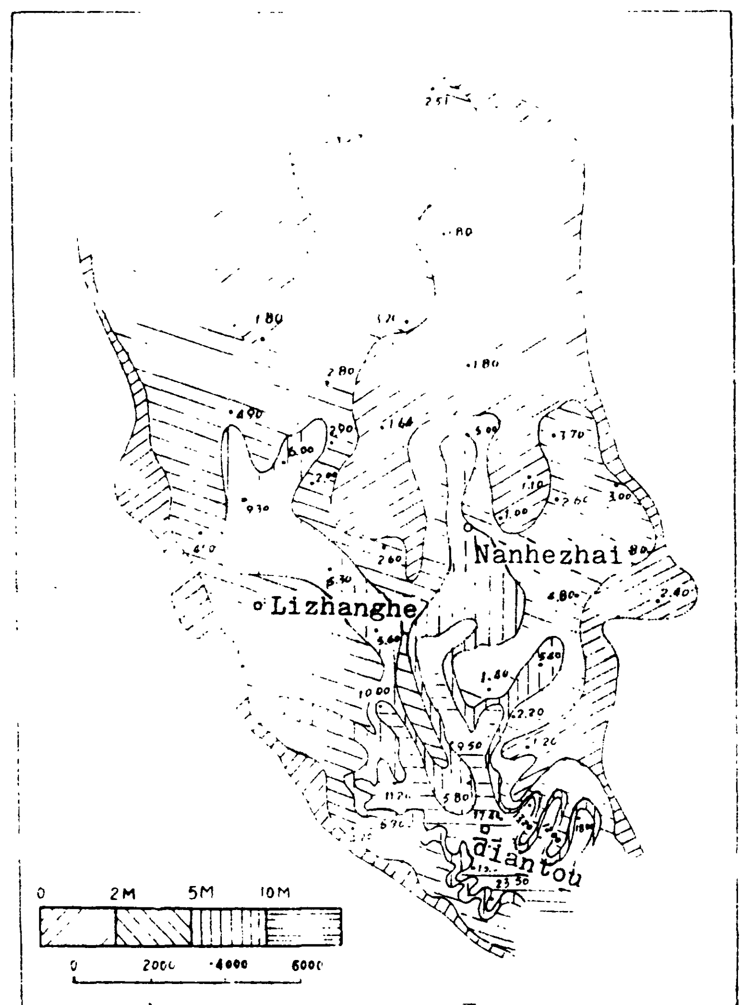


Fig.12 Isopath of Diantou Sandstone body

A/ <u>Predelta facies</u> consist mainly of dark green siltstone, mudstone and a limited amount of fine-grain sandstone interbedding one another, which displaies horizontal and current bedding to form the sedimentary ripple lamination commonly marked by abundant charcoal and plantfragments on the layer surface as well as a few whole leaves.

B/ Delta front facies is sedimented on the front of delta plain because of the variation of underwater topography and reducing of the current velocity, the facies deltaic deposits can be grouped into distributary mouth bar, interdistributary bay and distal bar subfacies.

(a) Distributary Mouth Bar Subfacies

This deposits accumulated on the delta front at the lake ward terminus of distributary channels. The detritus was deposited as a result of the reduction of water velocity and transporting competence in the distributary channels as it debouched into the lake marked by the wedge cross bedding, current-bedding and coarsen upward sequences of sandbodies, this subfacies grade laterally into distributary channel deposits.

(b) Interdistributary Bay Subfacies

These deposits consist mainly of siltstone, fine-grained sandstone parting with a limited thin mudstone and show horizontal lamination, current bedding and oblique current bedding with the plant fossil fragments and coal shed. The division of lithostratigraphic boundary with predelta facies is difficult and also grading laterally into distributary mouth-bar surfacies.

(c) Distal Bar Deposits

These deposits consist mainly of horizantal and current bedding, fine-grained sandstone and siltstone which record deposition of coarse detritus generated by flood incursion from the distributary mouth is corroborated by the presence on front and flanks of deltaic sand body of wide spread sheet sand deposits.

C/ Delta plain facies is distributed on the upper part of delta depositional system , which can be subdivided into distributary channel and overbank plain deposits.

(a) Distributary Channel Subfacies

The distributary channel deposits are characterized by abundant sand content of the medium to fine-grained quartz arenites interbeded locally with coarse lense-shaped sandstone which mainly show medium size wedge cross-bedding; medium to thick bedded, and poor to moderate sort as well as cross-beds, current bedding. A small amount of ironized wood, mud enclaves and ripple marks in parts of the area. The sandbody distributed like a belt laterally shows large-scale lenticular deposits which changed into siltstone and fine-grained sandstones gradually (Fig.13).

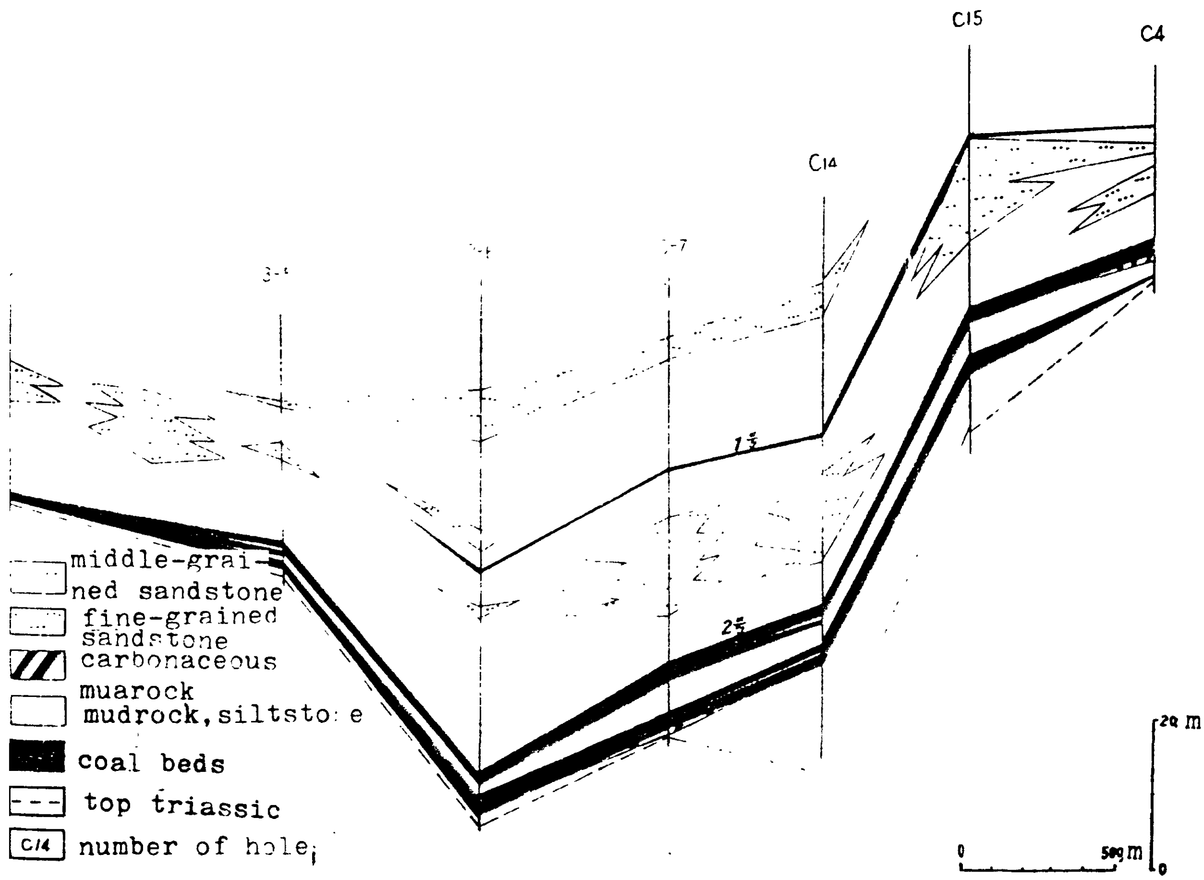
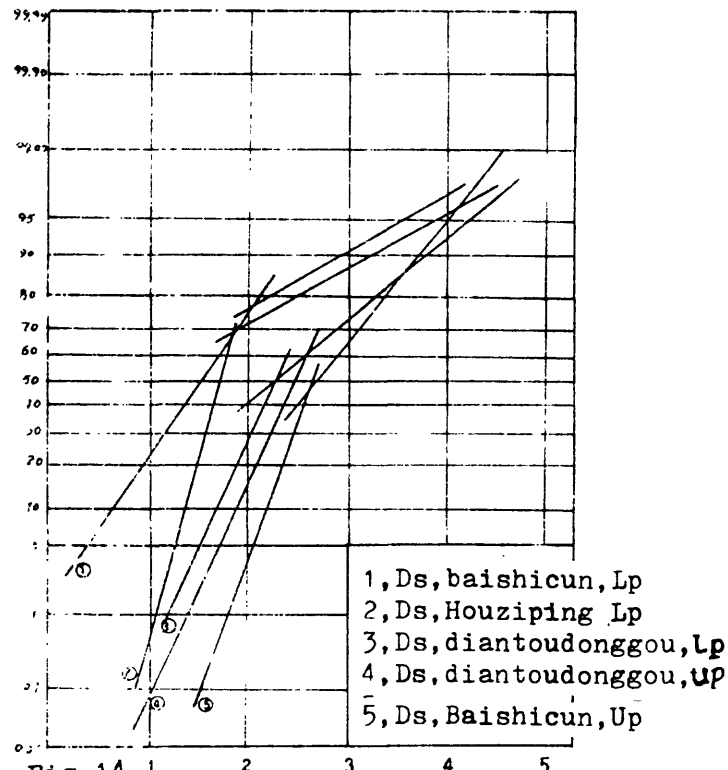


FIG. 13 VARIATION MAP OF SANDSTONE BODY OF THE LOWER YANAN FM.

As illustrated in Fig.14, the pattern of the grain-size probability plots of Member II sandstone of Yan'an formation is shown on Fig.14, the characteristics of curve represented by two-segment lineament which is indicative of the jump-subsegment and suspending sub-population and lack of draw-flowing particle generally.

Jump sub-population (deposits), occupied 64 to 75 percent, dipping from 55° to 75° on probability curves, is well sorted, whereas the oblique angle suspending population grade from 30° to 49° and moderate-sorted. The eritical points is about 2 Φ according to above features, it should belong to distributary channel sand.



Fig,14 Probability Diagram of grain_size of the
*Ds-Diantou sandstone
*Lp-lower permian
*Up-upper permian

(b) Overbank plain subfacies (flood plain)

Consisted mainly of lacustrine, marsh swamp, peat-swamp deposits, and overbank plain facies are characterized by its siltstone, mudstone and coal deposits with fine-grained sand-stone in parts of area. The characteristics of peat swamp sediments are persistent, thin and laterally widesoread across the extensively area which delineates the delta deposits system (coincident with the delta deposits system).

(4) Lacustrine Facies.

Occopied in Member III and IV of Yan'an formation, continental lacustrine deposits are characterized by their extensively widespread and stable lithofacies as well as lithologic characters. The Member I and II, however, show variable lithofacies and lithological features reflecting the releatively limited distributary area. The facies of those rock units can be subdivided into lake-beach, lake shore and lake subfacies according to the sedimentary characteristics. All releationships were illustrated on Figs. 15, 16 & 17.

A/ Lake-beach Subfacies

This facies are mainly distributed in lake beach area in which influened frequently by wave breaker such as Wangjiaping and Xiantoucun in the northeast study area. Sandbeach sedimentation records the fine-grained detritus brought into deep water body settling along the lake shore. Sands generated in beach area are well sorted, and showing current-bedding-dominated as well as small-medium gentle lineament, horizontal bedded, lense-shaped beds and plant fossil fregments and charcoals on the bedding surface with facies changing upward into lake shore deposits.

B/ Lake Shore Subfacies.

The deposits consist mainly of medium sorted, current-bedding and lense-shaped beds, irregular horizontal lamination fine-grained sandstone and siltstone, which contain plant fossil fregments and charcoals passing below the basement of Member III and V of Yan'an formation and distributed between lake surface and wave base level.

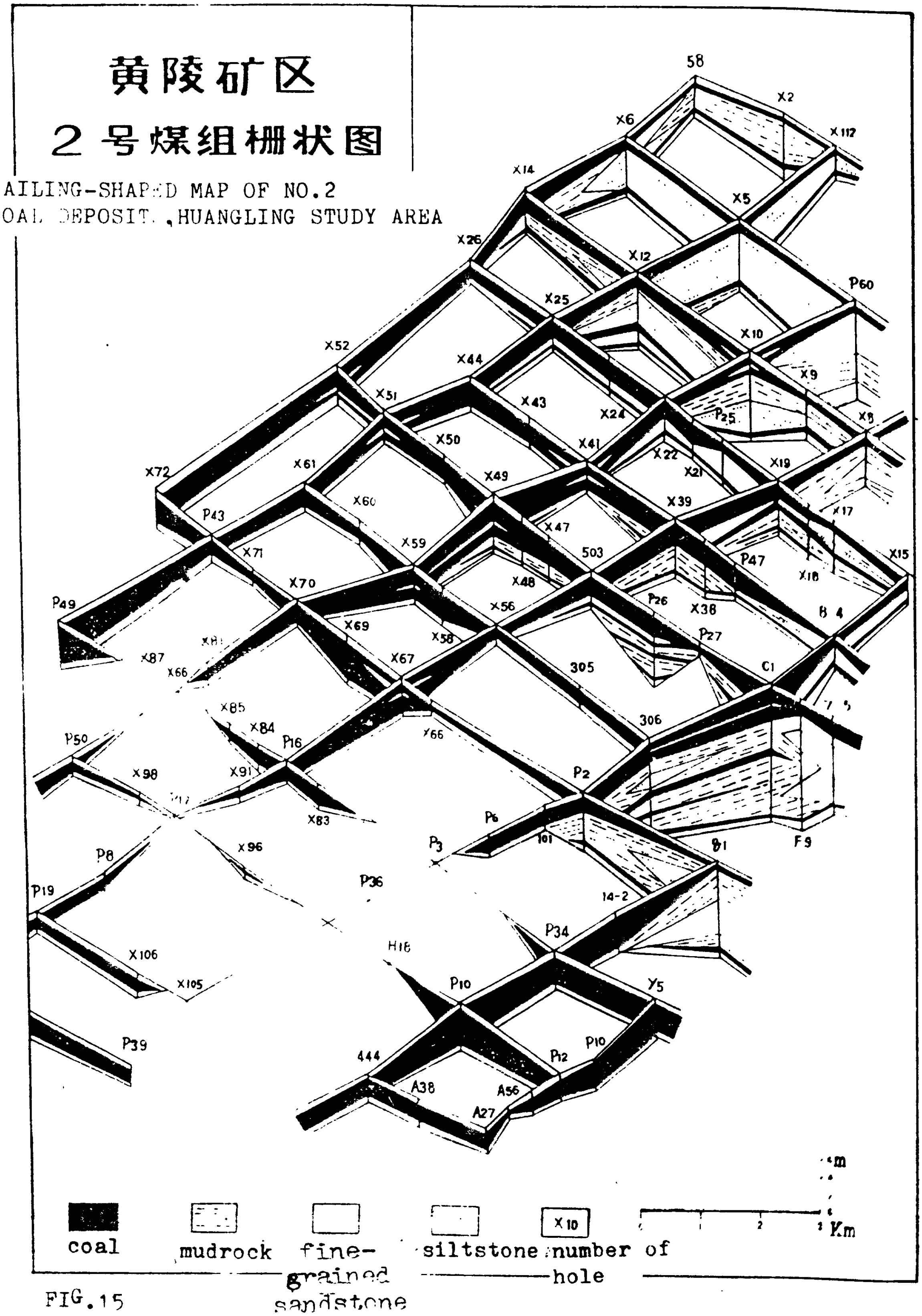

黄陵矿区
2号煤组栅状图
RAILING-SHAPED MAP OF NO.2
COAL DEPOSIT ,HUANGLING STUDY AREA
coal
mudrock
fine-grained sandstone
siltstone
number of hole
X10
Km

FIG.15

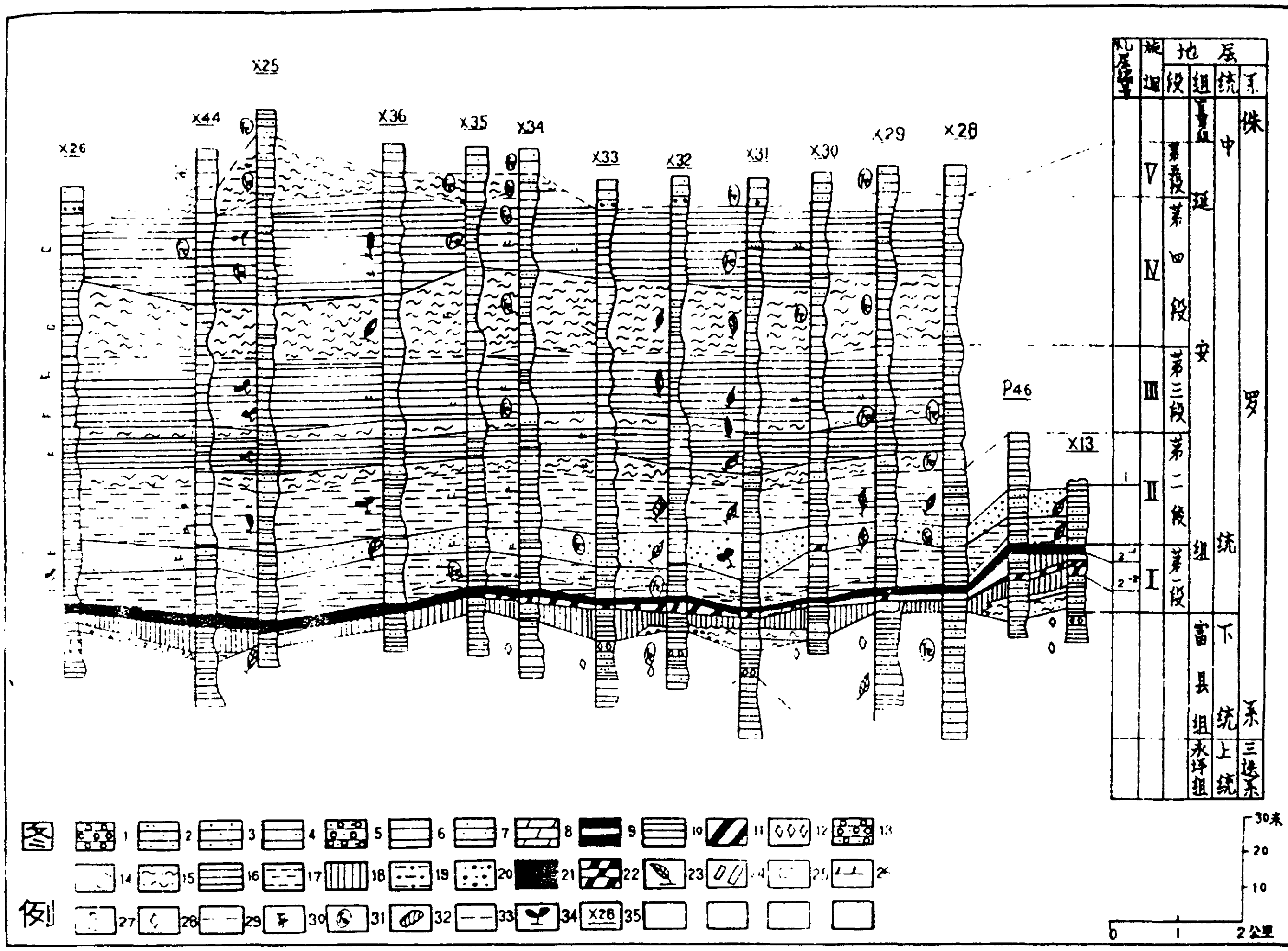


图 16 Lithofacies section (dip-direction) of Yan'an Fm. Huangling Mining area.

1. conglomerate.
2. middle-grained sandstone.
3. coarse sandstone.
4. fine-grained sandstone.
5. sandy conglomerate.
6. sandstone with gravel.
7. siltstone.
8. marl.
9. coal & parting.
10. mudrock.
11. carbonaceous mudrock.
12. sideritic layer.
13. fluvial channel facies.
14. lake shore facies.
15. over-bank plain.
16. lake.
17. delta plain.
18. closed marsh.
19. sand beach of lake shore.
20. delta front.
21. coal.
22. open swamp.
23. plant fossils.
24. ironized wood.
25. pyrite.
26. plant fragment.
27. animal fossils.
28. siderite.
29. boundary of cycles.
30. plant root.
31. iron concretion.
32. mud enclave.
33. parrallel-nonconformable lines.
34. carbonized wood fragment.
35. number of drill hole.

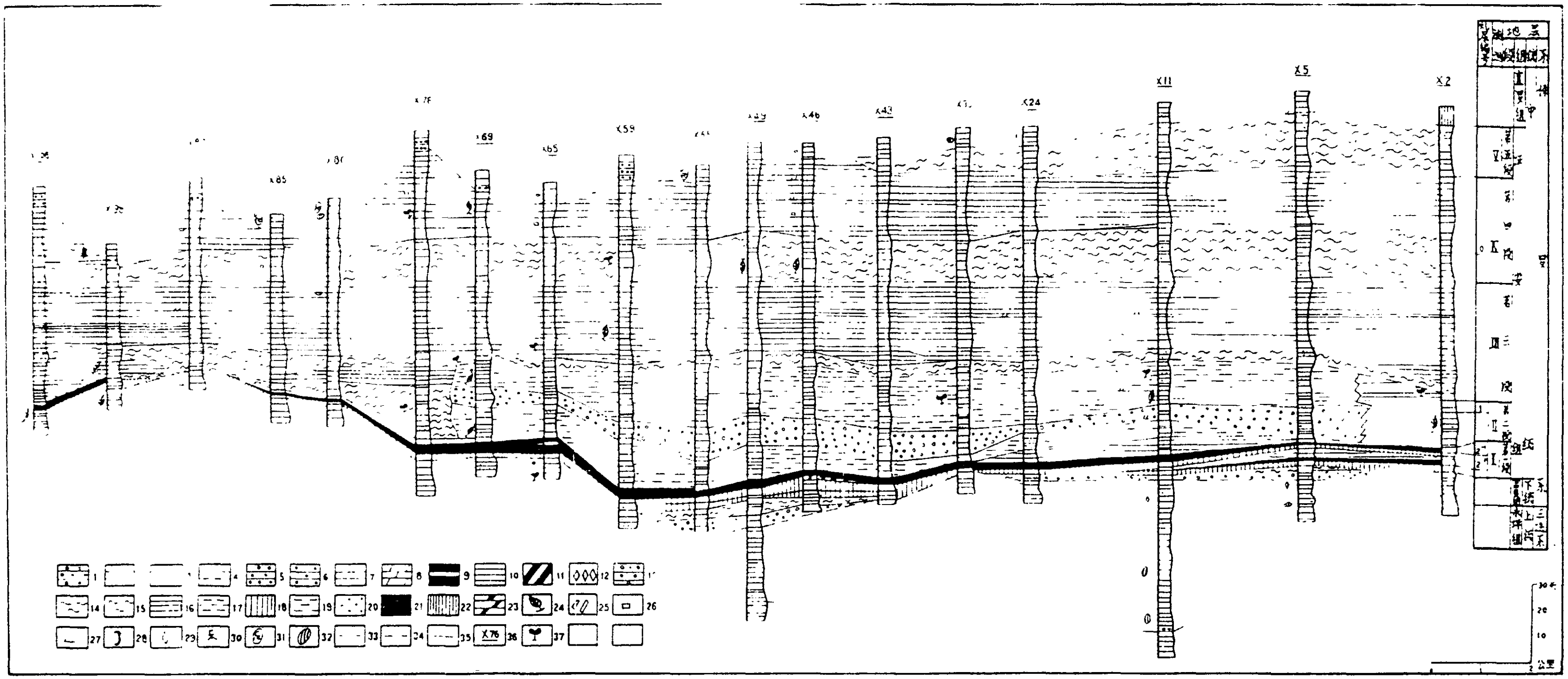


FIG.17 LITHOFACIES SECTION (STRIKE DIRECTION) OF YANAN FORMATION, HUANGLING MINING AREA

1. conglomerate
2. middle-grained sandstone
3. coarse sandstone
4. fine-grained sandstone
5. sandy conglomerate
6. sandstone with gravel
7. siltstone
8. marl
9. coal and parting
10. mudrock
11. carbonaceous mudrock
12. siderite layer
13. fluvial channel facies
14. shore lake facies
15. over-bank plain
16. lake
17. delta plain
18. closed marsh
19. sand beach
20. delta front
21. peat swamp
22. loess
23. Open swamp
24. plant fossils
25. ironized wood
26. pyrite
27. plant fragment
28. animal fossils
29. siderite
30. plant root
31. iron concretion
32. enclave
33. parrallel nonconformable line
34. cycle border-line
35. boundary
36. number of drill hole
37. carbonized wood fragment

C/ Lake Subfacies

The characteristics of this facies are indicated by its mudstone-domminated content and limited amount of siltstone, fine-grained sandstone, calcareous siltstone and marl. The uniform laminated structures display alternating dark and light layers (varves) which containing whole plant and pelecypoda fossil were reoresented as the seasonal fluctuation of lake-water body.

