Field Geology Course - Part One

The Geological Corridor from Ordos Basin to Qinling Orogen, North-Central China

Wan Yang
Wichita State University

Dan Lehrmann
University of Wisconsin, Oshkosh

WICHITA STATE UNIVERSITY

THE UNIVERSITY OF WISCONSIN OSHKOSH

西北大学 Northwest University

Department of Geology, Wichita State University, Wichita, Kansas
Department of Geology, University of Wisconsin, Oshkosh, Wisconsin

May, 2007

General Geology of China

One of the fundamental differences between the geology of China and that of North America is that China is made up of numerous smaller continental blocks (or plates) that many researchers refer to as a "tectonic collage" (cf. Sengor, 1987), whereas North America contains a very large continental nucleus or craton that has been tectonically stable throughout the Phanerozoic. Therefore in considering the geology of China, a large part of the discussion focuses on the continental blocks (plates), the various basins that reside within and between these blocks, the orogenic belts (mountain belts) that occur between the blocks and mark collisions (suture zones) and the provenance and timing of amalgamation of the blocks to form China.

Before summarizing the lay out of the geology of China it is useful to begin with a global perspective. Global plate arrangements during the Late Paleozoic were dominated by the supercontinent Pangea bounded to the west by the Panthalassa Ocean and to the east by the tropical Tethys seaway (Fig. 1). During the Late Paleozoic and Triassic, China consisted of several isolated small continents that existed in the Tethys seaway and were part of a group of small continents (also referred to as Cimeria; Sengor, 1987) which rifted from Gondwanna along the southern margin of the Tethys and migrated northward across the Tethys to eventually collide with and accrete to Asia (Fig. 1).

Continental blocks that make up China include the North China block (Sino-Korean Craton) the South China Block (Yangtze Craton), Tarim, and several smaller continental blocks such as Lhasa, Qiangtang etc. (Fig. 2). To the southwest is the Indian plate and to the southwest there are several additional plates that comprise southeast Asia (Fig. 2). Many of the continental blocks contain Archean and Proterozoic basement and contain Neoproterozoic sedimentary cover demonstrating that these blocks became stable cratonic elements during the Precambrian. For

Table of Contents

List of Course Participants

Wichita State University, Wichita, Kansas, U.S.A.:

Dr. Wan Yang, co-instructor
Dr. John Gries, guest participant

Adam El Dano (undergraduate, geology)
Byron Lynn Pound (undergraduate, anthropology)
Holly Fae Goering (undergraduate, geology)
Jaclyn Camille Venhaus (graduate, geology)
Michael Benjamin Lichtenwalter (graduate, geology)
Patricia Ann Stepanek (graduate, anthropology)
Renee Vardy (graduate, geology)
Ryan Michael Dixon (undergraduate, geology)
Zachary Wylie Koch (undergraduate, geology)
Travis Yang (middle school, guest participant)

From University of Wisconsin, Oshkosh, U.S.A.:
Dr. Dan Lehrmann (co-instructor)

Maggie Attoe (undergraduate, environmental studies)
Jacob Baus (undergraduate, chemistry)
Lesley Byatt (undergraduate, geology, Texas A&M University, Corpus Christie)
Leah Cardimona (undergraduate, art)
Rhyan Dhillon (undergraduate, geology)
Christopher Hanson (undergraduate, anthropology)
Brad Jeffrey (undergraduate, geology)
Kelsey Putman (undergraduate, geology)
Paula Richter (undergraduate, geology)
Derrick Wagner (undergraduate, geology)
Leonard Wesner (undergraduate, geology)

From Northwestern University, Xian, China:
Professor Dingwu Zhou (co-instructor) (now at Shangdong University of Science and Technology, Qingdao, China)
Others – To be listed.

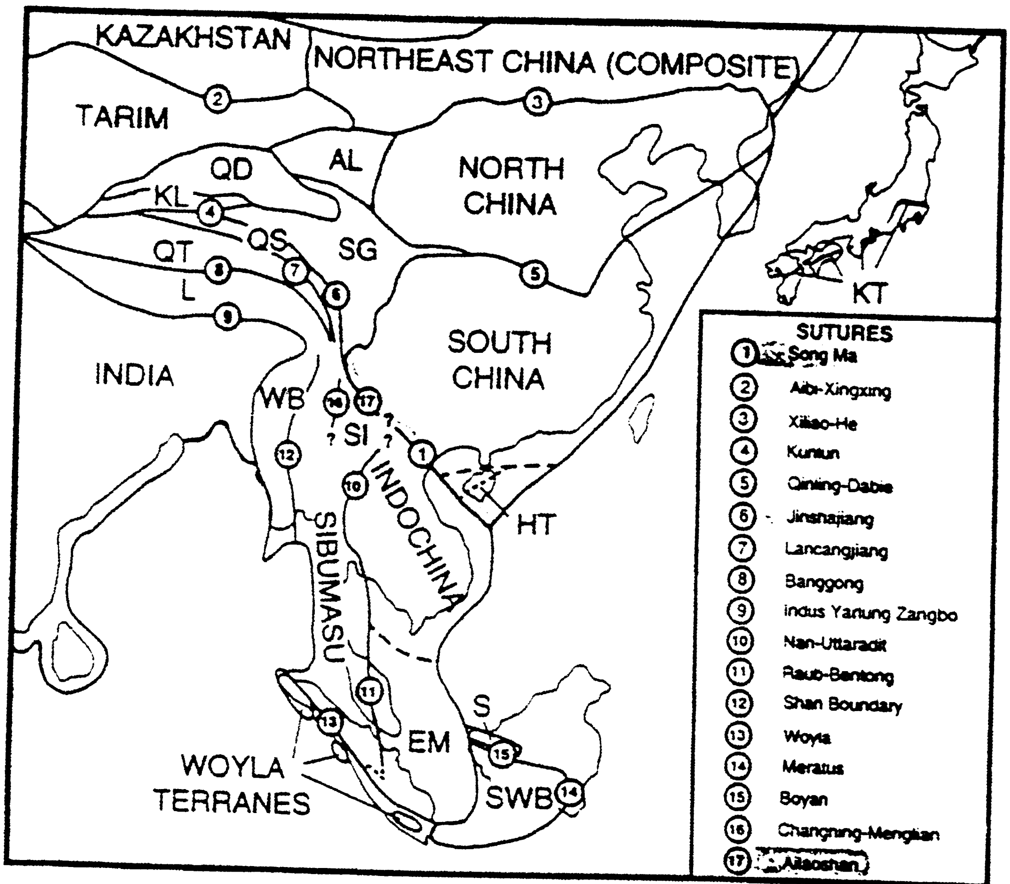


Fig. 2 Distribution of principal continental terranes and sutures of East and SE Asia. EM, East Malaya; WB, West Burma; SWB, South West Borneo; S, Semitau Terrane; HT, Hainan Island terranes; L, Lhasa Terrane; QT, Qiangtang Terrane; QS, Qamdo–Simao Terrane; SI= Simao Terrane, SG, Songpan Ganzi accretionary complex; KL, Kunlun Terrane; QD, Qaidam Terrane; AL, Ala Shan Terrane; KT, Kurosegawa Terrane.

Itinerary

June 14, 2007
- Depart U.S.

June 15, 2007
- Arrive Xi'an
- Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**. Phone # 029-8830-3928; e-mail: cice@nwu.edu.cn; web address : http://222.90.74.124/exchange/zh/lxxd/fwss.php

June 16, 2007
- Tour Northwest University campus and city of Xi'an
- Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**

June 17, 2007
- Travel to Lingtong to see the Terra Cotta Warriors of the Qing Dynasty (2-hour bus ride each way)
- Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**

June 18, 2007
- Morning lecture by Chinese instructors of the Geology Department of Northwest University
- Afternoon field preparation
- Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**

Geological Field Traverse Leg 1 - Ordos Block

June 19, 2007
- Xian – Yan'an (Overnight stay at Yan'an) **Yan'an is a large town with many excellent hotels. Hotel selection has not yet been made for this town.**

Stop 1: Yan'an
- Visit the city of Yan'an: Yan'an, the ancient Yan Zhou (the state of Yan), is the political, economic, cultural, and military center of northwestern China. The Central Committee of the Chinese Communist Part was located here during the anti-Japanese War and the Liberation (Civil) War from 1937 to 1947. Chair Mao Ze Dong and the Central Committee commanded the two wars from this location. Thus, Yan'an is called the cradle of Chinese revolution.
- Sedimentology and stratigraphy of Jurassic nonmarine deposits of the Baotashan (Treasure Pagoda Mount) Formation.