4. Types of Associated Facies of Sedimentary Cycles.

The lithostratigrapgic division of Yan'an formation coincides with the differentiatation of sedimentary cycles which reflect the depth variation of the lake resulting from the crustal oscillation events during the early-middle Jurassic period.

(1) Cycle I

Cycle I is a principal coal-bearing cycle which can be grouped into two associated lithofacies types:

A/ Fluvial-lacustrine swamp.

The fluvial-lacustrine deposits are local distributed on the basal sandstone of Yan'an formation which probably prm iarily controlled by predecessor of Changcunhe river during the early middle Jurassic period, with its base on Fuxian formation of lower Jurassic or Yongping formation of upper Triassic system, the accumulation of thick peat may have been present on the base of fluvial channel, overbank plain deposits systems. As shown in Fig.18, the planimetric distribution of this is mainly of carbonaceous rock and sandstone facies districts with facies sequences as following: fluvial-channel - overback - swamp - peat - swamp - lacustrine (lake swamp facies) facies, generally speaking, range from 20 to 30 meters in thickness.

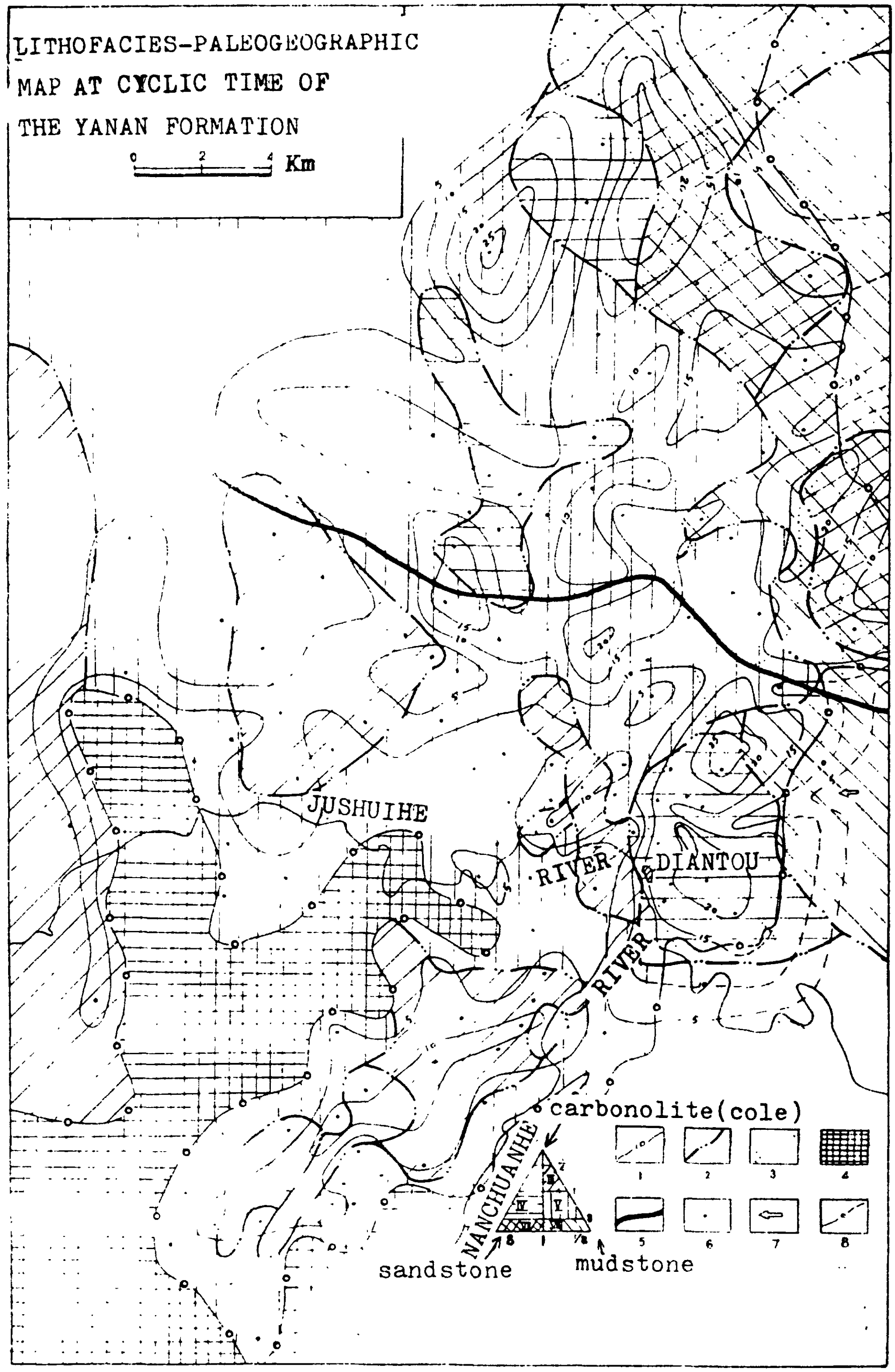


FIG.18 1.isopach line 2.zonning line of lithologic correlation 3. paleo channel of yanan Fm. 4.uplift area 5.boundary between areas of lake-swamp in hill and in plain 6.drilling hole 7.sources area 8.boundary of mining area

B/ Lacustrine Peat Swamp.

The characteristics of lacustrine type deposits are defined by their extensively distributation except for a few palaeo-uplifts. The peat swamp is distributed on the erosional surface of Fuxian formation and slope wash, dilluvial deposits contain shallow lake which predominately located on the carbonaceous rock, mud-carbonaceous, carbonaceous-mudstone and mudstone facies areas(Fig.18). Generalized sequences of lithofacies arranged in upward order: swamp → peat swamp → lacustrine facies (lake- swamp), range from 5 to 10 meters in thickness.

(2) Cycle II.

Associated sediments of cycle II can be subdivided into two types:

A/ Lacustrine-delta type.

Distributed on the middle part of the study area, lacustrine-delta's sandbody elongates from edge of the basin to northwest direction with some variation in lithologic character and thickness. The generalized trend of variation is that: grain size getting finer to northwest direction, decreasing of sand content while mudrock content and number of sand layers increasing; thickness getting thinner single bed. Delta sandstone body can be divided into "back seat", "core" and "front marginal" three zones. As shown in Fig.19, we can obviously observe the "core" and "front marginal" zones while the "back seat" zone had been already eroded.

Generalized stratigraphic lithofacies of lacustrine delta associated section arranged in predelta, delta front and delta plain facies from lower to upper, ranges from 30 to 40 meters in thickness, so lacustrine delta deposits can basically be divided into three types according to the characteristics of sandstone body in different place of delta deposits system (as illustrated in Fig.20).

Lithofacies-paleogeographic map at cycle II time of Yan'an Formation.

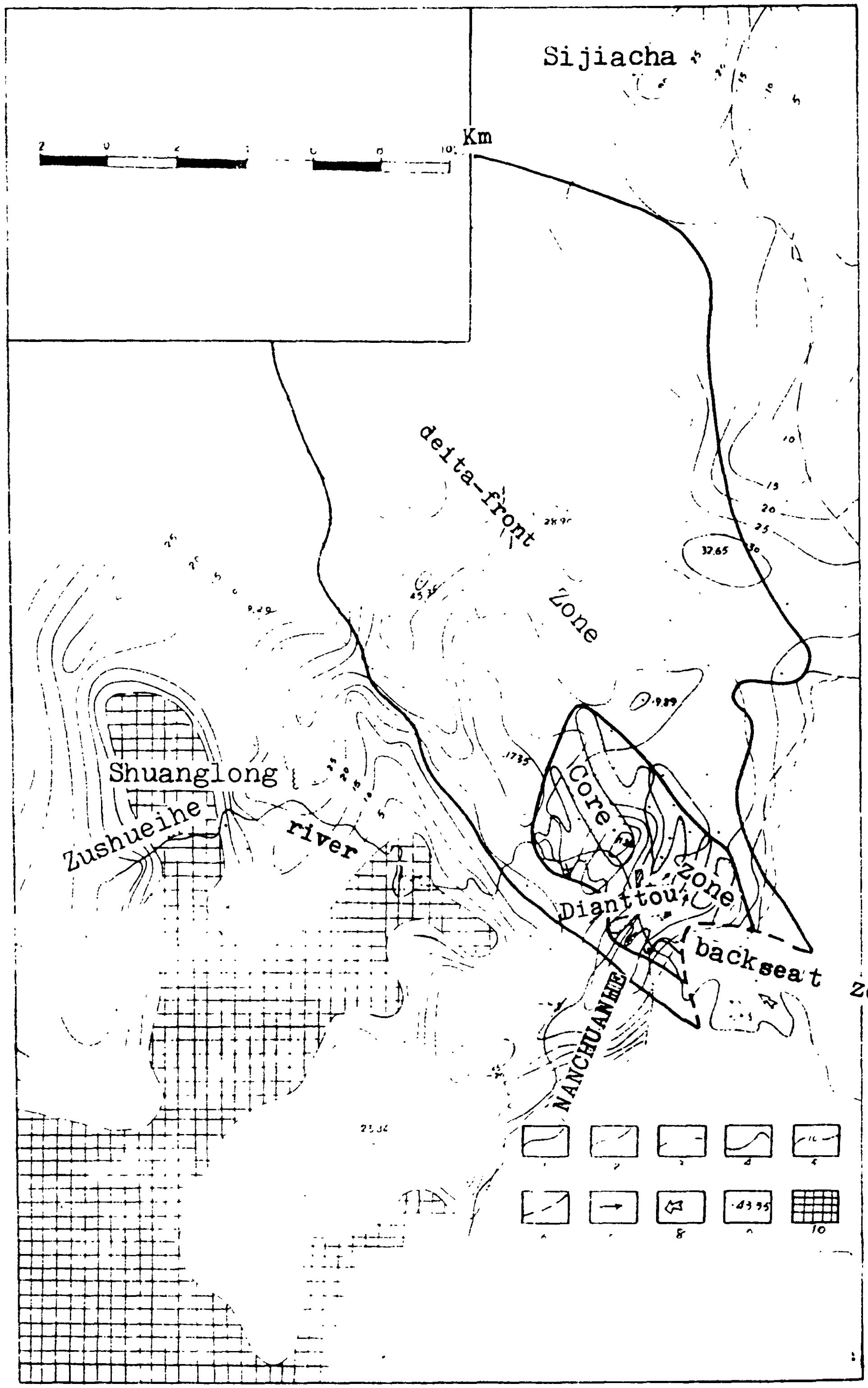


Fig.19.

1. boundary between lake and delta system.
2. boundary of "delta-front" zone and "delta-core" zone of delta sand body
3. boundary of "coae" and "back-seat" zones.
4. distributary channel.
5. isopach line.
6. border line of mining area.
7. distributary channel direction.
8. main stream direction.
9. measured point and sediment thickness in cycle II.
10. uplift area.

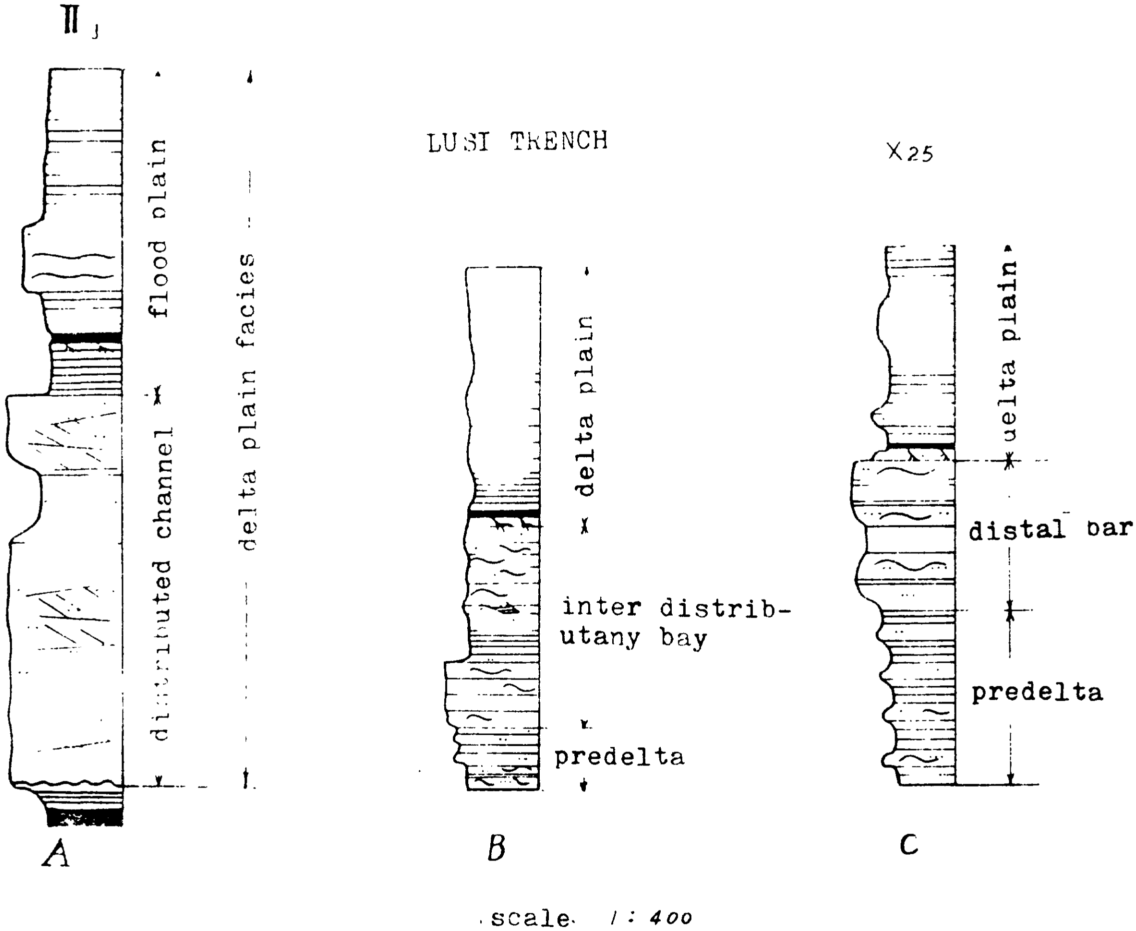


FIG.20 SHOWING MODEL OF VERTICAL SEQUENCE OF DELTA CYCLES

Delta plain facies are most favorable accumulated in distributary channel area with the sequences of distributary channel-overbank plain subfacies after the delta front and predelta deposits had been scoured by the distributary channels, Fig.20-B is located between distributary channels, recognized as the delta front deposits consisting of interdistributary bay subfacies in which sandstone interbedded with siltstone showing similar characteristics to the predelta sediments with the sequences of predelta → inter-distributary bay – delta plain facies, Fig.20-c, however, distributed on front area of delta and its both flanks, consists of distal bar deposition with the sequences of predelta → distal bar - delta plain facies.

B/ The Type of Lacustrine Deposits.

Distributed on both sides (flanks) of lacustrine delta deposits, this area is between Caojiayu and Dianzigou creck. The associated lithofacies of lacustrine consists mainly of lake shore-shallow lake subfacies with less than 20 meters in thickness, whereas associated lithofacies in Wangjiaping of southern study area and Xiantoucun in the north show the sequences of sand beach-shallow lake subfacies resulting from far distance to lake shore, more than 20 meters in thickness.

(3) Cycle III.

The associated lithofacies of cycle III is well defined as lake shore-lake facies characterized by simple cyclic texture, extensive and stable distribution of sediments which overlying on the Yongping formation of later Traissic period in Wangjiaping of southern study area, ranging from 20 to 30 meters in thickness.

(4) Cycle IV.

The characteristics of cycle IV are similar to cycle III associated with the lake shore-lake deposits with also simple cyclic texture widespread and usually more than 40 meters thick swamp facies distributed locally.

(5) Cycle V.

The cycle V, however, is an incomplete cycle remaining only the lake shore subfacies in the lower part, the upper part already eroded, which represented the crustal uplift during the post-Yan'an time.

The sedimentary of coal-bearing Yan'an formation, based on vertical grain-size variation, nature of coal-bearing, the differenttiated associated relationship of lithologic, lithofacies, had been grouped into fluvial-lacustrine swamp, lacustrine swamp, lacustrine delta and lacustrine four sedimentary systems. Those characteristics on facies are probably directly related to the evolution of sedimentary environment at Yan'an time. Table 3 shows relationship of sedimentary system, and their associated with variation types of lithologic and lithofacies, abundance of coal.

Sedimantary system	Lithologic character	Lithofacies	Stratigraphic position	Abundance of coal	Coal-accum. environ.
Lacustrine system	Muddy-clastic-dominated	Lacustrine-facies-dominated	Upper	Very poor	Lake-shore swamp
Delta system	Sandstone-siltstone-dominated	Predelta, delta front delta plain	Middle -lower	Poor	Delta plain
Fluvial-lacustrine -swamp system	Sandstone in basement mudrock - coal-dominated	Alluvial in lower part, lacustrine on upper	lower	good	Fluvial-channel lake
Lacustrine -swamp system	Mudrock-coal-dominated	Swamp-dominated	lower	very good excellent	Lacustrine-swamp

5. Sedimentary Environment of Coal-bearing Yan'an Formation.

(1) General Survey of Palaeogeography of Pre-Yan'an Deposition.

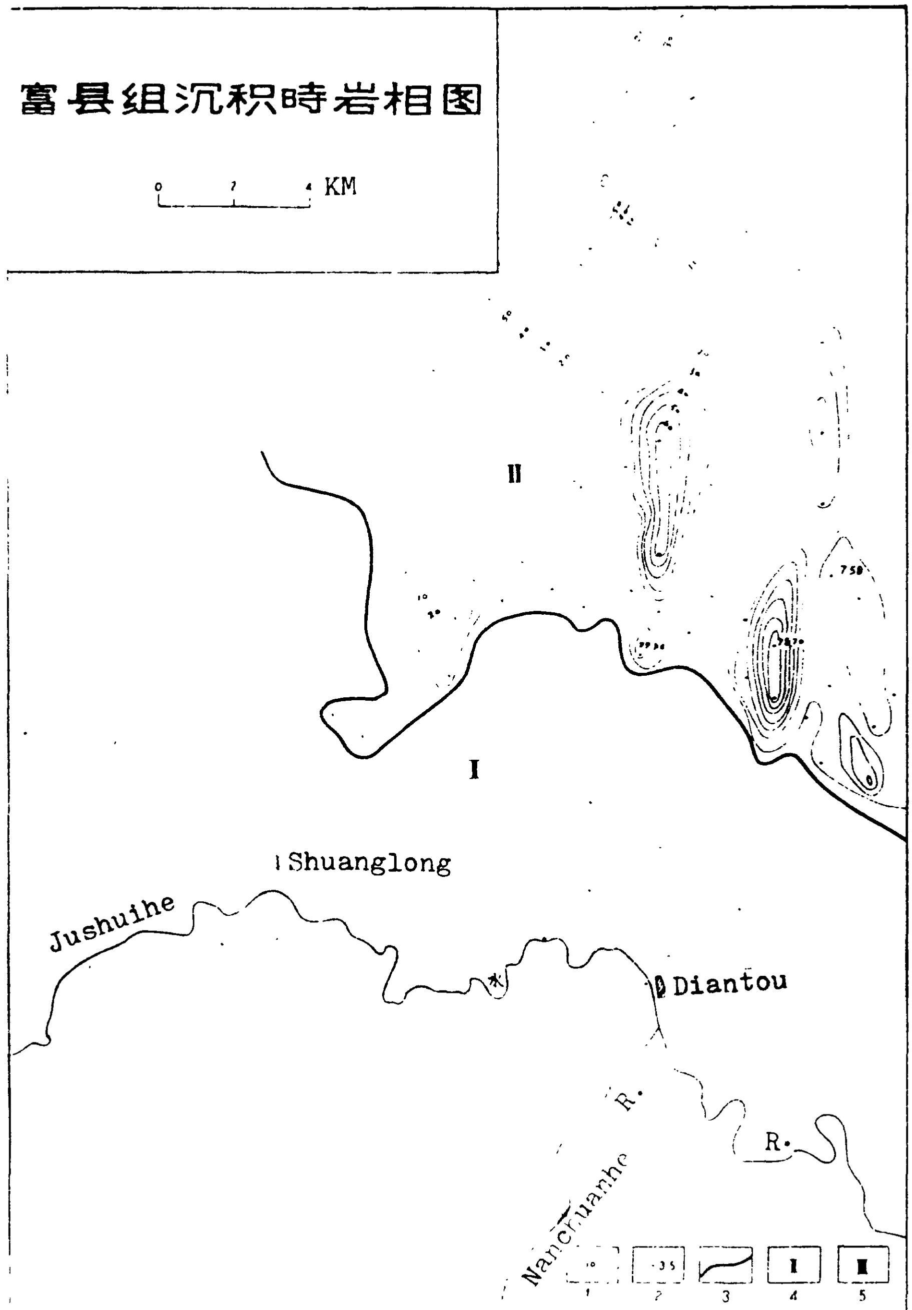
Reconstruction of the palaeogeography of coal-bearing Yan'an formation is made possibly by the analysis of distribution of Triassic strata which had undergone different degrees of erosions due to the uplifting resulted from the Indo-China movement after Triassic system deposition to form topographic high in northwest. Wayaobu formation of upper Triassic in study area of southeast edge of Ordos basin is absent because of extensively erosion by tectonic denudation of Indo-China movement to form geographical landscape tilted northward at that time. Fuxian formation, however, is underlying immediately on the erosional relief showing the variation of thickness and lithologic characters strictly controlled by palaeotopography.

As shown in Fig.21, the topographic high of south of Niujiazhuang-Nanhezhai-Liozhanghe line are characterized by the erosional and residual facies regions, mottled mudstone and alluminium mudstone with usually less than 1 meter thick up to a few meters locally, which was obviously recognized as the weathering mantle.

This is local residual facies on the erosional surface, whereas the northern part at this line, is belong to the shallow lacustrine slope-alluvial facies district characterizing by the gray-green, purple-mottled-dominated mudrock, siltstone interbeded with grayish white medium arenites with the basal conglomeratic sandstone and conglomerate, and comparatively thick in topographic lows.

Fuxian formation of low Jurassic is, on the whole, defined as a series of slope-alluvial deposits far from the sources areas with arid palaeoclimate.

FIG.21 LITHOFACIES MAP SHOWING THE CHARACTERS AT FUXIAN TIME



1.isopach 2.thickness 3.boundary between lithofacies zonning 4.erosion and eluvian area 5.area of slope-diluviol deposite with shallow lake deposits :

Although the palaeotopographic variation of Huangling study area caused the differentiated sedimentation in erosional uplift of southern part and accumulation in topographic low of north part, topographic irregularity nevertheless was reduced from the process of fill-erosion interaction which served as a most favorable presupposition of topography for (attributing to) sedimentary of coal-bearing Yan'an formation.

(2) Palaeogeographic Outline of Deposition at Yan'an Time.

The generalized trend of the topographic landscape, however, was still high in south and low in north even though reuplifts caused by early Yanshan movement after deposition of Fuxian formation of lower Triassic period, whereas the sub-topographic high and low in Nanyukou, Xiyucun, Yaoping and Qiulinzi-Cangcun, Siwan and Shuanglong, the south Ninjiazhuang-Nanhuzhai-Lizhanghe line, are further intensified which attributed to differentiation of a chain of undulating hills on the south and northward tilted plain in the north part at the beginning of deposition of Yan'an formation during middle Jurassic period.

The deposition of Yan'an formation, based on the analysis of lithologic characters, lithofacies and the relationship of associated facies cycles, was emphasized to grouped into fluvial-lacustrine swamp, lacustrine-swamp, lacustrine delta and lacustrine four sedimentary system arranged in a upward order. The distribution of each system was shared horizontal association with another depositional series, which is probably directly related to the differentiation of subfacies distribution at the same time. The example like that :
The environment for basal sandstone of Yan'an formation deposited in depressional predcessor of Cangcunhe river before the accumulation of lacustrine system was changed lately into peat swamps which response to fluvial-lacustrine swamp deposits to share associated with the lacustrine settling system to both flanks. The vertical sequences and relationship of

coexistion of sedimentary system probably reflects depositional variation during the different periods which is illustrated by the lacustrine-swamp deposits grading into lacustrine delta, and further to lacustrine deposition series in upward order in Huangling study area, it suggested that thansgressive process attributing to depositional cycles of Yan'an formation in which fluctuation of lake shore were the result of changes in the direction of flow. The lacustrine facies characterized by their stable variation of lithologic and lithofacies of cycle III , IV of Yan'an formation can be recognized as a regional marker bed for lithostratigraphic correlation. Lacustrine deposits in cycle IV consist mainly of grayish mudstone with very fine component and seasonal varve except some mudstone and calcareous siltstone representing the culmination of lake development which possibly correspond to the most extensive distribution and stable period of lake itself. The cycle IV, however, was defined as the regressive process causing by the crustal uplift at that time to indicate another development stage of Ordos basin.

As mentioned above, the component for clay mineral, in muddy rock of Yan'an formation was comprised of two different types arranged descending order of abundance: kaolinite, illite commonly cemented by iron and mud as well as plant fossils in the form of the genera:Coniopteris SP and Ginkgoites SP. in lower part and illite, kaolinite in decreasing content which were commonly cemented by calcareous and muddy matrix as well as calcareous siltstone and mudstone. So palaeoclimate variation at Yan'an time can be demonstrated from warmhumid to arid climate and water medium,. which also was interpreated change from acidity-basicity - poor reduction environment.

To summarize sedimentary environments of coal-bearing formation are basically related to the continental lake with three stages of development. The process of lake shore based on local fluvial environment was the fundamental process of cycle I at pre-Yan'an time. Accumulation of thick peats may previously have been present in a fluvial settling area building from the swamping across the lake shore area. Warm humid palaeo climate and acidic water medium (Matrix) probably supporting growth of vegetation origin of peat deposits. Consideration of palaeotopographic characteristics can subdivided into lacustrine-swamp hills (topographic high) in south and lacustrine-swamp plain (topographic low) in the north study area.

Construction of the delta system at mid-Yan'an time are made possibly by the process of fluvial sediments changed into lake during the regressive period, generalized trend of building-process is in an orientation from Diantou to northwest direction showing tongue schematic profile and lacustrine accumulated to both flanks of delta system, which suggested that accumulation of coal in swamp was probably controlled by paleotopography as well as interval of peat accumulation, proximity to sediment influx (rate of influx) and the chemical properity of swamp waters, so that coal deposits based on the delta plain are relatively thin and have no economic value to exploration and development. The shallow lake dominated environment at post-Yan'an time with characteristics of coal deposits in the local marginal area, such as Qiulinzi area, had a short duration of environment for accumulation of peats.

PART 5. DISTRIBUTION AND CONTROL-FACTORS OF COAL BEDS

The coal-bearing strata of Yan'an formation in study area contained three coal beds, named No.0, NO.1 and No.2, and No.2 coal bed of lower Yan'an formation, however, is the main group of seams which can be subdivided into following four coal seams arranged in an upward order : 2^{-4}, 2^{-3}, 2^{-2} and 2^{-1}. Generalized variation and stratigraphic position were shown on Table 4.

No. of coal bed	Thickness (M)	Texture	Stratigraphic position	Distribution
No.0	$\frac{0-0.5}{0.25}$	very simple	middle of cycle IV	scattered
No.1	$\frac{0-0.7}{0.3-0.4}$	simple	middle of cycle II	delta area
No.2^{-1}	$\frac{0-4.35}{1.3-2.7}$	very complex	middle of cycle I	whole area studied
No.2^{-2}	$\frac{0-2.93}{0.7}$	very complex	middle of cycle I	extensively
No.2^{-3}	$\frac{0-1.91}{0.3-0.5}$	very simple	middle of cycle I	local area
No.2^{-4}	$\frac{0-0.86}{0.4}$	simple	middle of cycle I	scattered

Table 4. Showing coal thickness and others.

As illustrated on Table 4, No.0 and No.1 coal beds were too thin to mine, while No.2 coal beds, however, is target of exploration and development, and also defined as a focal point to be analysed and assessed.

Detailed analysis from the previous information and results of cooperative research project suggested the

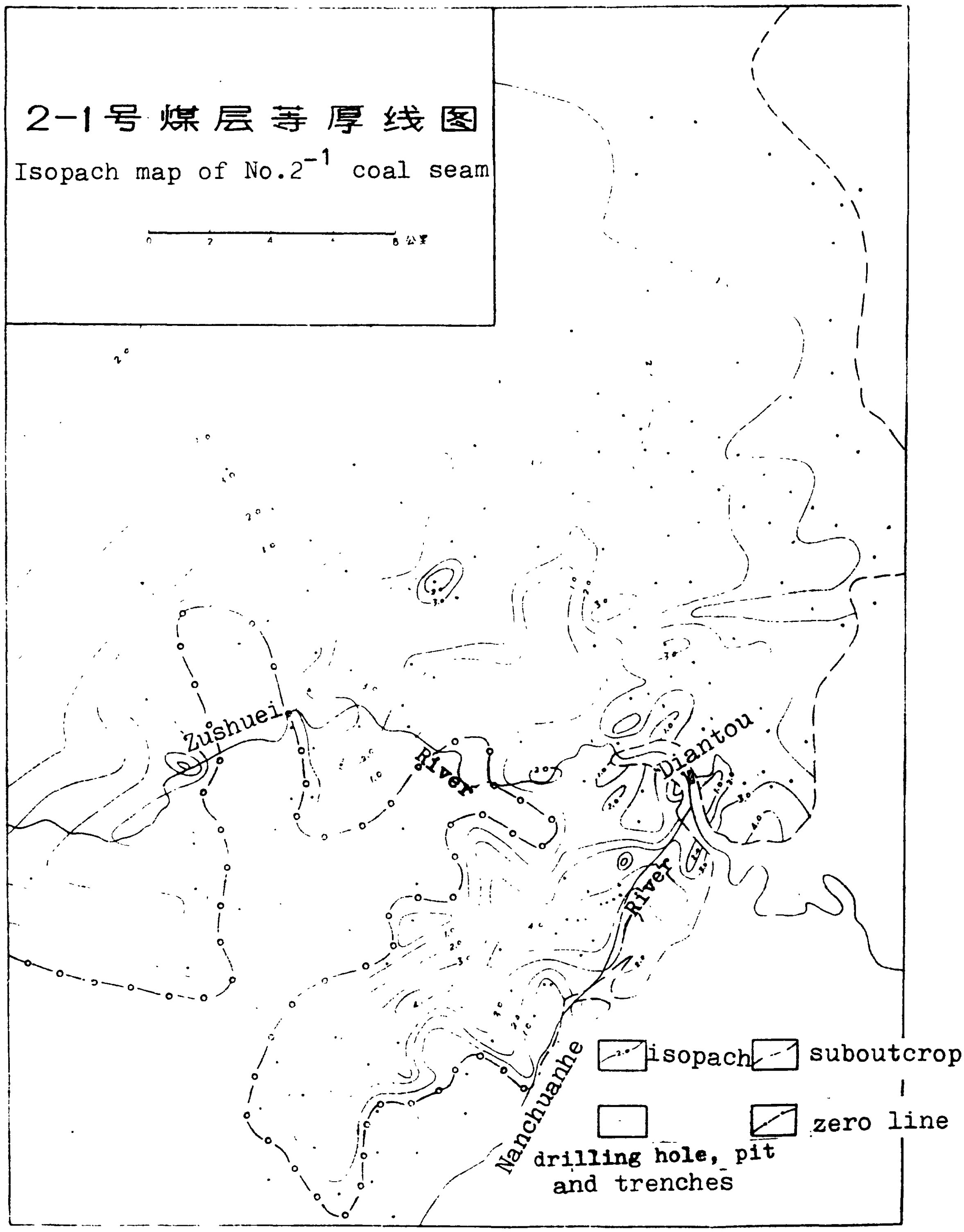

2-1号煤层等厚线图
Isopach map of No.2-1 coal seam
Zushuei
River
Diantou
River
Nanchuanhe
isopach
suboutcrop
zero line
drilling hole, pit
and trenches

FIG.22

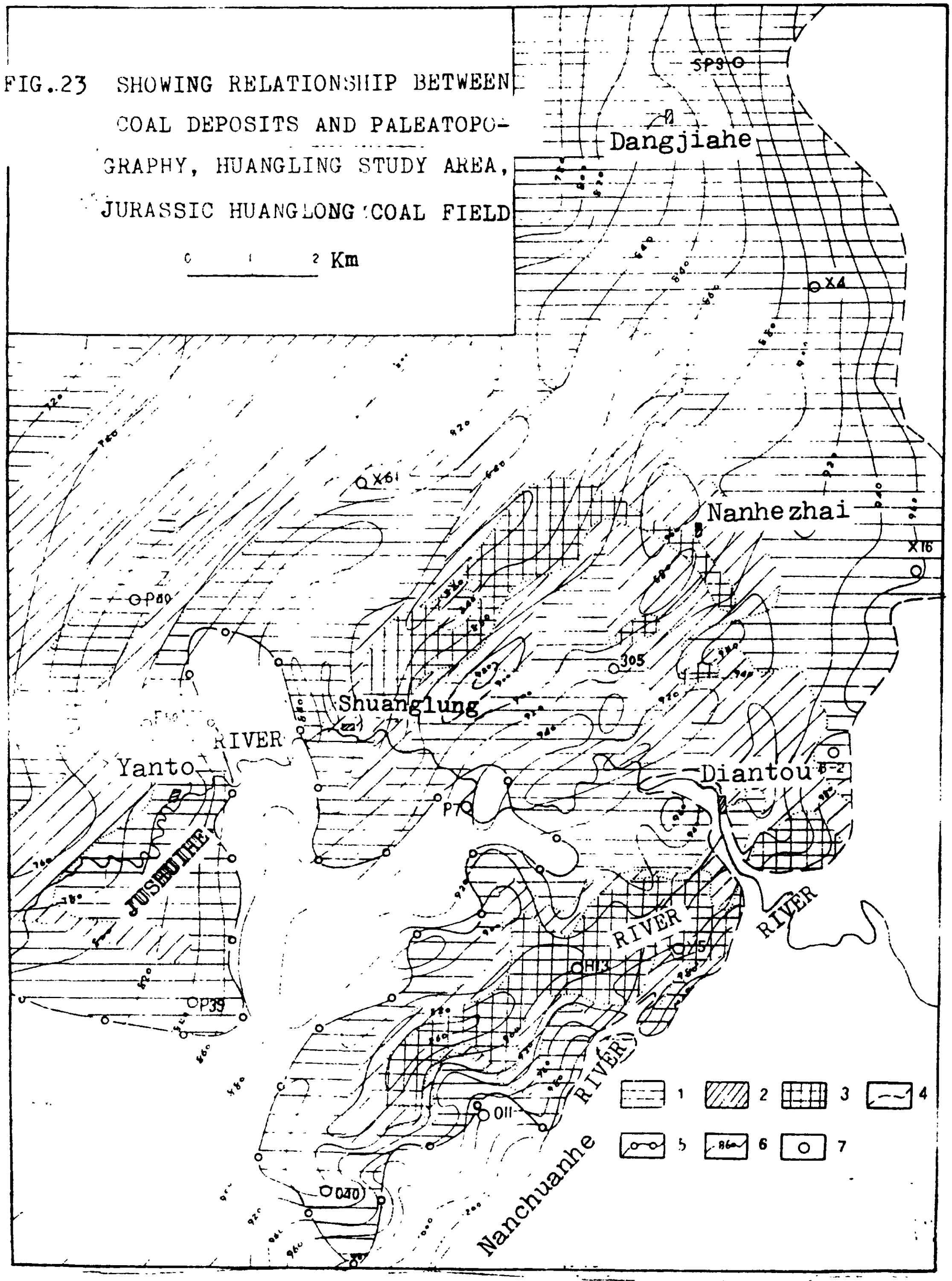


FIG.23 1. coal thinckniss less than 2 m.
2. coal thickniss 2-3 m.
3. coal thickniss more than 3 m.
4. coal outcrops
5. zero line
6. isopach of erosion surfarce of the top part of Triassic
7. drilling hole

ssic.

characteristics of No.2 coal deposits as following:

(1) The distribution of No.2 group of seams shows a trend of continuous expansion of coal deposit upward, for example, No.2^{-4} coal bed is distributed only near the centre of Qinlinzi-Cangcun and Siwan depression, while the area of distribution of No.2^{-3} coal bed, however, is more larger than No.2^{-4}. Further, No.2^{-2} & No.2^{-1} coal beds appear in a complex shaped and also widely dispersed all over the region.

(2) The coal beds are thickest at the middle area of palaeodepression, oppositly, thiner both in palaeotopographic high and lake direction even having no coal accumulation. As shown on Figs. 22 and 23, on the flanks of palaeotopographic high and low, abundance of coal is moderate and stable widespread along the NE-SW orientation, axis of palaeotopographic low direction. The coal deposits are more changable in westeast direction to result in a number of thick, thin or non-coal depositional zone.

(3) As shown in Fig.24, the relationship of apliting

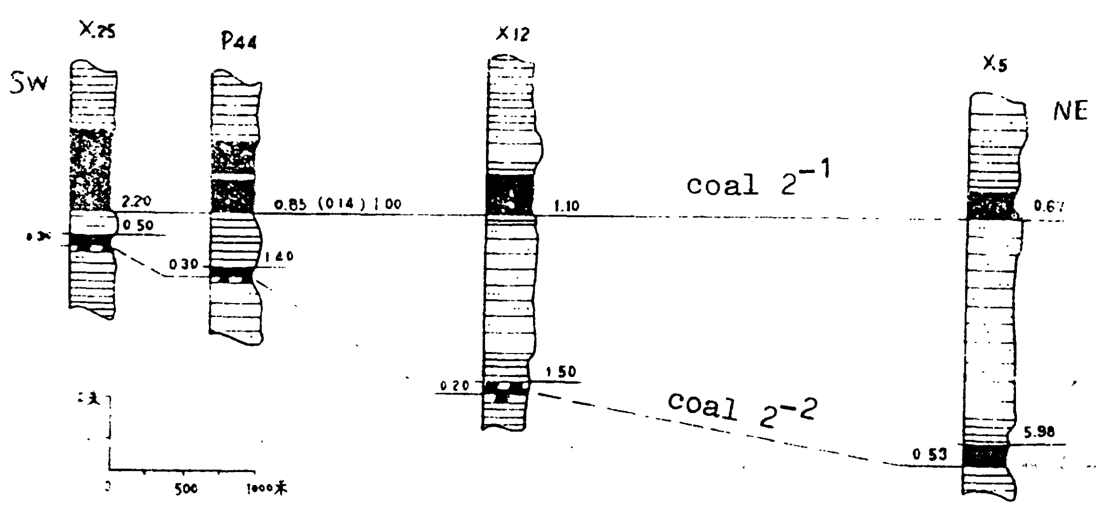


FIG.24 Sketch section of coal seams 2^{-1} and 2^{-2} variation.

and merging of No.2 coal seams suggested that the interval of coal beds is enlarged to both lake and centre of depression to form a independent coal bed(Fig.24), and decreasing interval from palaeotopographic low to high resulted in merging of coal beds, so the texture of coal beds is generally complex at the centre of palaeodepression.

(4) The caal quality of this region is low-rank bituminous coal, the physical properties of each coal bed are usually the same, black, semidull coal and semibright coal, take first place dull coal comes second with striped and lineation texture. Microlithotype are mostly fusain-duro clarite and fusain-clarodurite with vitrinite (about 62-86%) and fusinite (about 7.8-31%) as well as a limited amount of liptinite (2-4% generally). The chemical composition, however, shows compartively less variable as shown in Table 5, the coal-rank belongs to bituminous coal with lower-medium ash and sulfur content and high heat value named weakly coking coal and gas coal according Chinese coal clasification. Weakly coking coal is usually distributed in the south part of the study area and gas coal, however, in the northeast and northwest parts. As illustrated in Table 5, harmful component decreases upward in general such as Ag is more than 31% in $No.2^{-3}$ coal bed, and 19.41-29.57% in $No.2^{-2}$ coal bed, 9.62-23.39% in $No.2^{-1}$ coal bed.

Table 5 showing component of No.2 coal bed.

Content / No.2 Coal	$A^g\%$	$S^g_Q\%$	$Q^g_D k/g$	$C^r\%$	$H^r\%$	$N^r\%$	$O^r\%$
No.2	$\frac{3.34-38.07}{14-19}$	$\frac{0.28-2.74}{0.5-1.5}$	$\frac{7602-8360}{8100}$	$\frac{83-86}{85}$	$\frac{4.4-5.6}{5.2}$	$\frac{0.43-1.6}{1.20}$	$\frac{6.02-10.6}{8.5}$

Although coal deposits in study area showing variable in certain degrees, the characteristics of various coal-control factors were still indicated to have some law to following :

1) As illustrated in Fig.23, the orientation of coal deposits and variation in thickness are probably coincident with palaeoerosional topography of peat accumulation, which indicated that distribution of coal deposits probably reflects the differentiation of palaeotopographic high and low at pre-Yan'an time in which most favorable places for peat accumulation are depressions marked by compartively thick coal in the hilly area on the south, while northern plain in study area characterized by its thin, widespread coal deposits attributing to the area where near the lake centre and relatively deep water body as a result, thick coals distribute in south and thin coal beds in north part of the study area.

2) The peat-swamps were first, occured in the middle of some depressions which may served as a positive platform that supported initial growth for vegetation enlarging swamps permitted establishment of interval drainage for accumulation of coal beds through time, to form coal deposition in large area, showed increasing coal distribution and decreasing ash content in an upward order.

3) The movement of tectonic inheritance and differential compacting of coal-forming material during the process of peat-swamp development permitted continuous accumulation of peat and compartively limited changes, which also demonstrated as the reason of thick coal in depositional palaeotopographic low and splitting or merging of coal beds on the uplift. So, the direction of elongation of the thick extensively coal is in line with the axis of palaeodepressions and more changable cross the axis orientation of palaeotopographic low.

4) The relationship between the rate of basement subsidence and the rate of plante remain accumulation was the basic factor for peat accumulation.

The sedimentation in Huangling study area during the process of peat-forming temporarily does not keep pace with a rapid rate of subsidence, so the coal texture in palaeodepression is relatively complex, the interval between coal seams is larger than that in palaeotopographic highs

The relative thin coal deposits and increasing interval between coal beds is probably directly related to the situation of near lake centre with poor filling of plant materials.

5) The weathering of peat was the result of intermittent precipitation flew and the shallow water during the swamping period probably made deterioration of coal quality by the decreasing of coal cohesion, caused the differentiation in coal quality between hilly and plain, palaeotopographic high and low areas.

Part 6. EVALUATION OF COAL RESOURCES

In Huangling study area there are abundant economically workable coal resources has been found out by exploration over many years which provides the prerequisite for the development of coal mining.

The characteristics of coal forming environment are probably recognized as a large lake in an interior basin marked by stable extensively coal deposits and very good coal quality. The palaeotopography with compartively simple geologic structure, however, is a fundamental factor which controls the planimetric distribution of coal. The preliminary conclusion is that : The hilly area near the lake shore along Shangzhenzi and Xixiaocha on the west of Yaofutou on the north were probably favorable environment for coal-forming the coal . ranging from 1.5 to 2.0

meters in thickness, while west of Sijiapen characterized by slope area with compartively thin, but stable and extensive accumulation of coal deposits.

Part 7. CONCLUSION

1. A further understanding of orientiation of coal accumulation zone, factors of coal forming and assessment of coal resources as well as primarily depositional modals was made from cooperative research project -"project 6" in Huangling study area, and also pointed out the north and northwest part of Huangling probably indicate a favorable area for prospecting on the basis of sedimentary environment, and it has also interpreated the differentiation of coal quality.

So, Huangling joint-research for coal deposition provided a primary guide to resolve geological problems in a certain degree for coal basin exploration. The practical examples such as :

A) Different prospecting hole spacing must be used for coal field exploration according to the variation of trend of coal-deposits.

B) Geophysical logs and available data from limited number of holes combined with regional geologic characteristics may be put into prectise for the initial determination and prediction of favorable places of peat distribution so that can promote the efficiency of reconnaissance and shorten the daily routine of prospecting on the basis of the way coal deposits may correspond to palaeotopographic situation.

C) Continuous analysis of coal-forming environment in different stages including the reconnaissance and detailed prospecting is required for general evaluation of coal resources and utilization, to delineate a schematic profile, prospecting work, and also some problems of mining technical conditions.

Although the consideration of some problems such as the planimetric location of Diantou sandstone body, is that near lake or near channel, had still not reached an absolutely common recognition indeed, which probably resulting from the different opinion on some geological concepts such as the depositional characteristics and lithostratigraphy as well as coal-forming control factors. Nevertheless, were better demonstrated during the course of this cooperative study and more progress should be made from further discussion and coal exploration.

2. Cooperation research preject for sedimentary environment on Huangling study area also emphasized that field geological investigations were fundamental work for the analysis of depositional modals for coal exploration. The basic method used in our joint study may probably divided into three parts :

A) Measured the lithostratigraphic sections of Yan'an coal-bearing formation in detail; observing and describing the indexes of origin of rocks; collecting samples of coals and rocks as well as fossils, and to analysis the available information derived from drilling-holes as much as possible.

B) Statistical analysis of the reliable data may possibly reflect the geometry of sedimentary body, lithologic and lithofacies characteristics and abundance of coal on the basis of the coal seam and coal measures correlation.

C) Demonstrating of the general law and depositional modal by the compilation of corresponding maps and sections such as cross sections, isopach map of sandstone body, coal deposit maps and another planimetric maps.

Huangling field investigation routine had been proved that the methodology we dealing with was basically feasible. It's also suggested that detailed studies of the sedimentary structures, vertical texture changes, mineralogical variation and fossil contents of coal-bearing rocks would provide an prerequistite condition for further environmental analysis.

3. Differences in stratigraphic cross section, internal structure, as well as their vertical and lateral characteristics probably reflect the differentiated subenvironments and directly related to the variation of hydrodynamic condition through time, so, detailed description and study for vertical texture changes of stratigraphic cross section was primarily necessity for establishment of palaeogeographic location or subenvironments.

4. Detailed investigation and measurement of the orientation of palaeocurrent was probably assisted to delineate direction and distribution of channel system. Palaeocurrent, which was considered as one of basic works and feasible approaches for analysis of depositional environment, will probably be demonstrated during the futher cooperative research of sedimentary modal for coal exploration.

(References)

Xi'an

27th June, 1984

Appendix

鄂尔多斯盆地黄陵矿区侏罗纪延安组
沉积环境与控煤因素的研究

～～～～～～～～～☆～～～～～～～～～

（初　　稿）

《中美合作研究项目》

美国地调所

B。K。肯特，R。H。霍布斯

E。J。约翰逊，W。S。西格里奥

中华人民共和国煤炭工业部地质局

田　明　毛邦卓　刘　枢

张永霖　韩长林

一九八三年十一月于西安

目　　录

插　　图

鄂尔多斯盆地黄陵矿区侏罗纪延安组

沉积环境与控煤因素的研究

（初　稿）

《中美合作研究项目》

一、摘　要

延安组地层，是中国北方中生代最重要的含煤地层之一。通过对本区延安组地层的岩性、电性、岩相及其组合关系的分析，自下而上将延安组的沉积分为河湖沼、湖沼、湖泊三角洲和湖泊四个沉积体系。各沉积体系在平面上与一定的体系共生，反映的是同一时期内亚环境的不同，而在垂向上的共生关系，则反映了沉积环境随时间而发生的变化，即延安组沉积的早期，从最初的局部河流沉积发展为滨湖环境，中期是在湖水后退，河流充填湖泊过程中建造的三角洲环境，而在后期发展为湖泊沉积。泥炭沼泽是湖泊近岸沼泽化和三角洲平原沼泽化的结果。

本区聚煤作用，是以总体沉降的构造背景为前提的，主要受印支运动后形成的古剥蚀面形态的控制，即当时存在的几个古高地和古凹地，控制了主要煤层的区域分布和厚薄变化，其中古凹地为泥炭聚积的有利部位，且其中部沼泽发育早，延续的时间长，形成的煤层厚度大，而紧靠古高地部位，沼泽发育晚，形成的煤层薄。泥炭沼泽发育过程中的地壳振荡运动和成煤物质的差异压缩作用以及差异补偿作用，

的赋存、结构、间距及其分叉合并等出现一个复杂的状况。

二、前　　言

1. 研究目的

中美地学科学合作项目第六项“煤盆地的勘察与分析”的主要目标，是在中美双方各选定一个或两个主要煤盆地，研究地层、煤层、煤质、煤岩、古生物、构造、地球化学和地球物理勘探技术，并使用计算机化的数据系统总结煤盆地的成煤环境、煤资源的勘探与评价方法。目的是：研究煤盆地勘探与分析中的共同问题；了解双方科学家应用的有关概念、方法和技术。一起解决有代表性的共同问题。

美国西部波德河盆地和中国的鄂尔多斯盆地，是双方第一轮合作研究所选择的地点。按照计划安排，1982年9～11月中方地质学家和地球物理学家首次在美国进行了地质考察和研究工作，除考察了美国东部和西部煤田地质外，还深入到怀俄明州波德河盆地，对费里克斯（Felix）煤层进行了对比及其资源评价的研究。1983年9～11月美方地质和地球物理学家在中国鄂尔多斯盆地的黄陵矿区，研究了延安组的沉积环境和控煤因素，并考察了中国北方不同时代但具有代表性的辽宁抚顺第三纪煤田、阜新侏罗纪煤田、山西大同侏罗纪煤田和太原西山石炭二叠纪煤田，参观了煤

炭科学院西安分院、西安航测大队和渭南煤矿专用设备厂等单位，了解了有关的测试手段、仪器、设备等，通过座谈，进行了技术交流，从而结束了该项目第一轮双方的互访和合作研究的野外工作计划。

参加本项目的美国官方机构是：美国内政部地质调查所。中方机构是：中华人民共和国煤炭工业部地质局。美国方面的代表是：

B·H肯特

R·H·霍布浙

E·J·约翰逊

W·S·西格里奥

中国幅员广大，煤炭资源极其丰富，含煤时代较全，盆地构造和聚煤类型多，第一轮研究计划的制定，是试图给美国地质学家提供一个考察和了解中国煤田地质特征和煤炭资源概况的机会。我们之所以选择鄂尔多斯盆地的黄陵矿区之聚煤环境和控制因素做为合作研究的课题，是因为该区代表了中国含煤盆地的一种重要类型，且在过去二十多年中曾进行过1：5万比例尺的地质测量和勘探工作，有一定的工作基础，而且目前仍在进行煤田地质勘探工作，这样就使美国地质学家能直接观察和熟悉中国在煤田地质研究中所采用的勘探方法和研究方法以及勘探技术设备手段，因此我们设想通过第一轮研究计划的实施，不但可使双方地质学家，在共同解决煤

田地质难题的过程中，进行充分的技术交流，了解双方应用的有关理论、概念、方法和技术，而且可为鄂尔多斯盆地第二轮合作研究创造条件和积累资料，最后提交一份合作研究报告。

2 研究区所在位置

黄陵矿区位于中国中部陕西省黄陵县境内（图1），包括葫芦河以南，腰坪、洪善寺梁一线以北，面积约2600平方公里。矿区地处陕北高原南部，地形以西高东低为特征，属侵蚀构造地形，由于河流之侵蚀、切割，塬面多已破坏，在店头、张村驿一线以东多为塬、梁、峁地形，以西山峦起伏，沟壑纵横，地形复杂，属森林区。区内树枝状水系发育，常年流水有横贯矿区中部的沮水河，自东西或南东向流经本区，于黄陵东注入洛河。矿区东距黄陵县城28公里，北距延安约200公里，南距西安约250公里，目前尚无铁路贯通。

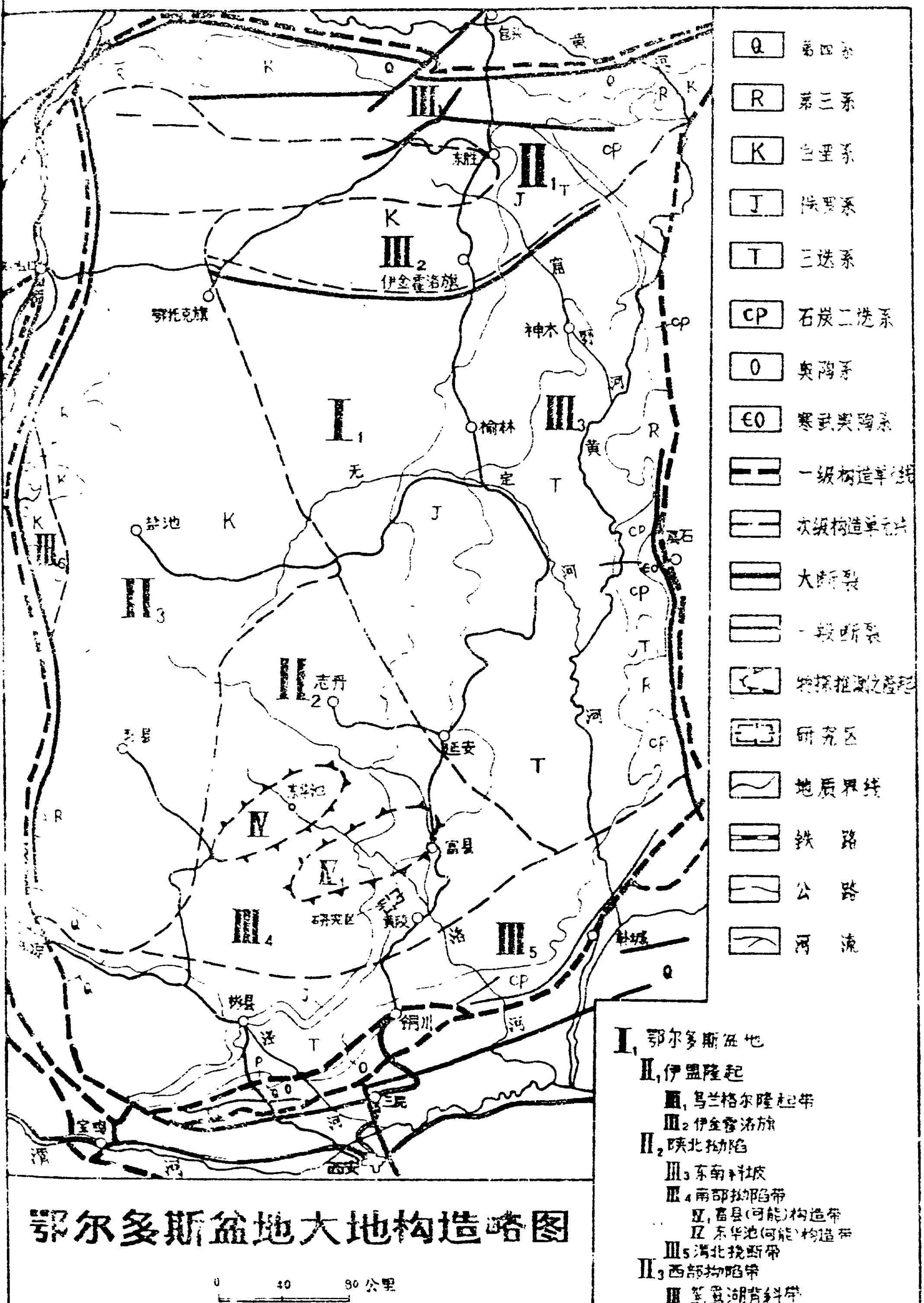
3. 煤田地质工作概况

陕西省煤田地质工作机构是1953年建立的，当时的工作重点是盆地南缘的石炭二叠纪煤田，中生代煤炭资源的调查，则开始于1957年，按其工作性质和目的，本区的煤田地质工作大致可分为三个阶段：1960年以前，主要进行的是区域性路线地质调查和1：5万比例尺的地质测量，并施工了部分控制性钻孔和轻型山地工作，属普查找煤性质，其主要任务是了解自然地理条件，第

四纪地质和地貌特征。初步查明地层层序和含煤地层时代及其可能的分布范围、煤层层数、厚度及其质量、埋藏深度、构造形态等，最后对其远景作出评价，为此还采集了生产煤样和部分煤层、煤岩煤样，对于技术加工性质进行了一定的了解，在此阶段提交的报告有“麟游—宜君煤田地质调查报告”和“黄陵七里镇煤田地质普查报告”等。在六十年代和七十年代前期，是本区煤田地质工作的第二阶段，此阶段主要是进行煤田地质勘探，其基本要求是除进一步搞清第一阶段所列各项任务外，还要查明煤田水文地质特征和开采技术条件，最后提交一定数量的可资利用的工业地质储量。在此阶段采用的技术手段主要有岩心钻探、地球物理测井和详细的地质测量及部分轻型山地工程等，先后提交了店头矿区普查勘探、详查等地质报告。1975年以后，除局部地区继续进行勘探外，已开始注意地质规律的研究和探讨，这期间比较重要的研究有煤田预测以及随后的侏罗系沉积特征和研究，并发表了相应的论文，试图从沉积的角度，探讨煤层展布和厚度变化规律，以便更好地指导煤资源的评价工作和勘探工作，可见此次中美合作所选择的聚煤环境和控煤因素的研究课题，是本区煤田地质第三阶段工作的继续和重要组成部分。

4 工作方法

研究方法是根据环境分析的要求拟定的，其工作程序可分为资



鄂尔多斯盆地大地构造略图

图1

料收集、野外工作和室内分析三个阶段进行。资料收集是尽可能多地收集合作研究区域已有的地层、构造、矿层、古生物和含煤地层岩性、岩相及钻孔剖面资料，确定地层对比关系和作图单元。野外调查是地质研究不可缺少的基础工作，由于黄陵矿区已进行过1:5万比例尺的地质测量，故这次野外工作没有安排，而重点是详细测制延安组地层的自然剖面和人工露头，对其岩性、结构和岩石的成因标志进行了认真的观察和描述，追索了煤层和某些有成因意义的岩层。为了揭露煤系地层和煤层，增加控制剖面的密度，以便更直观地进行观察和追索，我们施工了十九个探槽计2882立方米，并采集了相应的岩样、矿样和化石标本几百块。双方的地球物理学家，除参加地质剖面观察外，还参加了现场地球物理测井工作。室内研究工作是在资料收集和野外调查的基础上，按照作图的需要，统计反映沉积体的几何形态、沉积断面和含煤性的各种数据，编制了沉积岩相剖面图、构造等高线图、岩体和矿体等厚线图、岩相古地理图、岩煤层对比图、测井曲线对比图及其他分析性图件、图表，并利用自然伽玛曲线和视电阻率曲线，划分了钻孔地质剖面和沉积旋迥，上述成果均反映在本合作报告有关章节中。

三、区域地质背景

鄂尔多斯地台是中国华北陆台的一部分，地台本部中生代以前的地层与华北地区一致，缺失上奥陶系、志留系、泥盆系和下石炭

系。震旦纪以前的地層是以碎屑沉积为主的深度质岩。组成盆地的基底。震旦系至奥陶系是一套以灰岩为主的海相沉积，石炭系是海陆交互相，二叠系为陆相碎屑岩沉积。三叠系及其以后的沉积是内陆盆地型沉积，而区别于前三叠系地台型沉积。

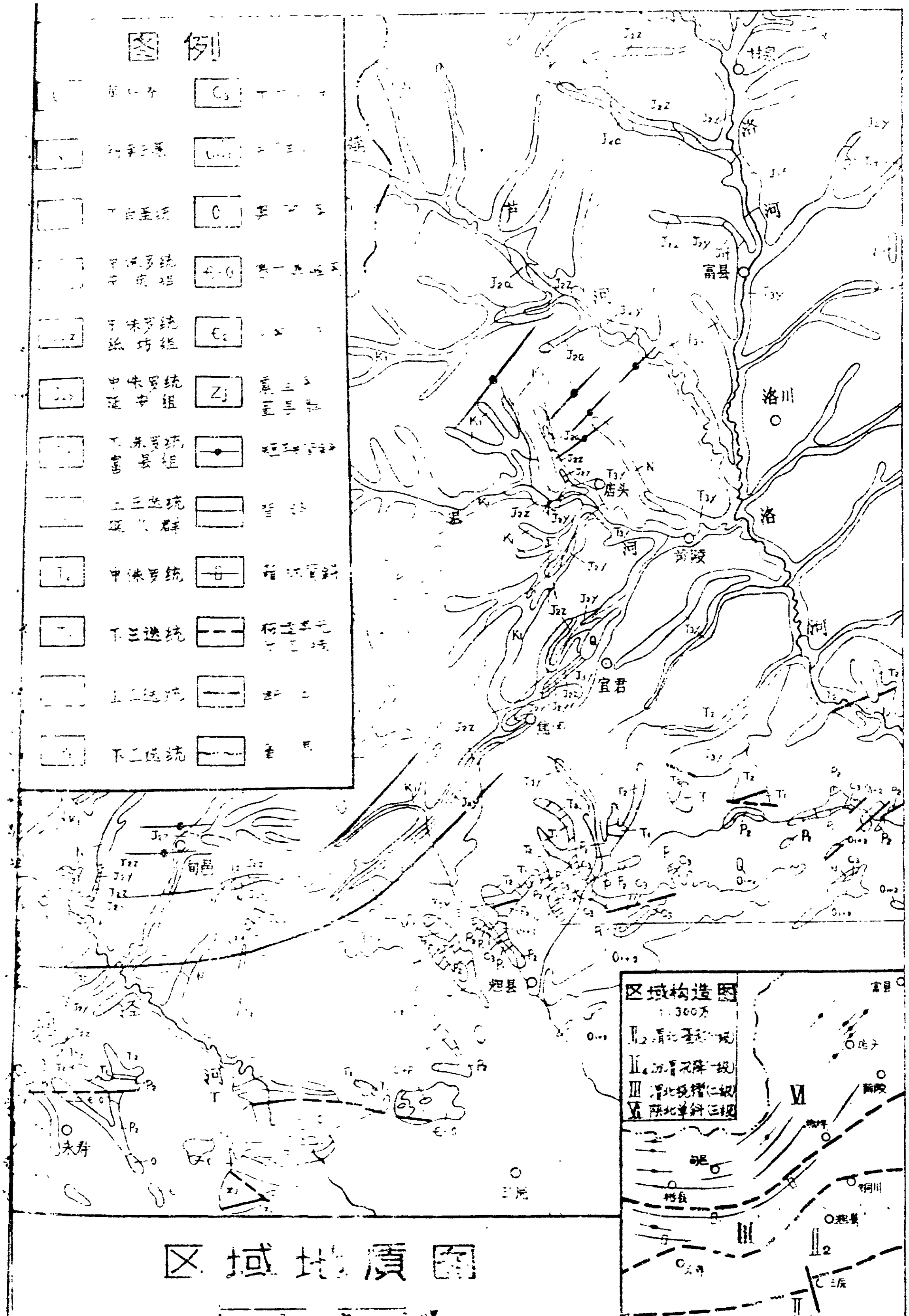
鄂尔多斯盆地是大型的内陆盆地型沉积。四周为老山环绕。盆地内部中、新生界地层呈环带状分布。黄陵矿区则位于该盆地的东南缘，出露地层有三叠系上统永坪组，侏罗系下统富县组，中统延安组、直罗组、安定组，白垩系下统志丹群，从东往西呈带状分布（图2）。

三叠系上统永坪组：出露于矿区东侧及店头附近沮水河和南川河谷李村、腰坪一带，岩性以黄绿色、灰绿色中、细粒砂岩夹灰绿、深灰色泥岩和煤线，含Danaeopsis fecunda

Cladophlebis Shensiensis Bernoullia zeilleri

Glossophyllum Shensiensis 植物化石。

侏罗系下统富县组：与永坪组呈假整合接触，主要分布在牛家庄～南河寨～李章河一线以北，下部为灰白色含砾砂岩或砾岩，中部为杂色泥岩、粉砂岩夹薄层 细 砂 岩 和 中 粒砂岩，上部为灰绿色泥岩夹粉砂岩、杂色泥岩和鲕状菱铁矿层，因受古地形影响，岩性、厚度变化大，最厚可达78·7米，一般厚10～20米，而在南部一般厚仅1米以内，个别可达数米，为紫红、灰紫色泥岩



区域地质图

及铝土质泥岩。

侏罗系中统延安组：与富县组呈假整合接触，为陆相碎屑岩含煤建造，厚0～180米，岩性主要由泥岩、粉砂岩、中细粒砂岩及煤层组成，中上部含薄层泥灰岩和瓣鳃类动物化石，有南薄北厚，东薄西厚，古高地薄而古凹地相对较厚的特征，据岩性和沉积旋迴可分为五段，从下往上粒度有细～粗～细的变化，沿倾斜方向，即由东往西，砂岩含量减少，而泥岩含量增大（图3）。主要可采煤层赋存于延安组下段，分布较广，往上含煤性变差，含丰富的化石：

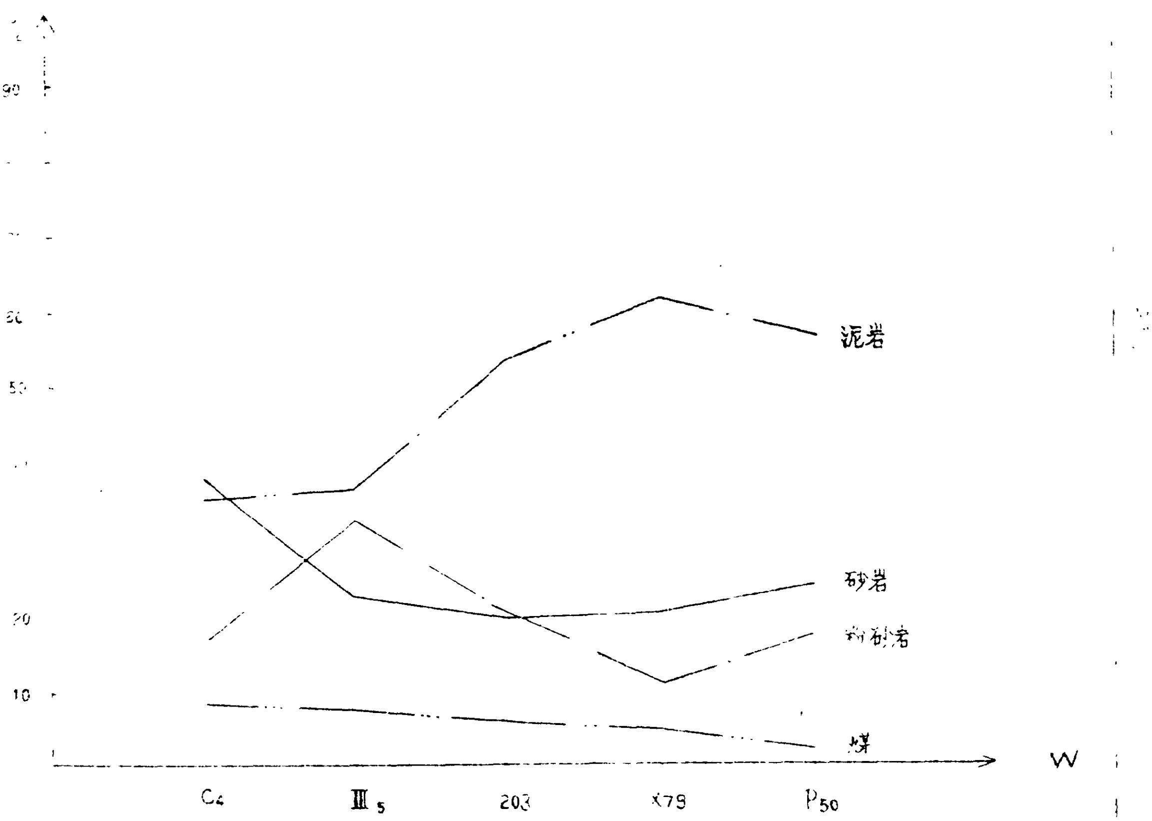


图3　延安组各类岩石含量变化曲线图(倾向)

一段有：Coniopteris hymenophylloides

C. tatungensis Sze

Eboracia lobifolia

Hausmannia leeiana Sze

Todites williamsoni

Czekanowskia rigida Heer

Pityophyllum longifolium

Podozamites lanceolatus

Nilssonia cf. sinensis

Pagiophyllum ? sp.

Ginkgoites sp.

二段有：Cladophlebis (todites) cf denticulata

Coniopteris sp.

Elatocladus sp.

三、四段：Tutuella ? sp.

Ferganoconcha sibirca Cherny

F. cf. Sibirca Cherny

侏罗系中统直罗组：为一套半干旱气候条件下的陆相碎屑岩沉积，厚70～200米，由两个粒度旋迴组成，底部为灰绿、黄绿、

灰白色厚层中、粗粒长石砂岩，具明显的沉积韵律，颗粒的滚园度和分选性差至中等，多见同向直线型斜层理，泥质胶结，含铁质斑点、煤屑、镜煤条带、泥岩包体和大型铁化木等，底面不平，见明显的冲刷现象，层位稳定，易于辨认，为区域性标志层。旋迴的中上部为紫红色、棕紫色泥岩，砂质泥岩夹粉细砂岩，泥岩层理不发育，且多具兰绿色园斑。与延安组呈假整合接触，在南部暖坪一带直接超复在永坪组之上。含Coniopteris hymenophylloides Podozamites lanceolatus等化石。

侏罗系中统安定组：与直罗组整合接触，为一套湖相沉积，分布在李章河沟脑以北，底部为黑色页岩或油页岩，中部为灰紫、浅黄色泥岩夹桃红色白云质泥灰岩、钙质粉砂岩，上部为泥灰岩与钙质泥岩互层，水平及不规则的微波状层理，含Psilunio cf. suni(Chow), P.sp 及鱼鳞、鱼刺、介形虫等化石，厚0～54米。

白垩系下统志丹群：与侏罗系呈假整合接触，为河流相、河湖相和风成沉积，盆地内从下往上可分为宜君组、洛河组、华池—环河组和泾川组，黄陵矿区内可见到洛河组和部分华池—环河组。洛河组为一巨厚的砖红、桔红色中粒砂岩夹泥岩透镜体，分选好，胶结疏松，具大型斜交层理为特征。一般厚约200米。华池—环河组出露不全为灰紫、灰绿色粉砂岩、细砂岩互层夹泥岩，水平及微

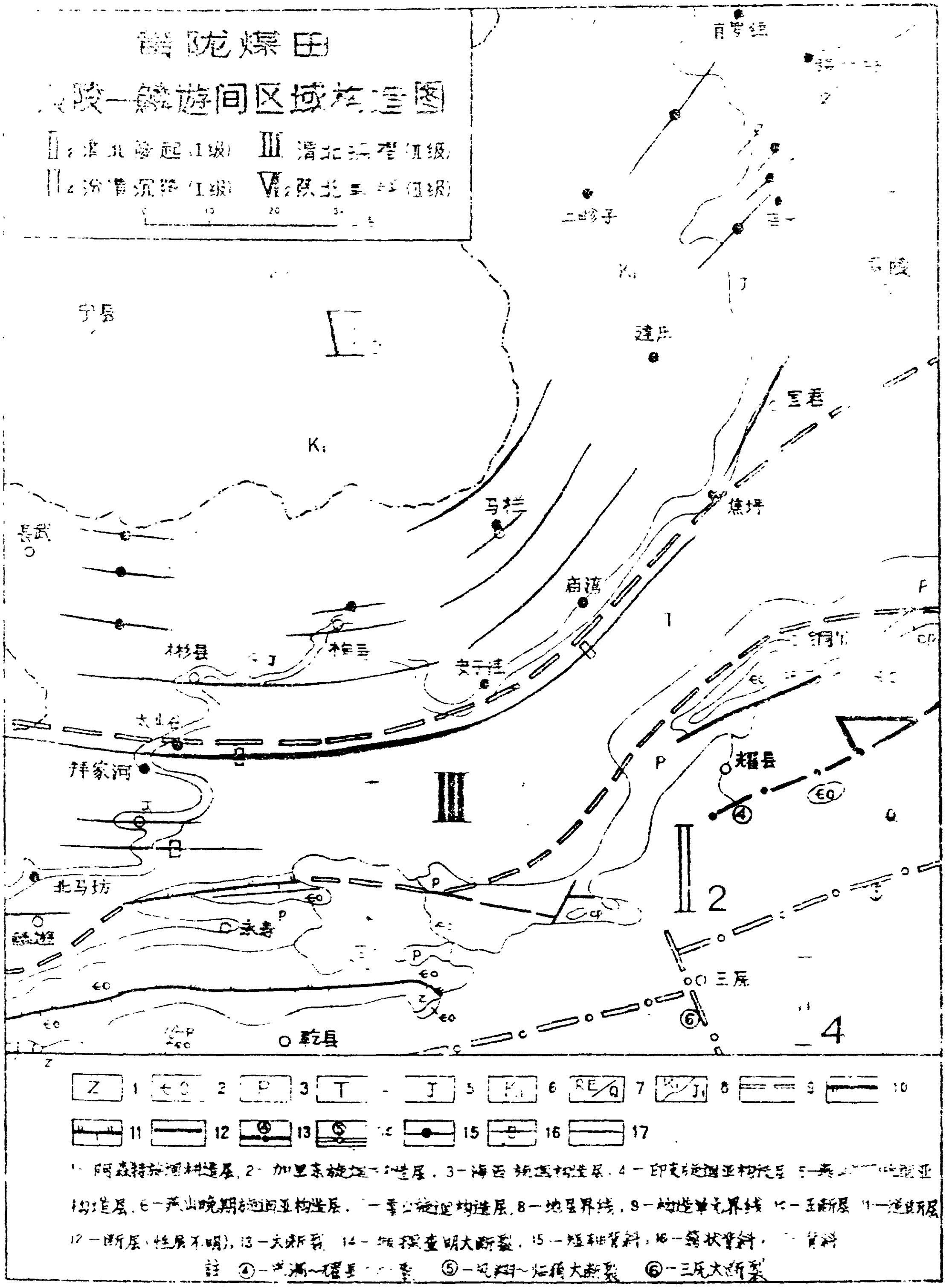
波状层理，钙质胶结，可见厚156米。

第三系：另星分布在北部太平村一带，主要为浅红色砂质粘土岩，厚0～60米，与下部地层为角度不整合接触。

第四系：　下部为黄土层，厚0～200米，上部为近代河床沉积，一般厚10米左右。

鄂尔多斯地台，是华北陆台上的一个典型陆向斜，其基底为前震旦系深度变质的结晶岩系，具有异常的稳定性，除边缘部分外，地台本部褶皱非常平缓，地台边缘构造线方向，与地台的轮廓相一致，即地台东缘和西缘之构造线呈南北向，南北边缘的构造线呈东西向，地台本部基本上是一区域性的西倾单斜，称陕北斜坡，倾角平缓，其西为天环向斜，南为渭北挠褶带和下古生代隆起带，再向南则为汾渭地堑（图4）。黄陵矿区位于陕北斜坡之东侧，故其构造较为简单，基本为一向西或西北倾斜的单斜构造，次一级构造为一组北东向的宽缓褶曲（图4）其规模较小，一般宽3000～4000米，并有从盆缘向盆中变弱的特点，对延安组地层和煤层的展布有密切关系。

在地质历史发展的长河中，鄂尔多斯地台经历了多次构造运动的影响，前震旦纪的吕梁运动，使前震旦系的地层变质而变化，造成震旦系与下复地层的广泛不整合。随后沉积了震旦系到中奥陶系浅海相地层。中奥陶系沉积之后的加里东运动，使地台上升为陆，



间区域构造图
III 渭北
马栏
焦坪
商湾
彬县
拜家河
北马坊
永寿
乾县
三原
耀县
建庄
II 2
4
1—阿森特旋回构造层，2—加里东旋回构造层，3—海西旋回构造层，4—印支旋回亚构造层
8—地层界线，9—构造单元界线
13—大断裂，14—钻探查明大断裂，15—钻孔资料
註 ④— ⑤— ⑥—三原大断裂

图4

造成上奥陶系到下石炭系地层的缺失和中石炭或上石炭系与中奥陶系的区域假整合。上古生代的海西宁运动，本区主要表现为稳定的下沉，形成中、上石炭系的海陆交互相和二叠系陆相碎屑岩的连续沉积。从三叠纪开始，地台沉积转变为内陆盆地型沉积。盆地的发展，亦经历了开始形成、稳定发展和萎缩消亡等过程。三叠纪时，是鄂尔多斯盆地发展的初期，当时的沉降中心位于盆地西南，三叠纪末的印支运动，使盆地上升，三叠系地层遭到剥蚀，形成三叠系地层顶部的剥蚀面，其基本形态在本区主要由若干个古高地和古凹地组成（图 5 ），在古凹地内沉积了早侏罗世富县组。富县组沉积之后，由于振荡运动，使盆地再度上升，形成延安组与富县组的假整合，随后盆地下降，盆地进入稳定发展阶段，沉积了中侏罗世延安组，延安组沉积后，地壳区域性上升，造成延安组与直罗组的假整合，并使延安组上部遭到不同程度的剥蚀。直罗组和安定组沉积之后，发生了剧烈的燕山运动A幕，该运动在地台边缘表现为褶皱上升运动，下白垩系与侏罗系呈不整合接触，而在地台本部，仍表现为升降运动，故下白垩与侏罗系呈假整合接触。白垩系沉积时，盆地处于萎缩阶段。随后的燕山运动B幕，使盆地整体上升，露出水面，遭到剥削，造成第三纪与下复地层的角度不整合。下第三纪时，盆地本部处于被剥蚀的状态，第三纪末的喜马拉亚运动，造成了现在的地貌概况。结束了内陆盆地型沉积的历史。

总之，本区构造运动频繁，但形式均以升降运动为主，特别是中生代以来，后期构造与前期相比，在量方面有显著的发展，而在质方面则有明显的继承，因此今日所见的北东向背向斜，都是沿袭印支运动形成的古高地和古凹地的基础上发展扩大而成的，它明显地控制着延安组，特别是延安组一、二段的沉积和厚度变化。

四、延安组沉积环境分析

1.岩性特征：延安组主要由泥岩、粉砂岩、中细粒砂岩及炭质页岩和煤层组成。按岩性及其旋迴可分为五段（图6）：一段以深灰色泥岩、粉砂岩为主夹薄层同色细砂岩、炭质泥岩和2煤组，局部地段底部为灰白色中～细粒长石石英砂岩，由于古地形的差异，厚度变化在0～30米之间，一般厚15米左右，在凹地中沉积较厚，高地上沉积较薄。二段主要以灰色中～细粒石英砂岩、粉砂岩为主夹薄层泥岩和煤层。砂岩在店头附近最厚可达22.4米，横向常变为细、粉砂岩与泥岩互层。该段一般厚20～30米。三段主要由灰色泥岩、粉砂岩、钙质粉砂岩和泥灰岩和菱铁矿透镜体组成，厚度较稳定，一般20～30米。四段下部为灰色泥岩为主夹粉砂岩，含鳞鳃类化石，厚35～50米。五段主要为灰绿、浅灰色粉砂岩、泥岩和砂岩，顶部见紫色泥岩和粉砂岩，分布在矿区北部，残存厚度一般不足10米，最大厚度22米。

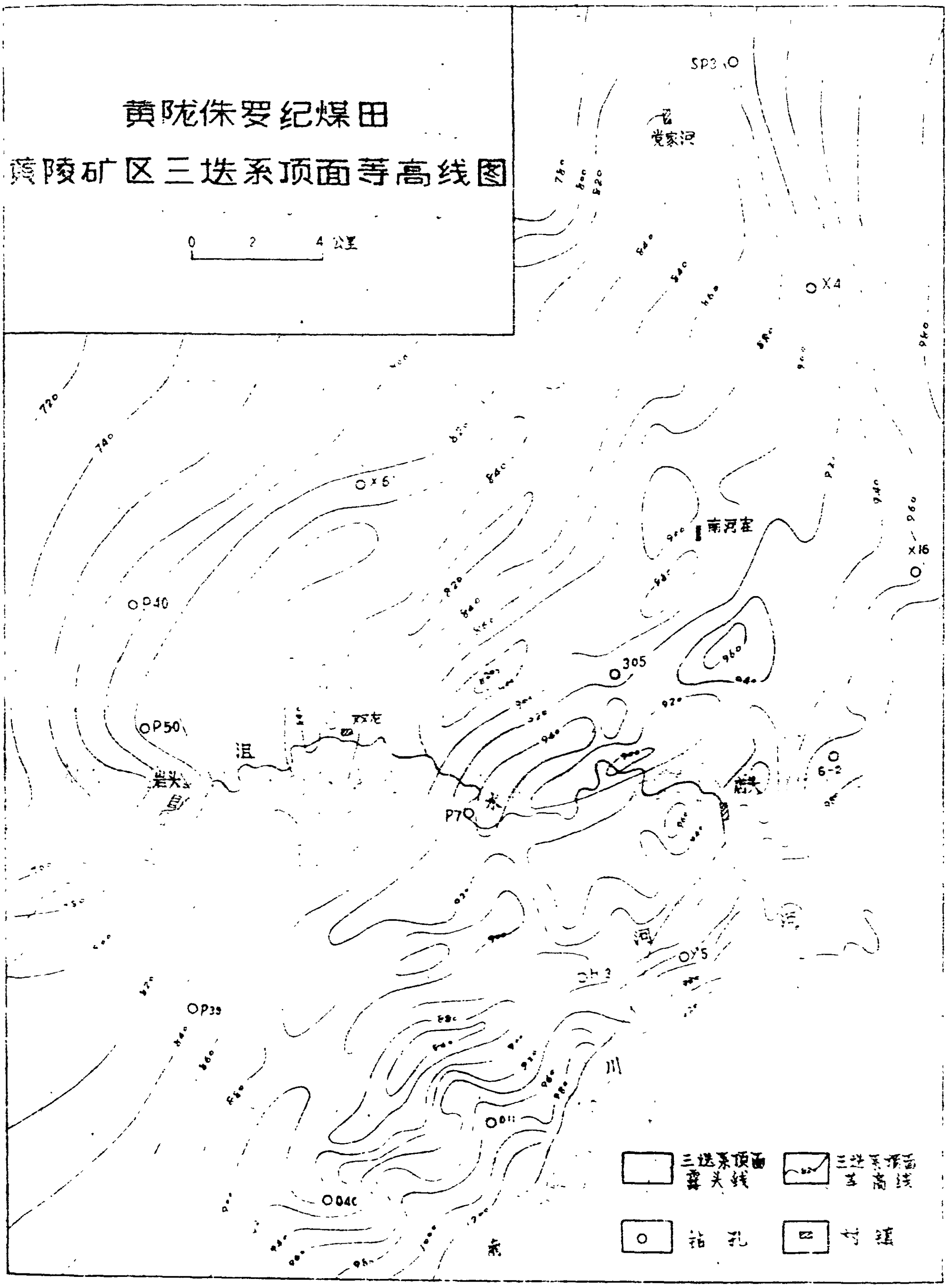

黄陇侏罗纪煤田
黄陵矿区三迭系顶面等高线图
0 2 4 公里
三迭系顶面露头线
三迭系顶面等高线
钻孔
村镇
SP3
X4
X6
南河寨
X16
P40
305
P50
双龙
沮
水
河
P7
店头
6-2
X5
P39
川
011
040

图 5

延安组砂岩中，碎屑成分以石英为主（88.3～91%），长石次之（3.6～9.2%），含少量岩屑（0—2%）及云母等（表1）。石英切面干净明亮，多为单晶颗粒，波状消光。长石主要为微斜长石、正长石及少许钠长石。岩屑主要为泥质岩碎屑。重矿物有锆石、电气石、金红石。分选性较差～中等，胶结物下部主要为泥质和铁质，上部为钙质，孔隙式～接触式胶结。

黄陵(店头)矿区综合地层柱状图

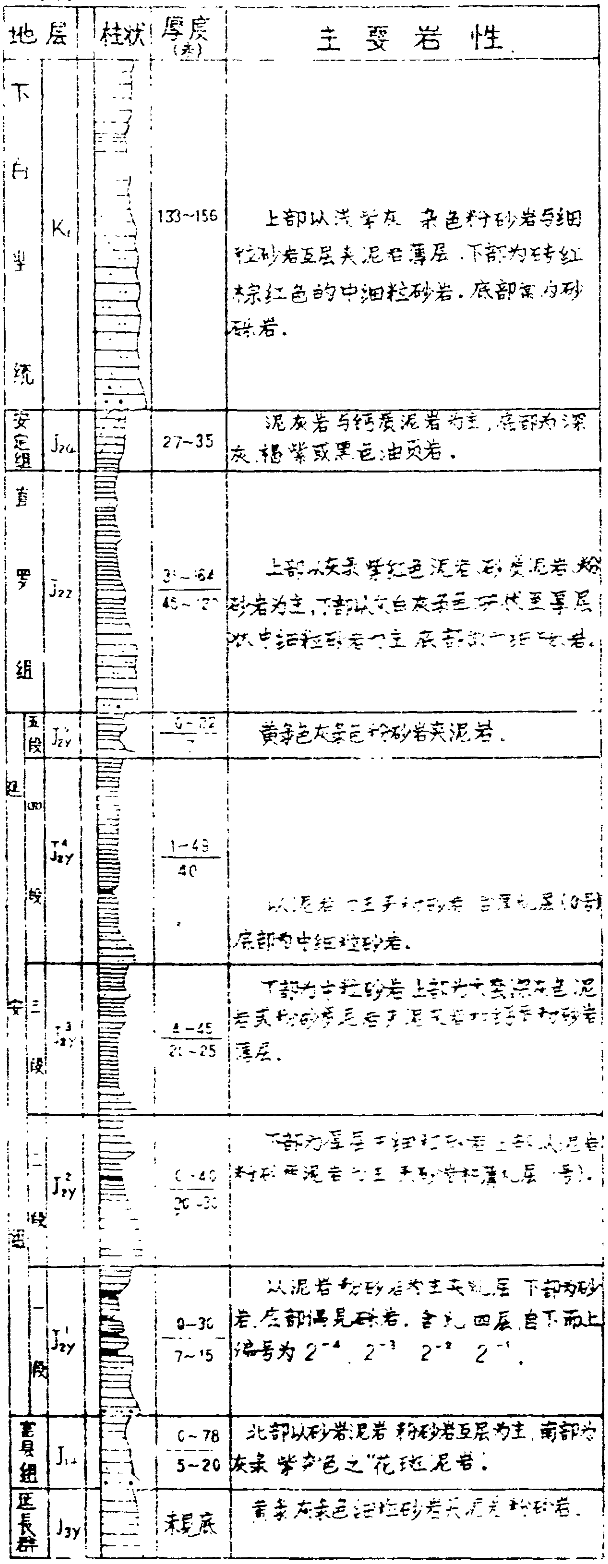


图6

延安组砂岩碎屑成分含量

表 1

成分 \ 含量% \ 层段	一段	二段	三段	四段
石英	88.25	87.08	91.—	88.3
长石	6.25	5.18	3.63	7.17
黑云母	1.±	<1.—	0.9	0.5
白云母	2.—	2.—	3.—	2.—
岩屑	2.—	2.—	0	0.5±

组成延安组泥质岩的粘土矿物成分，一、二段及三段下部主要为高岭石，其次为伊利石，其成分点均位于三角图解的酸性区中，而三段上部及四、五段则以蒙脱石为主，其次是伊利石，及菱铁矿、硫铁矿等自生矿物，其成分点均落于三角图解的碱性区中（图 7），说明延安组沉积时，早期古气候温热潮湿，水介质为酸性，并呈氧化反映，后期古气候炎热，水介质为碱性，呈弱还原反映，这对泥炭聚集具有控制性影响。

2.岩石地球物理特征：

地球物理测井工作，是煤田地质勘探的重要手段之一，其主要地质任务是：查明煤层的埋藏深度、厚度及结构，划分钻孔地质剖面，确定各层系深度、厚度，了解放射性矿物赋存情况并测量钻孔

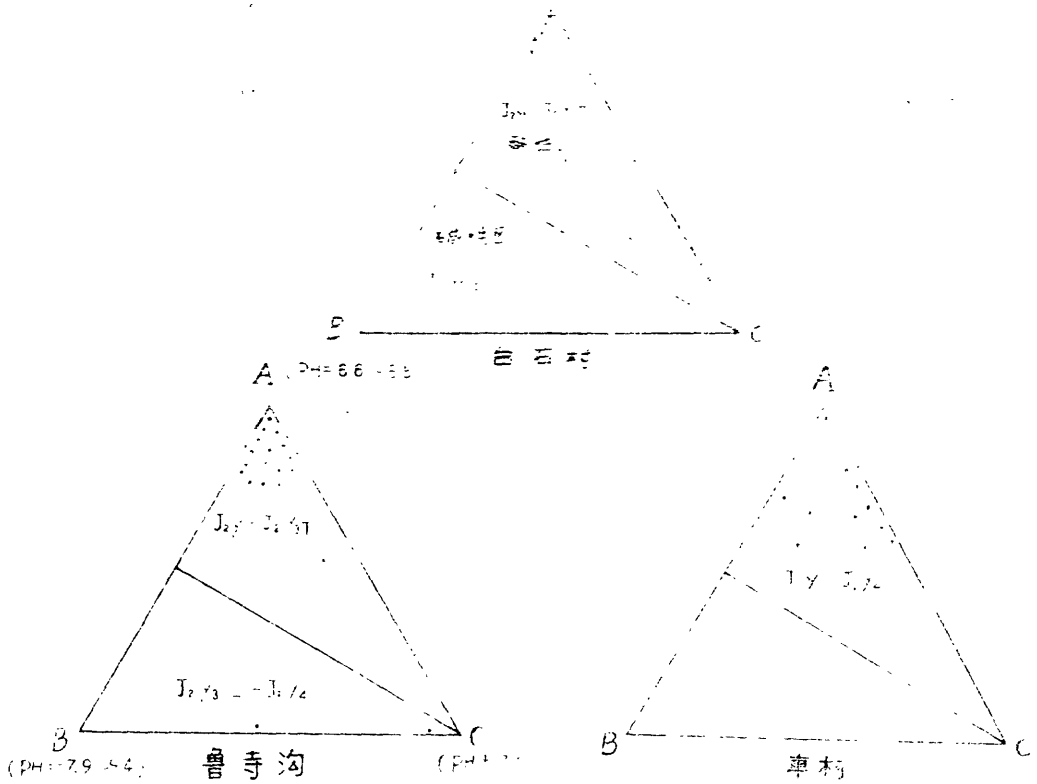


图7　延安组泥质岩粘土矿物含量三角图解

A—高岭石、石英…　B　蒙脱石、菱铁、硫铁矿　C　伊利石

歪斜度及井温。采用的主要测井方法有视电阻率、自然伽玛、伽玛伽玛、自然电位等。煤层定性及划分钻孔地质剖面，主要采用深度比例尺为1：200的视电阻率、自然伽玛和伽玛伽玛曲线进行综合解释。确定煤层深度、厚度及结构，主要利用深度比例尺为1：50的伽玛伽玛、视电阻率曲线及接地电阻梯度曲线等。

根据实际测井资料的统计分析，总结出黄陵矿区地层物性特征

如下（图8）。

三叠系上统

永坪组：本组上部地层以粉、细砂岩为主，视电阻率值在20～80Ω·M间，略高于富县组和延安组下部地层，而自然伽玛值则略低于富县组和延安组下部地层。

侏罗系下统

富县组：以低电阻、低密度为其主要特征，仅在底部之含砾砂岩或砾岩，视电阻率和密度略高于永坪组顶部地层。

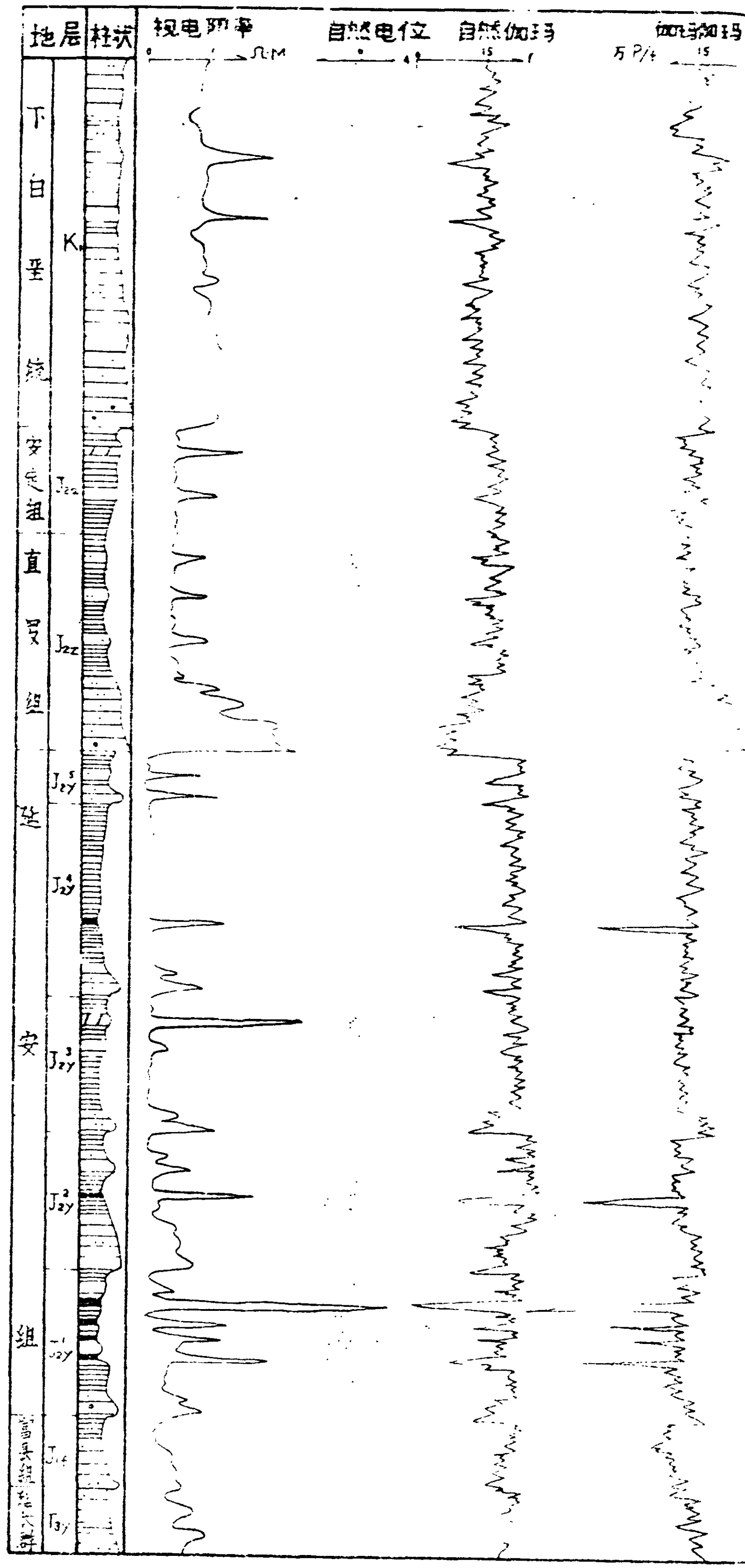


图8　黄陵矿区测井综合柱状图

侏罗系中统延安组，本组地层中泥岩和粉砂岩占的比例较大，除煤层、中、细粒砂岩和钙质粉砂岩外，整个地层基本上以低电阻、中密度、放射性元素含量较高为其特征。中、细砂岩电阻率较高，密度较大，尤其在店头附近第二段下部的中粒砂岩，视电阻率值可高达150Ω·M，仅次于煤层和钙质砂岩的视电阻率值。在整个钻孔剖面中，煤层的电阻最高，密度最小，放射性元素含量最低，因而煤层在视电阻率、伽玛加玛曲线上均呈现非常突出的高异常，在自然伽玛曲线上也有明显显示。钙质粉砂岩的视电阻率仅低于煤层而远高于其它地层，所以在视电阻率曲线上也呈现比较高的异常。上述延安组的物性特征，沿走向和倾向变化甚小，可资对比（图9、图10），反映了延安组地层，尤其是三～五段比较稳定。延安组不同岩性及煤层的物性参数值见表2。

表2

岩性 \ 参数	视电阻率（Ω·m）	伽玛伽玛（P/Γ）	自然伽玛（γ）
泥岩	7～29	5～10万	18～30
粉砂岩	27～40	4·5～8万	17～24
钙质粉砂岩	158～283	4～6·5万	12～26
中、细砂岩	30～150	4～6·5万	15·20
煤层	80～420	7～26万	3～10

侏罗系中统直罗组：底部之厚层中、粗粒长石砂岩电阻较高，密度较大，曲线反映明显，是和延安组地层划分并进行曲线对比解释的一个主要标志层。中上部地层因较高电阻的砂岩与低电阻泥岩、砂质泥岩交替沉积，所以视电阻曲线形态高低变化剧烈，这是直罗组一个显著特征。

侏罗系中统安定组：本组地层以较低电阻的页岩、泥岩、粉砂岩为主，视电阻率值一般在１５～５０Ω·M之间，曲线反映低而平缓，只在泥灰岩或钙质砂岩处，视电阻率曲线才有明显的高异常。泥灰岩视电阻率可高达３００Ω·M。

白垩系下统洛河组：由于本组中粒砂岩胶结非常疏松，很易充水，所以视电阻率值很低，曲线形态平直，其他各种参数曲线也无明显异常。

白垩系下统华池环河组：视电阻率和密度均高于洛河组地层。

通过对黄陵矿区测井资料的综合分析表明，利用测井曲线划分钻孔地质剖面和确定的煤层深度、厚度，进行岩、煤层对比是可信的，选用自然伽玛曲线，辅以视电阻率曲线，可对延安组沉积环境进行初步探讨　（如图１１）。延安组三段电测曲线解释的厚层泥岩，其自然伽玛较高，视电阻率很低，两条曲线形态都比较平直，反映了安静稳定的较深水沉积，而四段细砂岩和粉砂岩交互沉积，成层较薄，自然伽玛曲线和视电阻率曲线形态高低相间，变化明显，

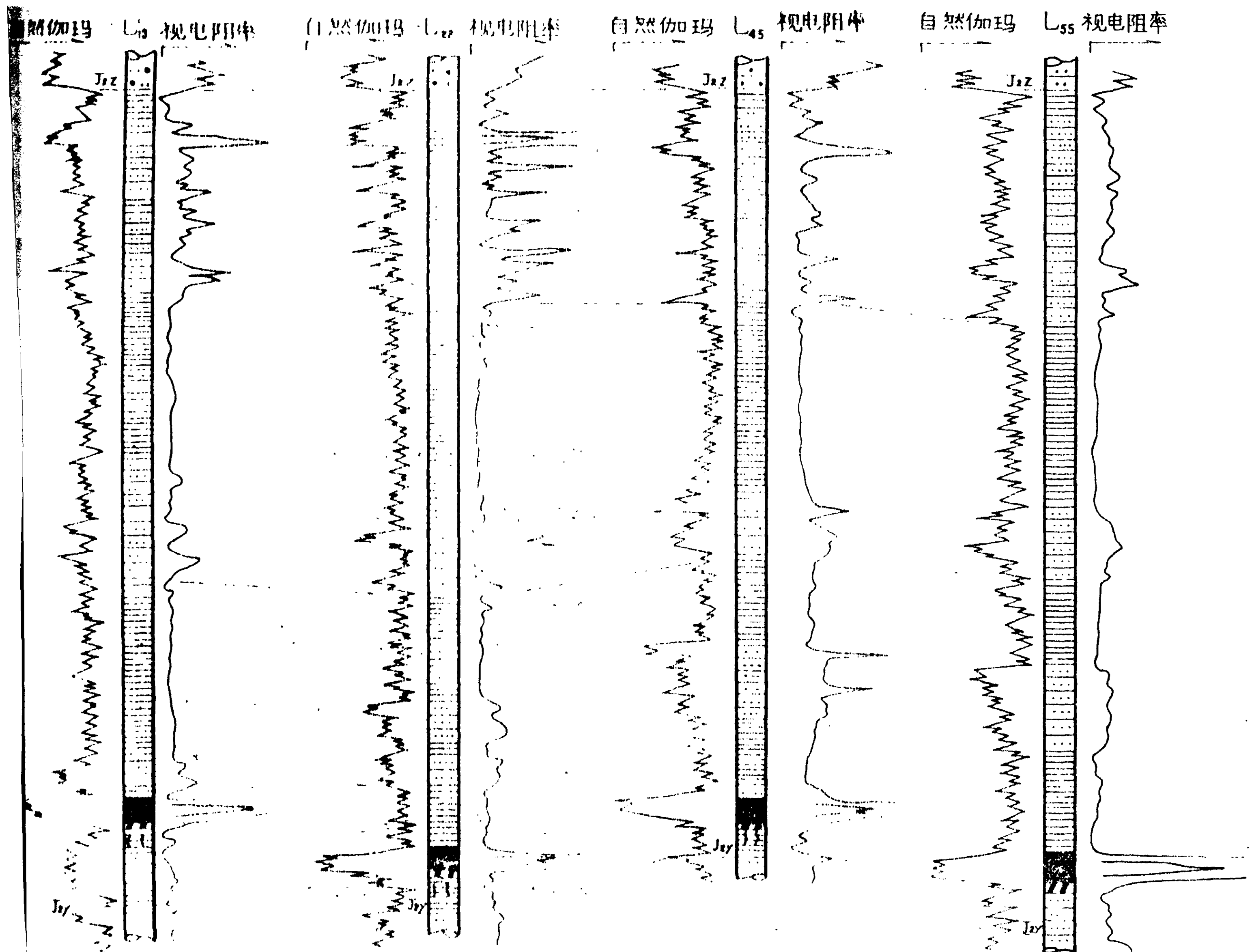


图8 黄陵矿区延安組沿走向测井曲线对比图

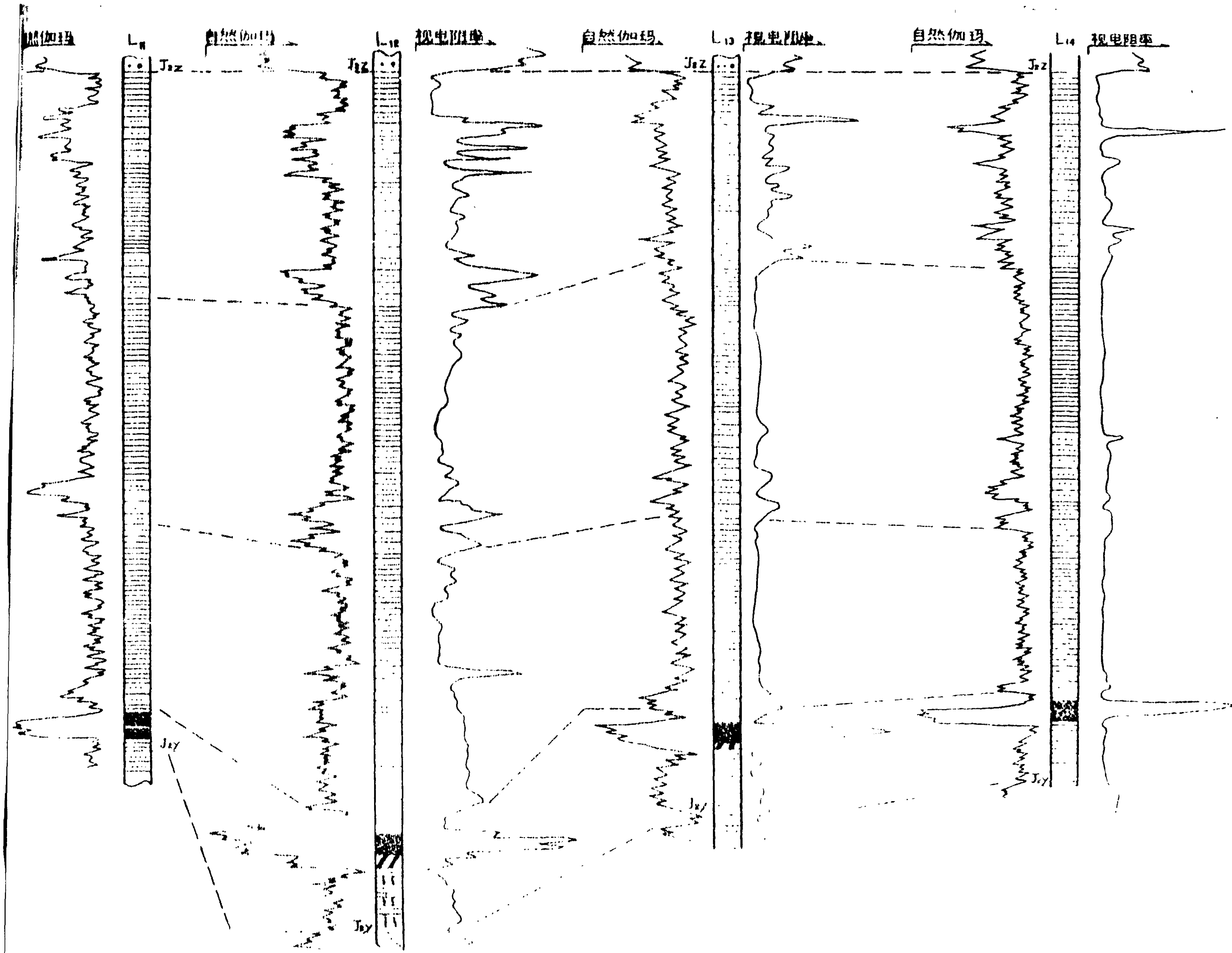


图10　黄陵矿区延安组沿倾向测井曲线对比图

可以推断当时水进、水退交替频繁的滨湖相沉积。延安组二段下部店头砂岩，在自然伽玛曲线上物性稳定，曲线特征性强，利用测井曲线能勾划出它的形状。因此测井资料对分析研究沉积环境确有一定的参考价值。

3.岩相特征：本区为内陆盆地型沉积，延安组地层之岩相，由冲积相、沼泽相、湖泊三角洲相和湖泊相所组成。

（1）冲积相：发育在中侏罗世早期，主要分布在仓村及其以北的局部地区，平面呈条带状，位于延安组底部，其厚度变化较大，仓村一带厚达25米，一般均在10米以内。按其特征可分为河床亚相和河漫滩亚相。

河床亚相：由浅灰色中～粗粒砂岩组成，底部局部见有砾岩，砾石成分为石英和燧石。具直线型斜层理及交错层理，分选较差。

河漫滩亚相：主要由浅灰色细砂岩、粉砂岩组成，与河床亚相共生。

（2）沼泽相：根据水动力条件及沉积物特征，沼泽相可分为闭流沼泽相、复水沼泽相和泥炭沼泽相。

闭流沼泽相：由灰色粉砂岩、泥岩组成，含大量垂直层面的植物根化石。团块状结构，常位于复水沼泽相或泥炭沼泽相之下，为煤层的底板和夹矸。

复水沼泽相：主要为鲕颗泥岩和含炭质较高的粉砂岩。具水

平层理或不规则水平层理，含大量炭化植物化石及碎片，常为煤层顶底板和夹矸。

泥炭沼泽相，为泥炭堆积，形成煤层。本区延安组沉积时，曾发生过多次泥炭沼泽，按其成因，主要可分为两种类型，第一种为湖泊近岸沼泽化。

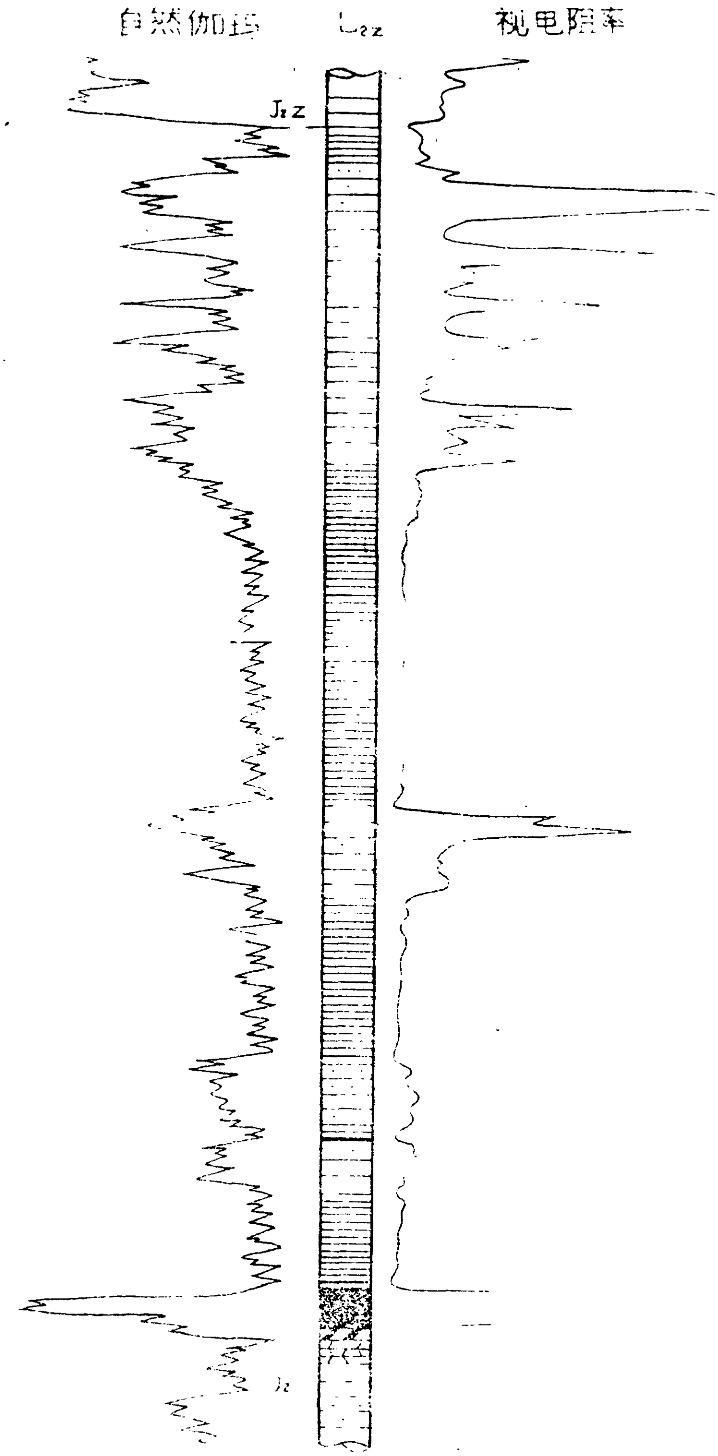


图11　黄陵矿区L_{2z}号钻孔延安组测井

第二种为三角洲平原局部沼泽化。前者形成的煤层分布广，厚度中等。为本区的主要可采煤层，但因古地形的影响，其层数和厚度均有一定的变化。后者因发育的时间较短，并被湖进沉积物所复盖，故形成的煤层较薄，但较稳定，且分布在三角洲沉积范围内。

（3）湖泊三角洲相：发育于延安组二段，岩体由店头向北西方向呈指状、舌状延伸（图12），是河流充填浅水湖泊的过程中建造的。具有三角洲沉积的三层结构，即底部的前三角洲相，中部的三角洲前缘相，上部的三角洲平原相。

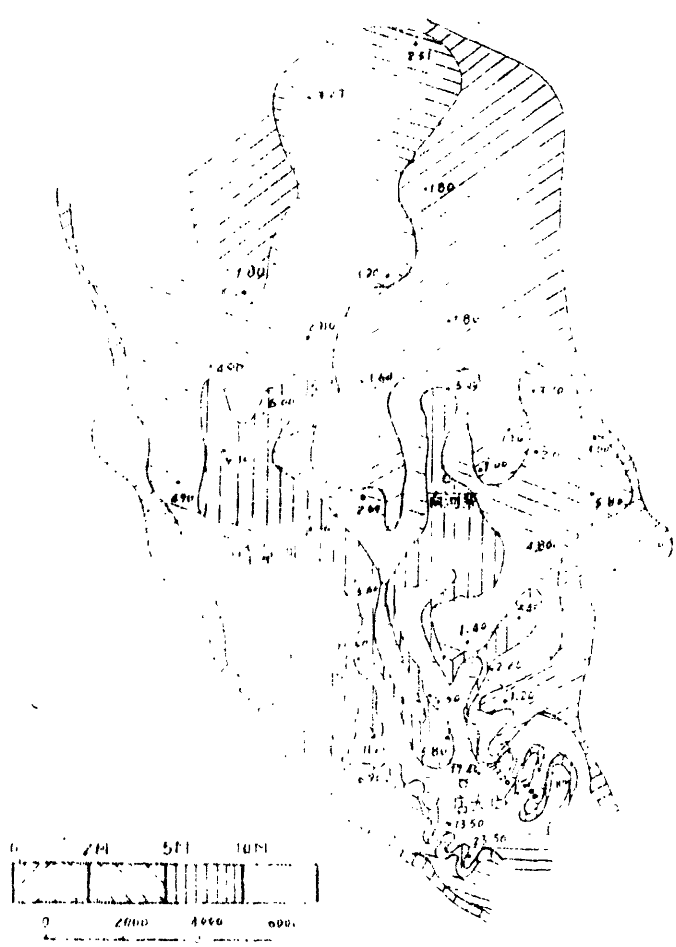


图12　店头砂岩砂体等厚线图

前三角洲相：主要由深

灰色粉砂岩、泥岩及少量细砂岩组成，常为互层状，具水平和波状层理，薄层状，层面含大量炭屑及白云母片，形成沉积纹层，含植物化石碎片及少量完整的叶化石。

三角洲前缘相：位于三角洲沉积的前缘，由于水下地形的变化和水流速度的减慢，故在不同部位，其沉积结构则有差异，据此可分为分流河口砂坝亚相、分流间湾亚相和远砂坝亚相。

a、分流河口砂坝亚相：位于分流入湖处，由于流速的降低，砂粒在河口沉积，加之湖水波浪的作用，使其形成的砂体具有楔形斜层理、波状层理，砂体由下而上颗粒变粗，在横向上常相变为分流河道亚相。

b、河流间湾亚相：主要由粉砂岩与细砂岩互层夹少量泥岩，薄层状，具水平层理、波状层理、斜波状层理及透镜状层理，含植物化石碎片及炭屑，它与前三角洲相界线不易划分，横向上常相变为分流河口砂坝亚相。

c、远砂坝亚相：主要由细、粉砂岩组成，以水平层理及波状层理为主，局部见有斜层理，它是由分流河口砂坝经湖水作用重新分布的结果，分布在三角洲砂岩体的前缘和两侧，形成广泛分布的席状砂体。

三角洲平原相：位于三角洲沉积的上部，主要由分流河道亚相和泛滥平原亚相组成。

a、分流河道亚相：是三角洲平原相中砂粒最多的部位，由中～细粒石英砂岩所组成，局部夹粗粒砂岩透镜体，中～厚层状，分选及园度差～中等，以中型楔状斜层理为主，局部为交错层理，波状层理，并见有少量铁化木、泥质包体及水流波痕，砂体呈长条状分布，横向上呈大的透镜体（图13），并相变为粉砂岩和细砂岩。

延安组二段砂岩部分粒度概率曲线为直线的二段型（图14），

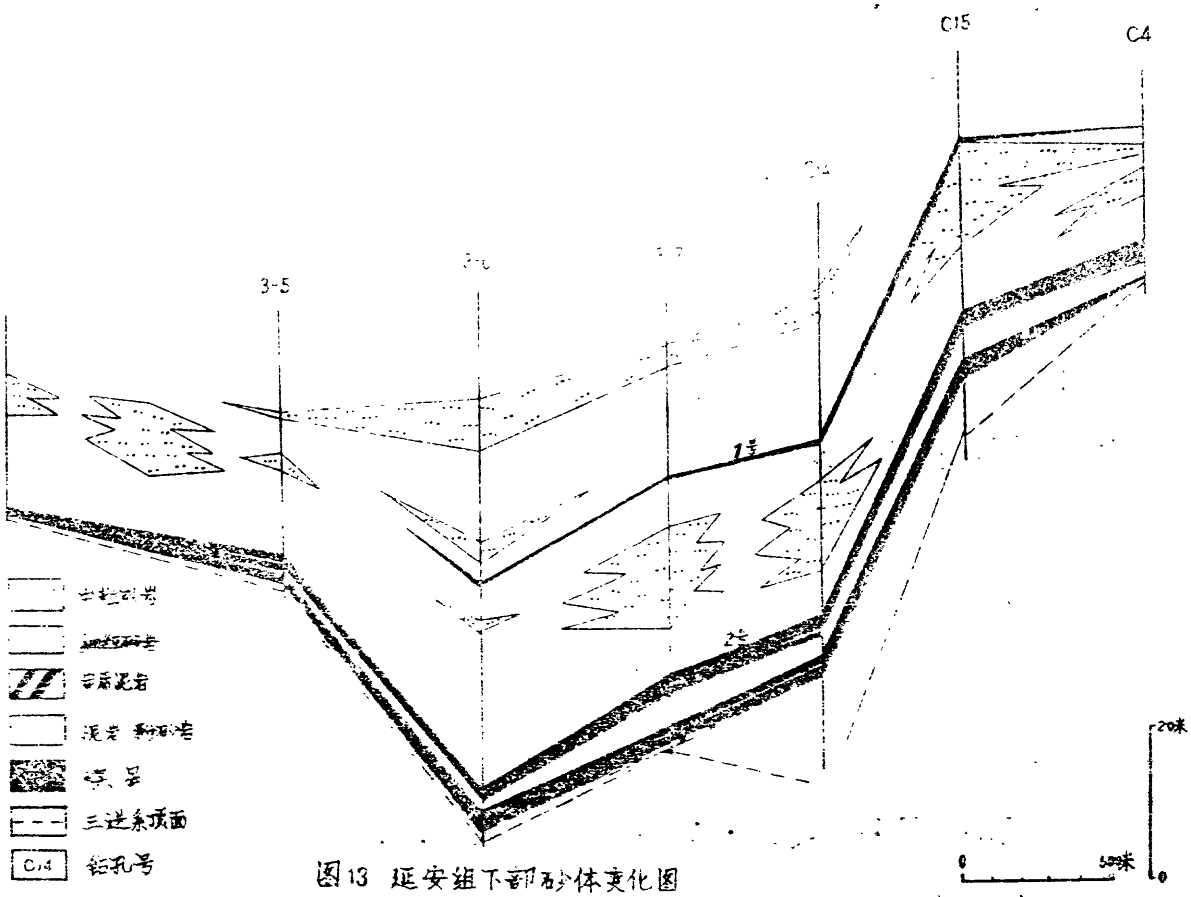


图13 延安组下部砂体变化图

曲线只有跳跃次总体和悬浮次总体，一般缺牵引次总体。跳跃次总体占64～75%，斜率55°～75°，分选较好。悬浮次总体斜率30°～49°，分选中等，截点一般在2ϕ左右处突变。据以上各点，该砂体为分流河道砂体。

b、泛滥平原亚相：由湖泊相、沼泽相、泥炭沼泽相组成，沉积物以粉砂岩、泥岩和煤组成，局部见有细砂岩，泥炭沼泽相具有分布广，横向上连续性好，但厚度较小的特点，可以根据泥炭沼泽相来圈定三角洲沉积的范围。

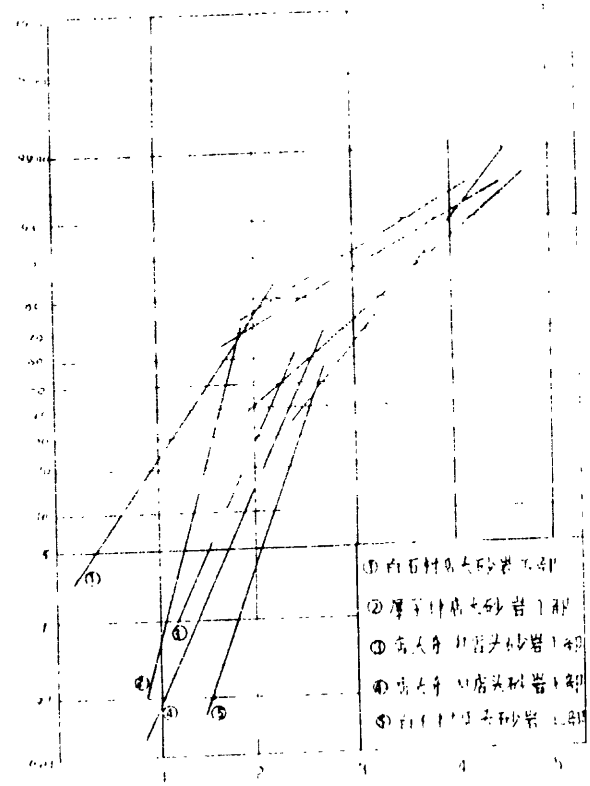


图14 店头砂岩粒度概率曲线图

4、大陆湖泊相：以延安组三、四段最为发育，分布面积广，岩性、岩相稳定（图15、16、17），一、二段湖水范围较小，岩性、岩相不太稳定，按其沉积特征，可进一步划分为湖岸沙滩亚相、滨湖亚相和湖泊亚相。

湖岸砂滩亚相：主要分布在受湖水波浪影响的湖岸地带，如南

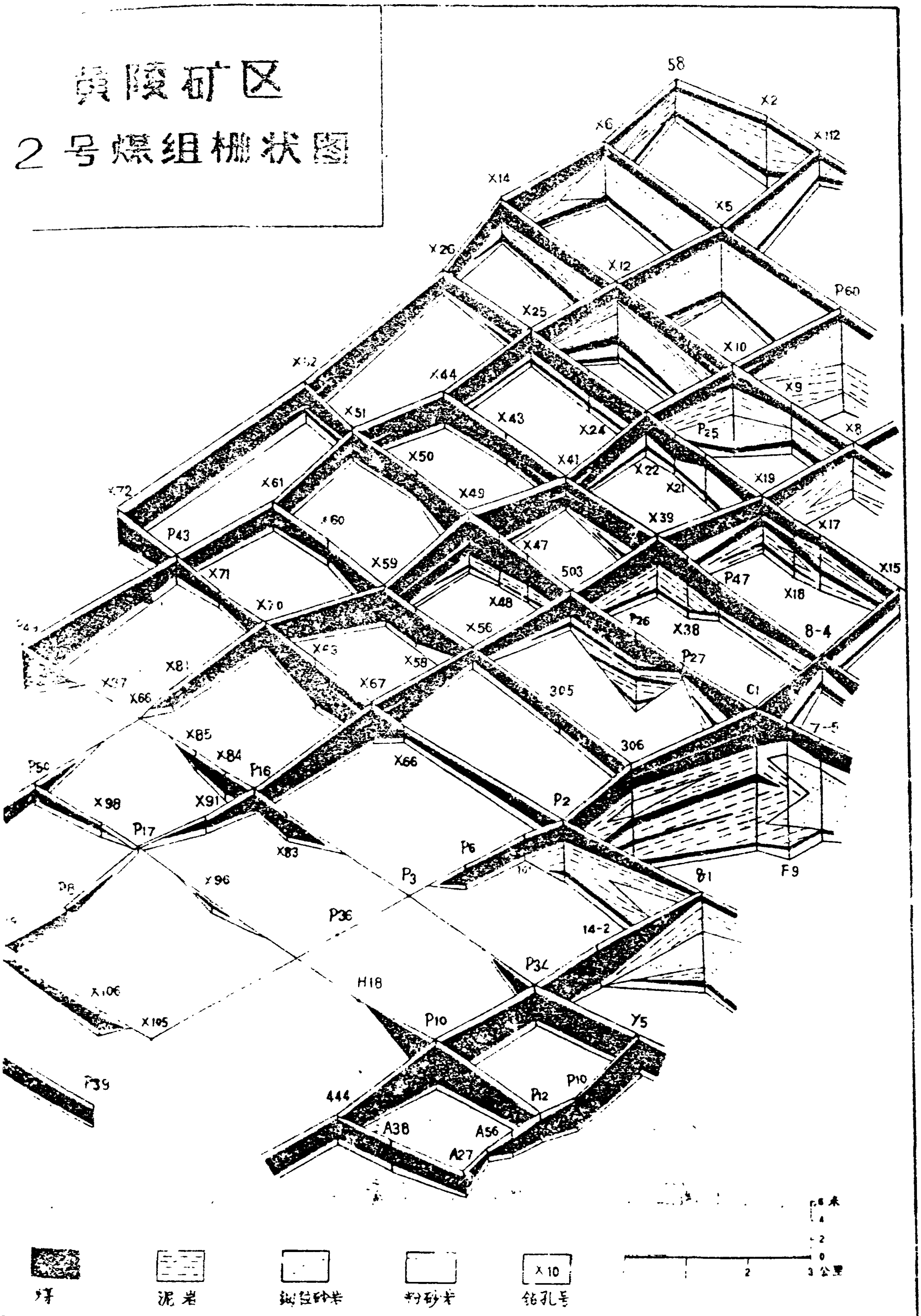


图15

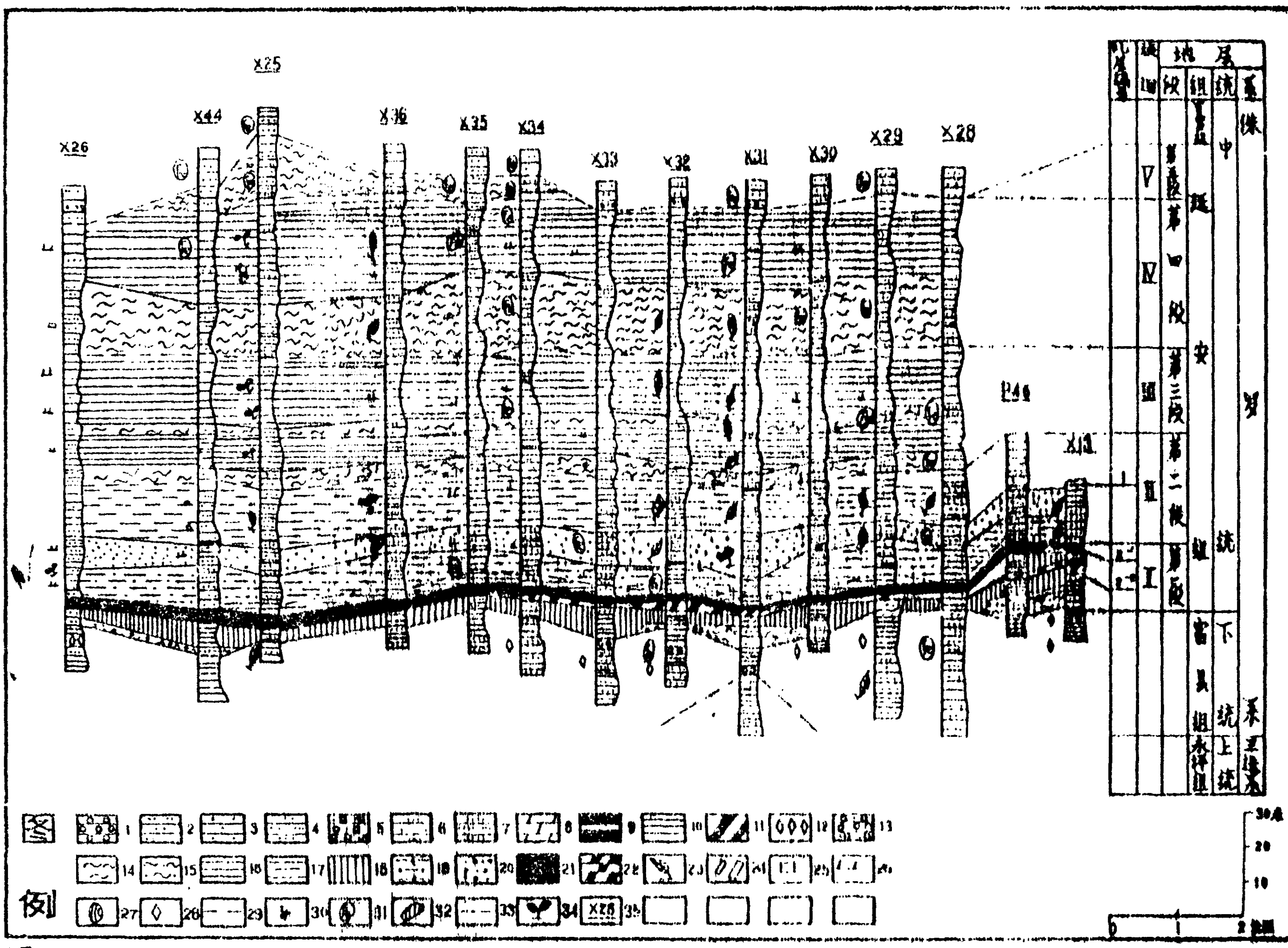


图16

黄陵矿区延安组岩相剖面图(傾向)

1砾岩 2.中砂岩 3.粗砂岩 4.细砂岩 5.砂砾岩 6.含砾砂岩 7.粉砂岩 8.泥灰岩 9.煤及夹矸 10.泥岩 11.炭质泥岩 12.菱铁矿层 13.河床相 14.浅湖相 15.河漫相 16.湖泊相 17.三角洲平原 18.曲流河道 19.湖岸砂堤 20.三角洲前缘 22.分水河道 23.植物化石 24.铁化木 25.黄铁矿 26.植物碎屑 27.动物化石 28.菱铁矿 29.旋回界线 30.植物根 31.铁质结核 32.泥质包体 33.平行不整合线 34.炭化植层 35.钻孔编号

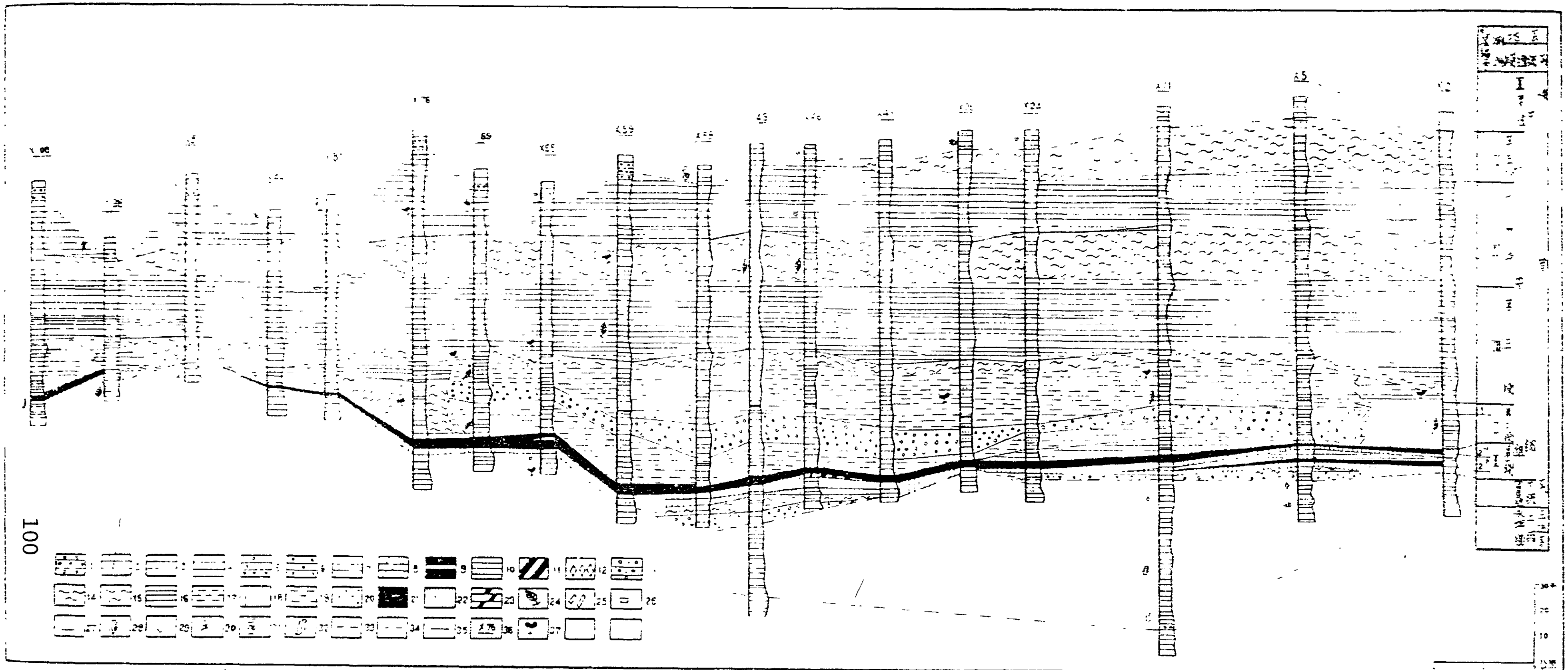


图17

黄陵矿区延安组岩相剖面图(走向)

1 砾岩 2 中砂岩 3 粗砂岩 4 细砂岩 5 砂砾岩 6 含砾砂岩 7 粉砂岩 8 泥灰岩 9 煤及夹矸 10 泥岩 11 炭质泥岩 12 菱铁矿 13 河床相 14 滨湖相 15 河漫相 16 湖泊相 17 三角洲平原 18 闭流沼泽 19 湖岸砂滩 20 三角洲前缘 21 泥炭沼泽 22 黄土层 23 复水沼泽 24 植物化石 25 铁化木 26 黄铁矿 27 植物碎屑 28 动物化石 29 菱铁矿 30 植物根 31 铁质结核 32 泥质包体 33 平行不整合线 34 旋回界线 35 界线 36 钻孔编号 37 炭化植屑

部王家坪和东北部现头村一带，较细的碎屑被冲到较深的水中，细粒砂及部分粉砂则沿着湖岸沉积，形成沙滩。湖岸沙滩形成的砂岩，分选较好，以波状层理为主，并见有小～中型缓直线型斜层理、水平层理和透镜状层理，层面含植物化石碎片及炭化碎屑，横向上常相变为滨湖亚相。

滨湖亚相：为湖水面以下，浪基面以上的沉积物，主要由细砂岩、粉砂岩组成。颗粒分选中等，具波状层理、透镜状层理及不规则的水平层理，含植物化石碎片及炭屑，位于三～五段的底部。

湖泊亚相：以泥岩为主，含少量粉砂岩、细砂岩、钙质粉砂岩、泥灰岩等，水平层理发育，含完整植物化石及瓣鳃类动物化石，尤其在延安组四段，层理特别均一，深浅色相间，代表湖水季节性的规律变化。

4、沉积旋回岩相组合类型：延安组地层的岩性分段，是与沉积旋回的划分相对应的，反映了中侏罗世早期由于地壳振荡运动而引起湖水深浅的变化，导致各旋回岩相组合的差异。

（1）Ⅰ旋回：是区内主要含煤旋回，其岩相组合有两种类型：

a、河湖沼型：分布在有延安组底部砂岩的局部区域，主要受中侏罗世早期古仓村河的控制，底部与早侏罗世富县组或晚三叠世永坪组接触。其泥炭沼泽是在河床相、河漫相的基础上发展起来

的，在平面分布上主要为炭质岩～砂岩相区（图18），其相序为河床相→河漫相→沼泽相→泥炭沼泽相→湖泊相（或湖沼相），一般厚20～30米。

b、湖沼型：分布范围较广，除几个古高地外均有分布。其泥炭沼泽是在富县组的剥蚀残积面上或含浅湖的坡、洪积沉积物上形成的，在平面上主要为炭质岩相、泥岩～炭质岩相及炭质岩～泥岩相分布区（图18）。其剖面相序为沼泽相→泥炭沼泽相→湖泊相（或湖沼相）。一般厚5～10米。

（2）Ⅱ旋迴：其岩相组合可分为两种类型。

a、湖泊三角洲：分布在矿区中部，三角洲中的砂体从边缘向北西方向延伸，其岩性及厚度都有一定的变化。总的变化趋势是粒度变细（由中粒砂岩变为细砂岩），砂岩百分含量减少，泥岩含量增加，砂岩层数增多，但单层厚度减薄，据此可将三角洲砂岩划分为后座带、核心带和前缘带（图19），当今能见到的主要是核心带和前缘带、后座带已被剥蚀。

湖泊三角洲型的剖面岩相组合为前三角洲相→三角洲前缘相→三角洲平原相，一般厚30～40米。但在三角洲的不同部位，其砂岩的特征有所不同，因此，可将其剖面相序分为三种基本型式（图20）。图20中A位于分流河道处，三角洲平原相特别发育，三角洲前缘相和前三角洲相可能被分支河道冲蚀掉，其相序为分流

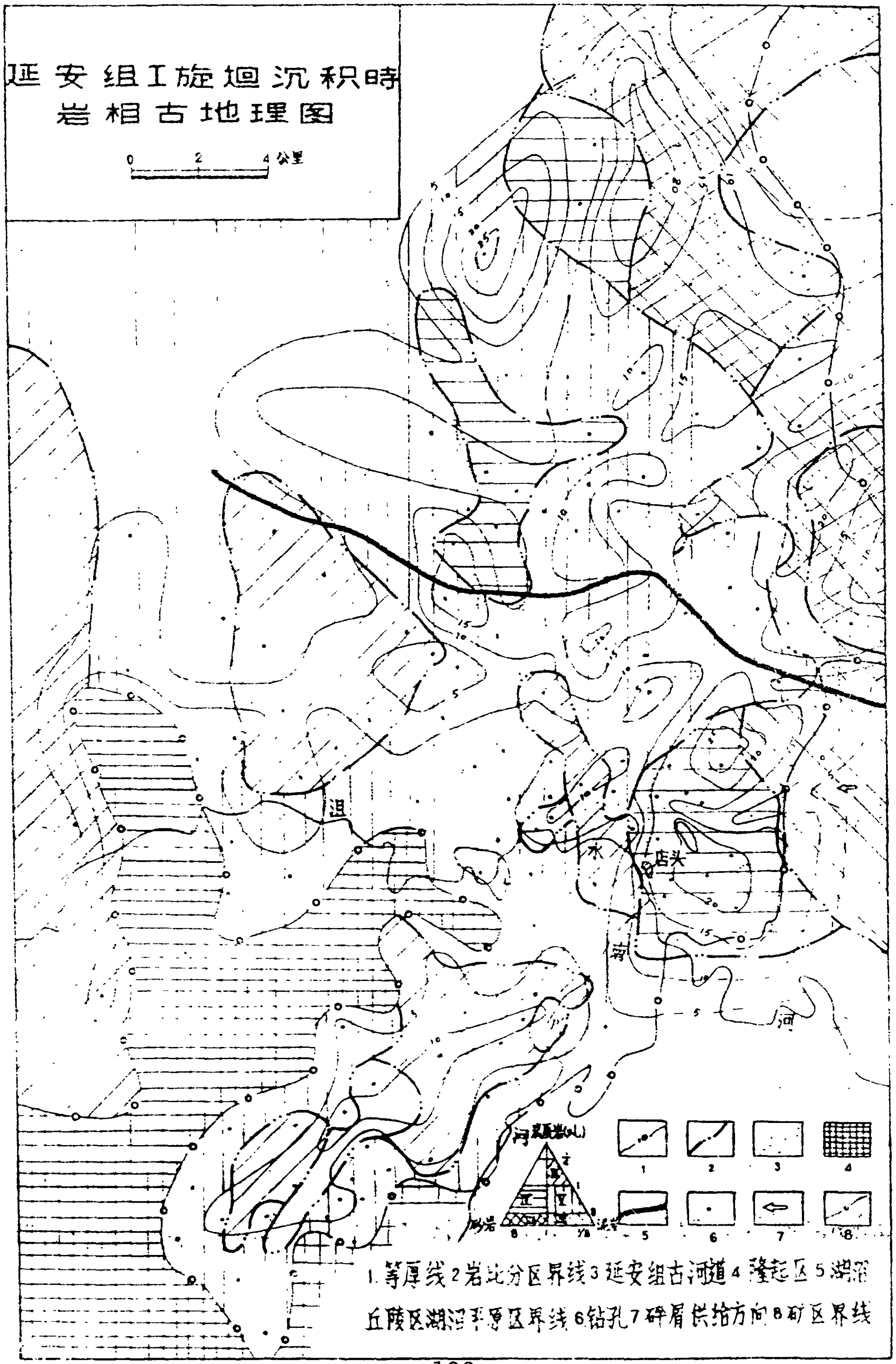

延安组Ⅰ旋迴沉积時
岩相古地理图
0 2 4 公里
沮
水
店头
河
1.等厚线 2岩比分区界线 3 延安组古河道 4 隆起区 5 湖沼
丘陵区湖沼平原区界线 6 钻孔 7 碎屑供给方向 8 矿区界线

图18

河道亚相—泛滥平原亚相。图20中B位于分流河道之间，三角洲前缘相由分流间湾亚相组成。主要为砂岩与粉砂岩互层，与前三角洲相不易区分。其相序为前三角洲相—分流间湾亚相—三角洲平原相。（图20）中C位于三角洲的前缘和两侧，三角洲前缘相由远砂坝亚相组成，其相序为前三角洲相—远砂坝亚相—三角洲平原相。

b、湖泊型：分布在湖泊三角洲的两侧，即曹家峪以南，店子沟以北，其岩相组合为滨湖亚相～浅湖亚相，厚度一般小于20米。在矿区南部王家坪及北部现头村一带，因远离三角洲而靠近湖岸，其岩相组合为湖岸砂滩亚相～浅湖相，厚一般大于20米。

（3）Ⅲ旋迴：旋迴结构简单，稳定，遍布全区，其岩相组合为滨湖亚相～湖泊相，在南部王家坪一带，超复在晚三叠世永坪组之上，厚20～30米。

（4）Ⅳ旋迴：旋迴结构亦较简单、稳定，一般厚40米，其岩相组合为滨湖亚相—湖泊相，在局部地方有沼泽相。

（5）Ⅴ旋迴：是一个不完整的旋迴，上部已被剥蚀，只有下部的滨湖亚相，代表延安组沉积后地壳的上升。

据上述各旋迴沉积相的组合关系，本区延安组的沉积可分为河湖沼、湖沼、湖泊三角洲和湖泊等四个体系，每个沉积体系无论在岩性、岩相和含煤性等方面都有其各自的特征（表3）。这些特点与当时的沉积环境密切相关。

表3

沉积体系	岩性特征	岩相特征	在剖面部位	含煤性	聚煤环境
湖泊体系	以泥质碎屑岩为主	以湖泊相为主	上部	最差	湖滨沼泽成煤
三角洲体系	以砂、粉砂岩为主	由前三角洲、三角洲前缘、三角洲平原相组成	中、下部	较差	三角洲平原成煤
河湖沼体系	底部以砂岩为主上部以泥岩、煤为主	底部为冲积相中、上部为湖泊相	下部	较好	河、湖泊成煤
湖沼体系	以泥岩、煤为主	以沼泽相为主	下部	最好	湖沼成煤

5.延安组沉积环境

（1）延安组沉积前古地理概况

三叠系沉积以后，印支运动使鄂尔多斯盆地上升，且盆地的西北部、东北部和南部上升较高，因此在盆地的不同部位，三叠纪地层遭到不同程度的侵蚀。本区位于盆地的东南缘，印支运动之后，三叠纪地层遭到侵蚀，因此缺失三叠系上统瓦窑堡组地层，并形成南高北低的地貌景观，在凹凸不平的侵蚀面上，沉积了早侏罗世的富县组，但其厚度和岩性变化较大，沉积类型严格受古地形的控制，大致以牛家庄～南河寨～李章河一线为界，以南地形较高，为剥蚀和残积相区（图21），岩性为杂色泥岩和铝土质泥岩，厚度一般在1米以内，局部达数米，显然属三叠系顶部的风化壳，经剥蚀面

延安组Ⅱ旋迴沉积时岩相古地理图

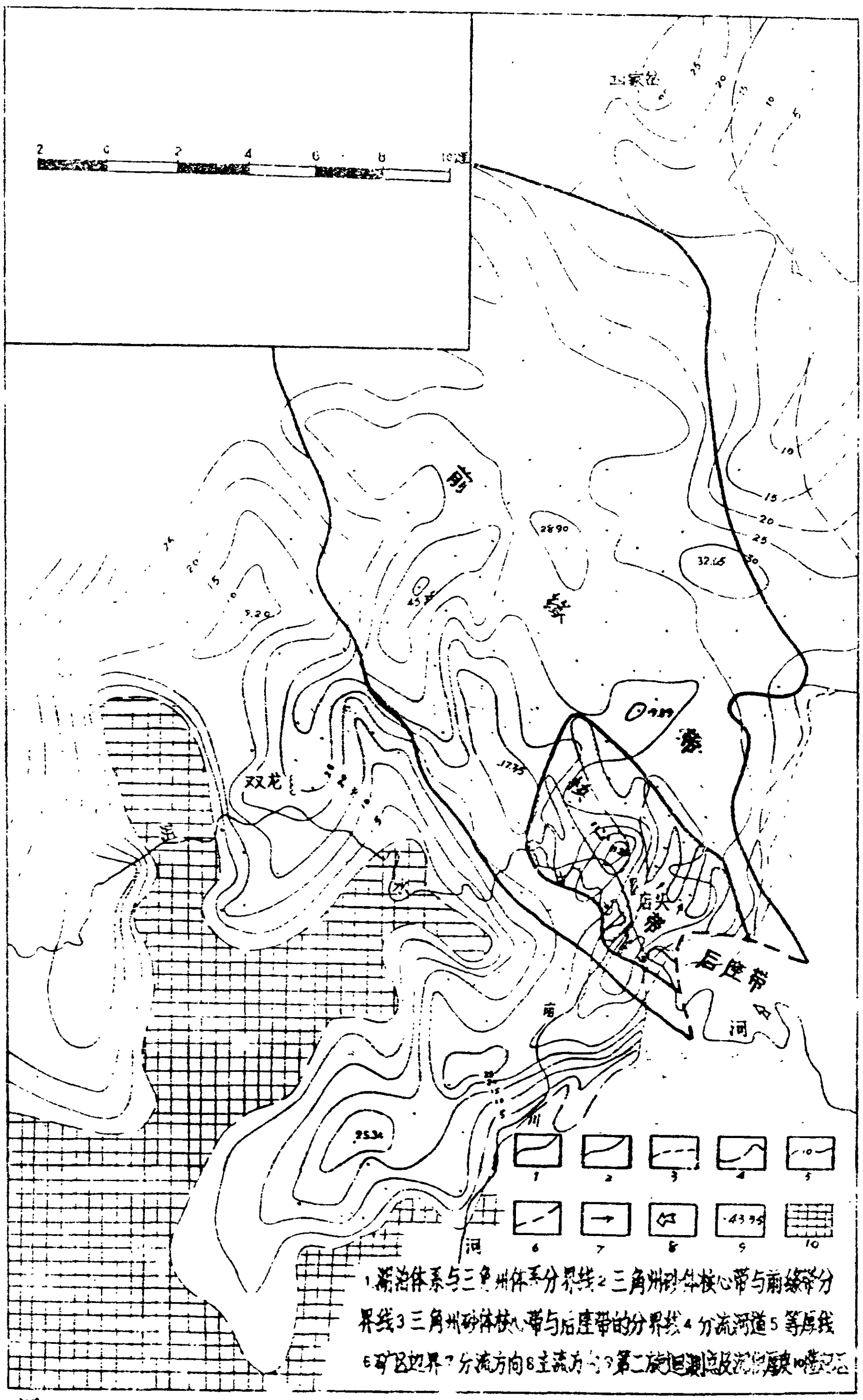


图19

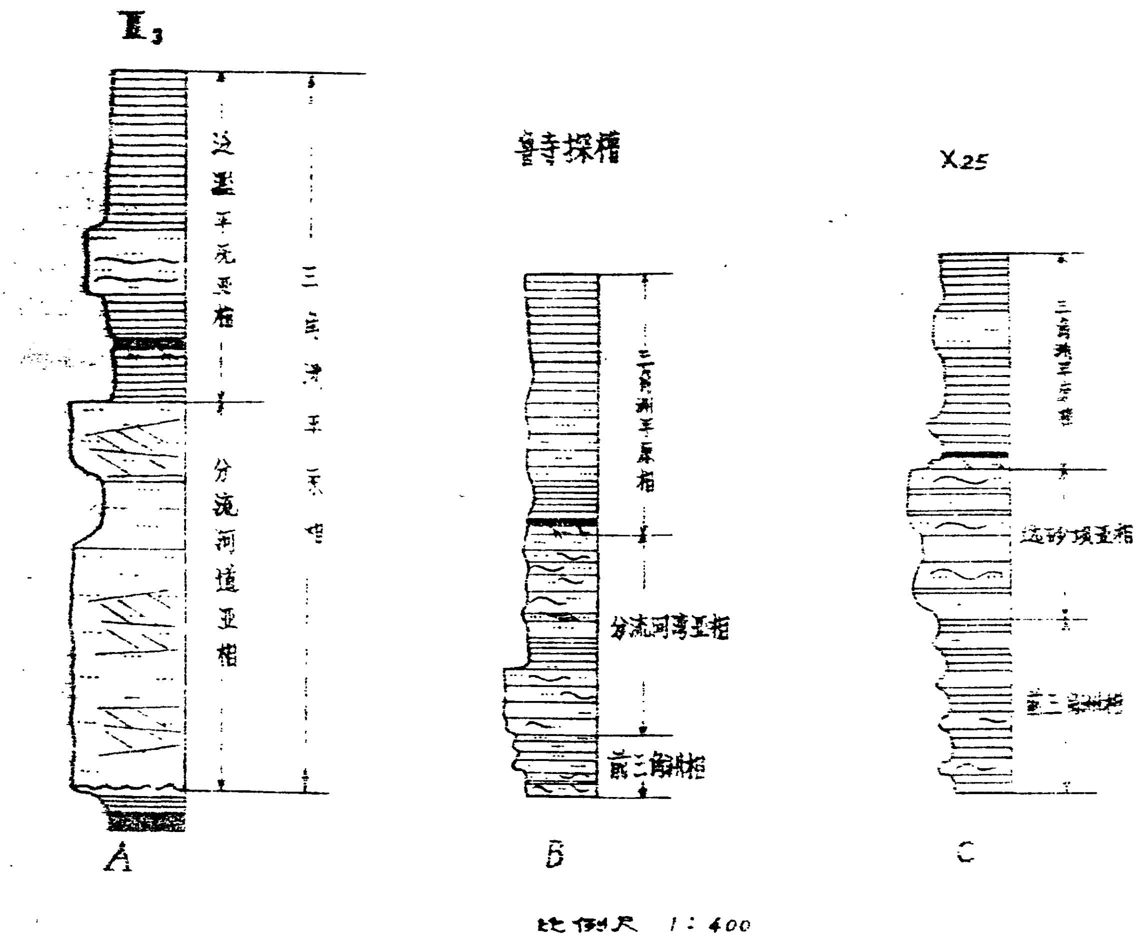


图 20　三角洲旋迴垂直沉积层序型式

局部保存的残积相。上述界线以北，地形较低，为含浅湖的坡～洪积相区（图21）。沉积了一套以灰绿色、紫杂色为主的泥岩、粉砂岩夹灰白色中粒砂岩，底部为含砾砂岩或砾岩，厚度变化较大，且在古地形低洼处，厚度较大（图21）。总之，早侏罗世富县组是距物源区较近的坡、洪积沉积，气候干热，尽管南部地势较高，以剥蚀为主，而北部地形较低，以沉积为主，但结果都是使地形不

断地夷平，起到填平补齐的作用，并为延安组含煤建造的形成，创造了有利的地形条件。

（2）延安组沉积时的古地理环境：

早侏罗世富县组沉积以后，早期燕山运动在本区表现为再度的上升，但当时的地貌景观总的趋势仍然是南高北低。而在牛家庄一南河寨一李章河一线以南，原有的南峪口、西峪村、 磨坪等高地和秋林子一仓村、寺湾、双龙等凹地及次一级高地和凹地进一步加强，形成南部的丘陵地形和北部的向北倾斜的平原，开始了中侏罗世早期延安组的沉积。

本文在分析了延安组地层的岩性、岩相特征和各旋迴岩相组合关系之后曾经指出，本区延安组的沉积，自下而上可分为河湖沼、湖沼、湖泊三角洲和湖泊等四个沉积体系，各沉积体系的分布，在平面上与一定的体系共生，反映了在同一时期内亚环境的区别，如当沉积湖沼体系前，在其低凹处有一古仓村河，沉积了延安组底部砂岩，随后发展为沼泽而形成河湖沼体系，它与湖沼体系共生。沉积湖泊三角洲体系时，其两侧为湖泊体系。沉积体系在垂向上的共生关系，反映了沉积环境随时间而发生的变化，区内湖沼体系向上过渡为湖泊三角洲体系，再向上过渡为湖泊体系，说明本区延安组沉积时，虽有小规模的湖进、湖退，湖水有涨有落，但总的是一个水进过程，这一过程是由各个沉积旋迴来完成的。延安组Ⅲ、Ⅳ旋

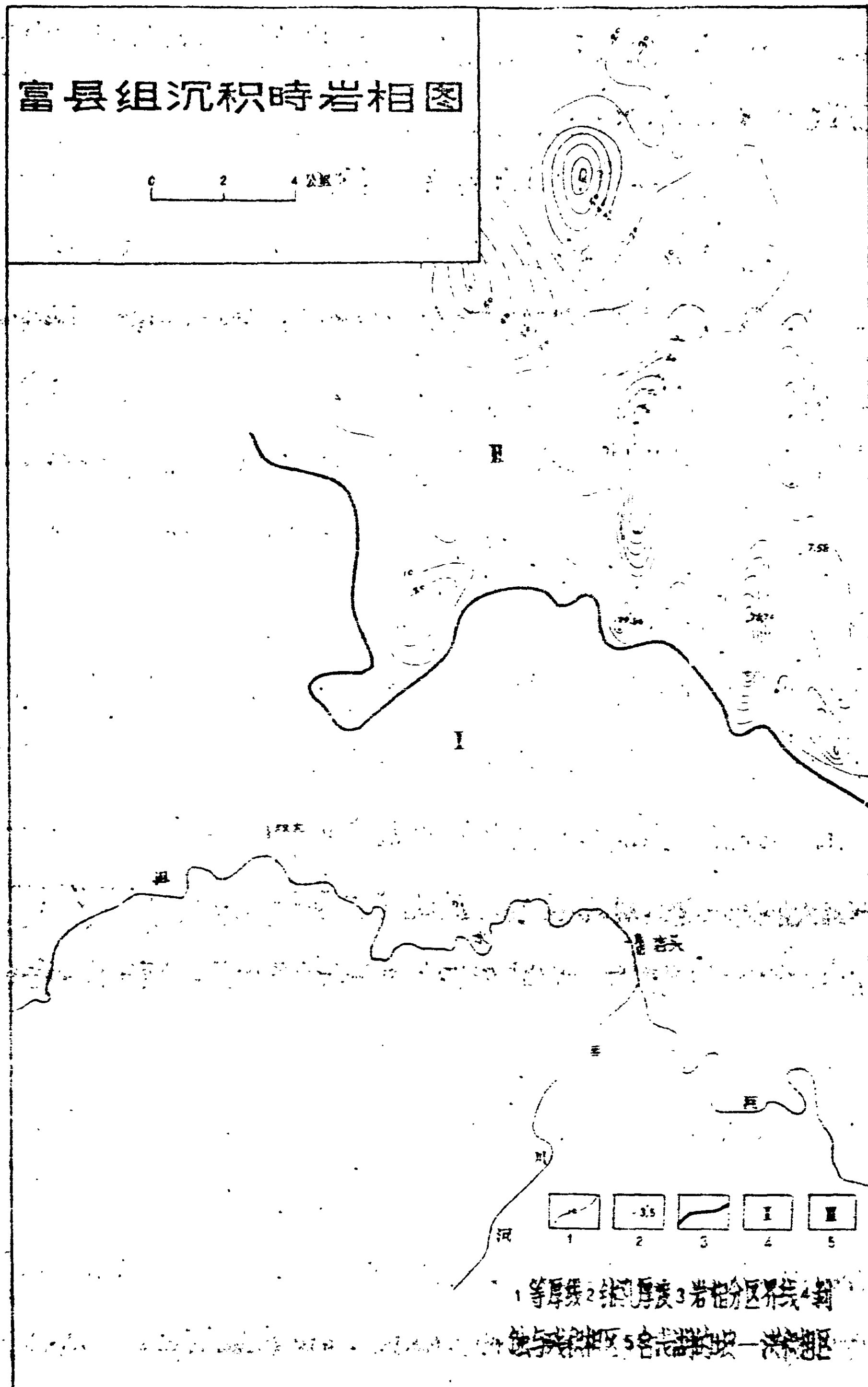


图7

迴中的湖泊相，其岩性、岩相稳定，可作为区域标志层进行对比，Ⅳ旋迴中的湖泊相，除有泥灰岩、钙质粉砂岩外，几乎全为灰色泥岩，且质地细腻，具季节性水平纹层，是湖水达到最大、最稳定的时期，而到Ⅴ旋迴沉积时，湖水开始后退，随后地壳上升，盆地进入另一发展阶段。

前已指出，延安组泥质岩的粘土矿物成分，下部主要为高岭石，其次为伊利石，而上部主要为蒙脱石，其次为伊利石，结合碎屑岩胶结物的成分，下部主要为铁质、泥质胶结，并产出大量的锥叶蕨—凤尾银杏植物群化石，而上部主要为钙质、泥质胶结，并有钙质粉砂岩和泥灰岩产出，推测延安组沉积时的古气候是从温热潮湿向炎热方向变化的，水介质是从酸性—碱性—弱还原方向发展。

综上所述，本区延安组的沉积环境，总的与大陆湖泊关系密切，其发展可分为三个阶段。延安组沉积的早期，即Ⅰ旋迴沉积时期，从最初的局部河流沉积发展为滨湖环境，泥炭沼泽是湖泊近岸沼泽化的结果，由于当时气候温热潮湿，水介质为酸性，有利于植物的生长，形成了本区主要的泥炭区，据古地形可进一步分为南部的湖沼丘陵区和北部的湖沼平原区。延安组沉积的中期，是在湖水后退，河流充填湖泊过程中建造的三角洲环境，主体从店头向北西方向呈舌状延伸，其两侧为湖泊沉积，在三角洲平原上，发育了泥炭沼泽，但因发育的时间较短，并很快被湖进沉积物所复盖，故形成的煤层

较薄，而失去经济价值。延安组沉积的后期，主要为浅湖环境，仅在边缘的局部地方和秋林子一带，曾发生过短暂的沼泽环境。

五、煤层分布与控制因素

本区延安组含煤三层（0号、1号、2号），主要的2号煤组位于延安组下部，并可分为2－4、2－3、2－2、2－1四个分层，其所在位置和厚度变化见表4。

煤层厚度表　　表4

层号	厚度（M）	结构	所在部位	分布
0号	$\frac{0\sim0.5}{0.25}$	较简单	Ⅳ旋迴中部	另星
1号	$\frac{0\sim0.7}{0.3\sim0.4}$	简单	Ⅱ旋迴中部	三角洲沉积部位
2－1	$\frac{0\sim4.35}{1.3\sim2.7}$	较复杂	Ⅰ旋迴中部	全区
2－2	$\frac{0\sim2.93}{0.7}$	较复杂	Ⅰ旋迴中部	较广
2－3	$\frac{0\sim1.91}{0.3\sim0.5}$	较简单	Ⅰ旋迴中部	局部地区
2－4	$\frac{0\sim0.86}{0.4}$	简单	Ⅰ旋迴中部	另星

从表4可以看出，本区0号和1号煤层，因厚度太薄而失去经

济价值，2号煤组是人们研究、生产的对象，也是我们论述和评价的重点。

根据已有资料和这次研究的结果表明，本区2号煤组有以下特征。

1. 2号煤组的分布范围，从下往上不断扩大，如2－4煤层仅分布在秋林子～仓村和寺湾凹地中心附近，2－3煤层分布范围有所扩大，而2－2、2－1煤层（或呈复合型式）则分布全区。

2. 煤层厚度在古凹地中部最大，向古高地方向和湖泊方向变薄（图22、23）以至尖灭，部分古高地上无煤，甚至无煤系的沉积，在古高地和古凹地之翼部，含煤性中常，且在古凹地轴线方向（NE～SW）煤层较稳定，而在北西方向则变化较大，形成若干个厚煤带和薄煤带或无煤带（图22）。

3. 2号煤的分叉复合关系，一般在凹地中部和指向湖泊的方向，各煤分层之间距加大而形成独立分层（图24），由古凹地向古高地方向，其间距变小，直至复合，因此煤层的结构，一般在凹地中部较复杂。

4. 本区煤质为低变质的烟煤，各煤层物理性质基本一致，煤呈黑色，以半亮和半暗型煤为主，暗淡型煤次之，条带状或线理状结构。显微煤岩类型多为丝炭暗煤质亮煤型和丝炭亮煤质暗煤型，煤岩组份以镜质为主，约占62～86%，其次为丝炭组，占7·8

～3·1%，稳定组分含量不大，一般2～4%。煤层的化学性质比较稳定，其主要指标和表5所示。属低～中灰、低～中硫、高发热量烟煤，牌号为弱粘煤～气煤，且弱粘煤一般分布在南部，而气煤多分布在东北部和西北部。有害组分总的趋势，是从下往上含量减少，如煤的灰分2^{-3}煤一般大于31%，2^{-2}煤19·41～29·57%，2^{-1}煤9·62～23·39%。

上述特点表形，本区煤层虽有一定的变化，但是有规律可循的，其控制因素是多种多样的，就本区而言，主要因素有以下几点：

1. 从图23可以看出，煤层的延展方向和厚薄变化与成煤前的古剥蚀面形态（古地形）

表5

项目 / 煤层	灰分 (A^g %)	全硫 (S^g_Q %)	发热量 (Q^g_{DT} 卡/克)	碳 (C^r %)	氢 (H^r %)	氮 (N^r %)	氧 (O^r %)
三号煤	3·34～38·07 / 14～19	0·28～2·74 / 0·5～1·50	7602～8360 / 8100	83～86 / 85	4·4～5·60 / 5·2	0·93～1·6 / 1·20	6·02～10·6 / 8·5

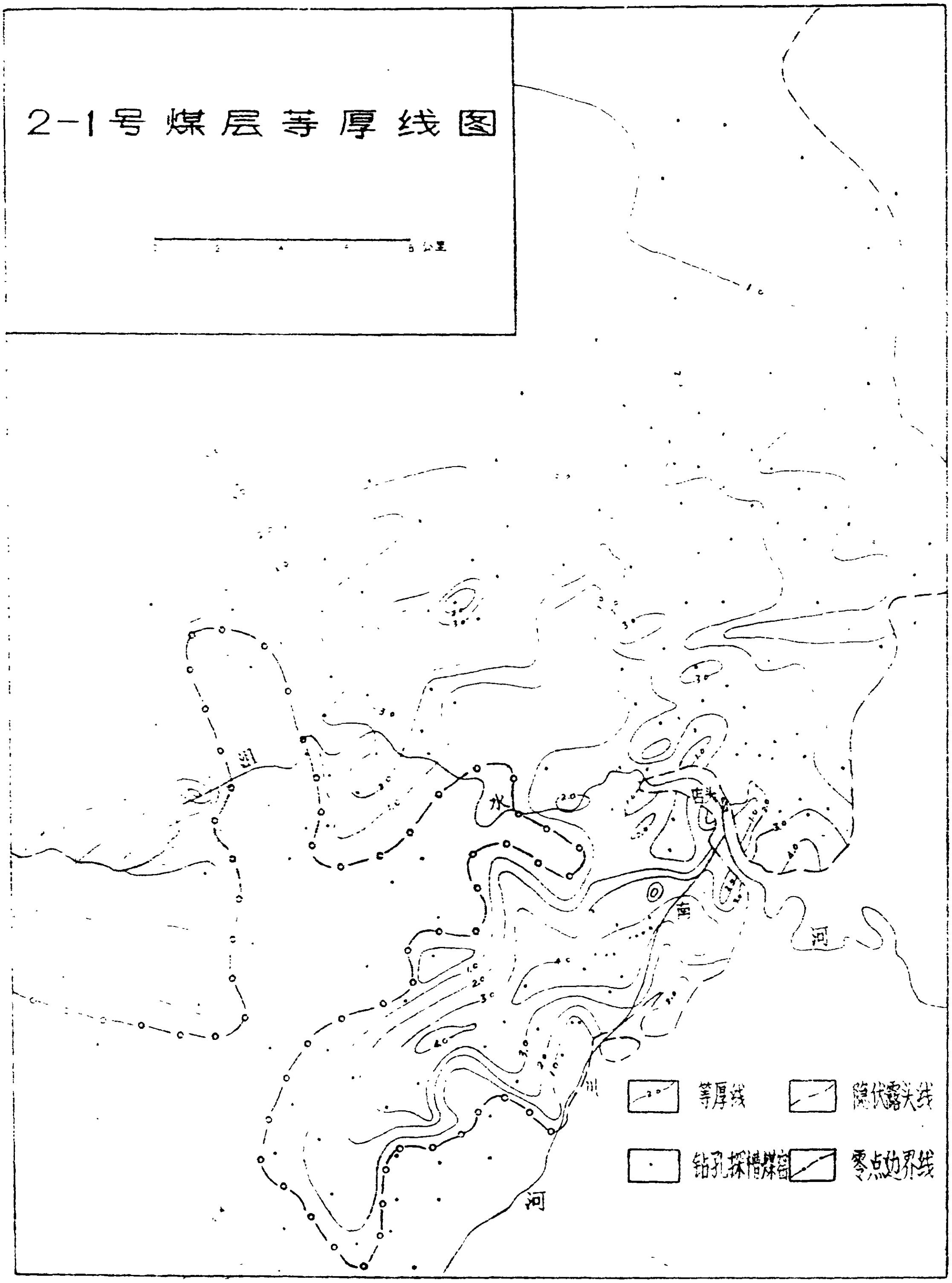


图24

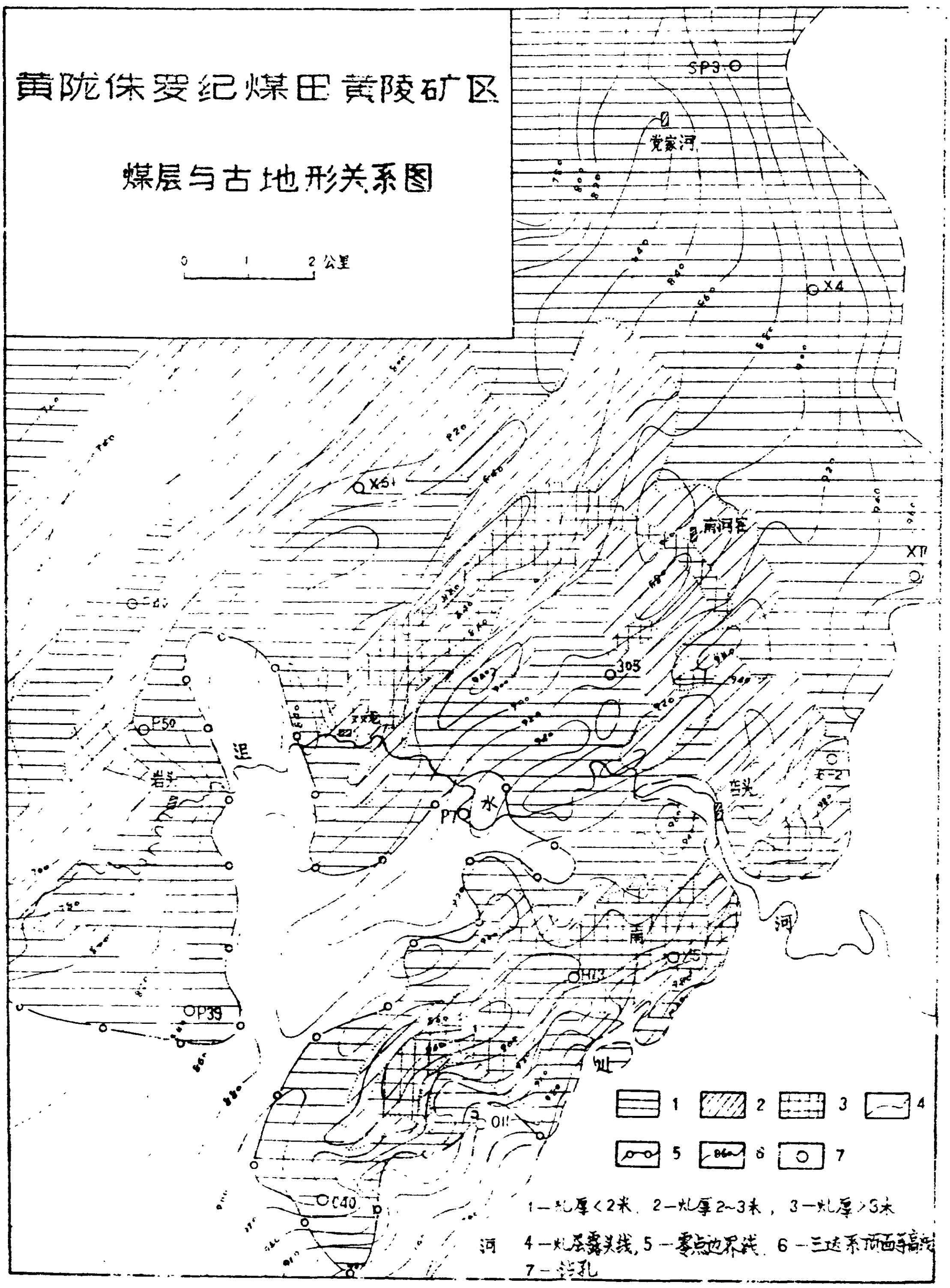

黄陇侏罗纪煤田黄陵矿区
煤层与古地形关系图
0 1 2公里
SP3
党家河
X4
X51
南河寨
305
P50
P7
水
沮
P39
H13
C40
河
1 2 3 4
5 6 7
1—煤厚<2米，2—煤厚2~3米，3—煤厚>3米
4—煤层露头线，5—零点边界线，6—三迭系顶面等高线
7—钻孔

图23

是一致的，说明当时存在的几个古高地和古凹地控制了煤层的区域分布，其中古凹地为泥炭聚积的有利部位，形成的煤层厚度相对较大，这是南部丘陵区的情况，而北部平原区，因指向湖心，积水较深，故形成南部煤层厚，北部煤层薄的总格局。

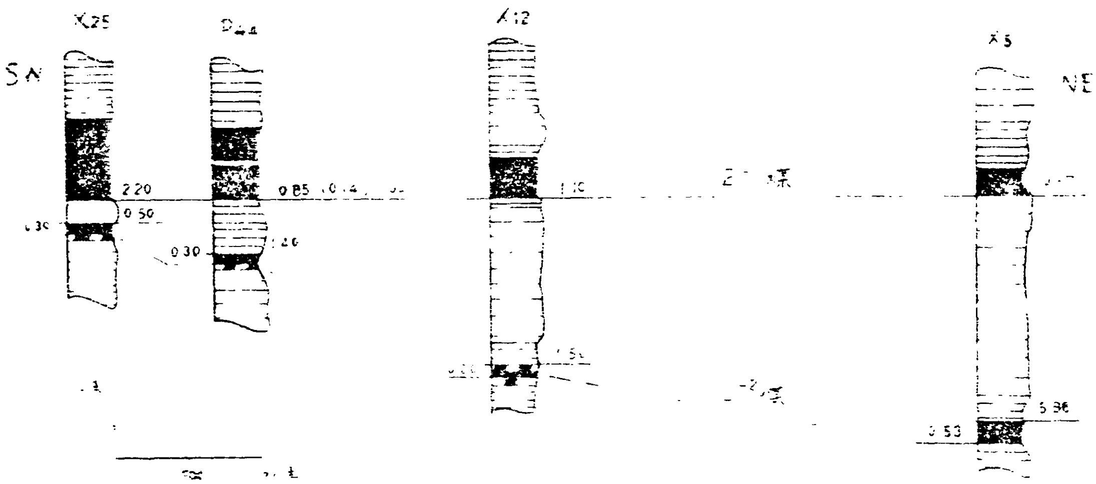


图24　　2⁻¹、2⁻²号煤层变化示意图

2. 本区泥炭沼泽，首先发育在古凹地中部，随着时间的推移植物不断的繁殖、扩大，最后连成一片，造成从下往上，煤层分布的范围不断扩大，和灰份从上往下逐步增高的特征。

3. 泥炭沼泽发育过程中的构造继承性活动和成煤物质的差异压实作用，使古凹地中心保持较长时间变化较小，这从另一侧面说明在古凹地部位煤层厚度较大，形成厚薄煤带的相间排列，以及煤

层沿古凹地轴线方向厚度稳定，而垂直轴线方向，煤层变化较大的特征。

4. 泥炭层的堆积，决定于基底沉降速度和植物遗体堆积速度之相互关系，本区在成煤过程中，曾间歇性地发生过沉降速度大于植物堆积速度的情况，造成植物堆积的欠补赏状态，造成古凹地的煤层结构比古高地复杂，煤层间距增大等特征。向北煤层逐步变薄，间距增大，是其距湖心较近（相对而言），复水较深，经常处于植物欠补的状况有关。

5. 盆地边缘和古高地周围，在沼泽发育期间，因复水较浅，且有大气降水间歇性地流入沼泽，使成煤物质遭到风化，形成较多丝质体（可达２８。３％），降低了煤层的粘结性能，造成南部丘陵区与北部平原区，古高地和古凹地的煤质差异。

六、 资源评价

黄陵矿区经多年勘探，在浅部已探明一定数量的工业储量，为矿区建设准备了资源条件。本区为内陆盆地型沉积，主要煤层的沉积环境为大型的湖沼，其稳定性较好，煤质较好，而控制煤层平面分布的主要因素是古地形，地质构造又简单，因此推断在矿区西部上畛子西小岔一带和北部药阜头以南，四家份以西等地为较有希望的远景区，前者为湖泊近岸丘陵区，应有聚煤坳陷存在，煤厚１·５

～2・0米。而后者古地形属斜坡带，古地形较平坦，煤层虽然较薄，但很稳定，分布广。

七、收　获

1. 黄陵矿区通过合作研究，使我们对该区主要煤层的展布方向、富煤带的位置、聚煤特征及其控制因素等与勘探和资源评价有关的主要地质问题，获得了比较清晰的概念。在此基础上，指出了该区北部与西北部为远景区，从沉积环境的角度，解释了煤质差异的原因，因此我们认为通过这次研究，提高了该区的地质研究程度，并对今后的勘探和邻区普查找煤工作有一定的指导意义。如根据煤层变化的趋势，可在不同方向采用不同的勘探工程密度，利用古地形控煤的特点，将来在其他地区工作中，可先用物探手段或通过少量钻孔资料结合区域地质特点，初步确定和推断聚煤的有利地段，这样可提高普查选点的精确度，缩短勘探周期。另外聚煤环境分析，不但普查阶段要搞，详精查阶段也要搞，因为前者解决研究区总的评价问题，而后者则可指导勘探工作，并可解决开采技术条件的某些问题。诚然，这次合作研究，双方对某些地质问题如对延安组二段砂岩认识的不同，正如美国同行指出的那样，可能是双方对某些问题的概念不一所造成。真正的问题是处在什么部位，是靠近湖还是靠近河？对于这些，我们还可继续进行讨论，即使不能统一认识，我们认为也是正常的现象，并不影响我们进一步的合作。

2. 野外地质工作是研究沉积环境的基础工作。这次环境分析采用的基本方法是详细测制延安组地层剖面、观察、描述岩石的成因标志，采集岩样、矿样和化石标本，尽可能多地收集和分析已有钻孔资料。在进行煤、岩层对比的基础上，统计反映沉积体的几何形态、岩性、岩相以及含煤性等方面的数据，并编制相应的沉积断面图、砂体图、矿体图及其他平面图，据此分析含煤岩系的沉积环境，实践证明，上述研究工作的思路和方法基本是可行的，但通过这次研究，也发现我们的工作程度与环境研究的要求还有一定的距离。

3. 要注意岩石垂向层序的描述和研究，因为不同环境下形成的地层剖面，其沉积构造的交替出现有一定的组合特征，是沉积时水动力条件随时间变化的反映，亦即是沉积环境变化的结果，研究剖面的垂向层序及其横向变化，以便确定研究区所在古地理位置的部位——即亚环境。

4. 古流向的分析和测量，有助于推测砂岩体的延伸方向和概略了解古水流体系，判断物源方向，是环境分析的重要内容和简便手段之一，在这次研究中，古流工作没做亦是一大缺陷。