June 20, 2007
- Yan-an to Yichuan (**overnight stay at Yichuan; Yichuan Hotel**)

Stop 2: Hukou

example the North China block contains Archean metamorphic complexes 2.5BY to as much as 3.1BY overlain by weakly deformed Proterozoic sedimentary cover (Ma et al., 2002).

Plate reconstructions have been made using the timing of deformation and magmatism in orogenic belts, paleomagnetism, and stratigraphy / paleobiogeography (Klimetz, 1983; Sengor, 1987; Enkin, 1993 and Metcalf, 1999, among many others). The reconstructions generally depict progressive collision and amalgamation of tectonic blocks in a "conveyor belt" fashion with earlier docking of northerly blocks (such as the Tarim and North China blocks) followed by successively later docking of southerly blocks (e.g. South China, followed by several blocks in Tibet and south east Asia, and followed finally by the India collision). Enkin et al's (1993) paleomagnetic reconstructions (Fig. 3) indicate Late Paleozoic docking of the North China block with Mongolia, followed by Triassic collision of the South China block with North China, Jurassic and Cretaceous collision of the Lhasa and Qiangtang blocks in front of India, and ultimately the collision of India with Asia in the Cenozoic.

The geological map of China dramatically reveals that the continent is subdivided by several long orogenic belts many of which can be characterized as suture zones marking the collisional plate boundary between continental blocks. Suture zones are characterized by deformation, ophiolite complexes (ultramafics, basalts, deep sea sediments), metamorphism sometimes characterized by paired high- and low-pressure metamorphic belts, and granitic magmatism. These suture zones include the Erenhot-Hegen (Late Paleozoic; Variscan age) boundary between North China and Mongolia, the Kunlun-Altun-Qilian (bordering the southern Tarim), the Qinling (Triassic, Indosinian age) boundary between the North and South China blocks, and the Himalaya (Cenozoic, Himalayan age) marking the leading edge of India (Fig. 4).

- Hukou (Sprout of the Teapot) waterfall of the Yellow River
  This waterfall is the largest along Yellow River, one of the longest rivers in the world and the so-called Chinese cradle. The channel narrows abruptly from ~400 m to ~40 m, forming torrential flow and a foaming horse-shoe-shaped waterfall with a more than 30 m drop. The roaring turbid fall is spectacular.
- Sedimentology and stratigraphy of nonmarine Triassic deposits along the channel.

June 21, 2007

- Yichuan to Huangling (**overnight at Huanling; Huanling Hotel**)

Stop 3: Hauangling and Luochuan

- Visit the Tomb of Huangling
  The Huang Emperor was a great tribal leader at the end of the Premeval Society. He is the first person who unified the Chinese peoples. His other historical deeds include planting a variety of grasses, trees, and crops which had greatly advanced farming, creating Chinese words, started manufacturing dresses, building boats and carts, inventing the compass cart, setting rules of numbers and music, and started medicine. Overall, he is the father of ancient Chinese civilization. The tomb hosts the first Huang emperor, Hanyuan and is identified as the First Tomb of China. It is a key protection site of Chinese archeology (amid countless sites). It is the hot destination of pilgrimage and tourists, and has been crowded by worshipers during the Chinese Memorial Day over thousands of years.
- Sedimentology and paleoclimatology of Yichuan Loess Section.

.June 22, 2007

- Jinsuoguan (Golden Lock Pass) to Xian (overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**)

Stop 4: Jinsuoguan

- Sedimentology and structural geology of Triassic oil shale in Yichuan.
- Sedimentology and paleontology of Triassic fluvial deposits in Jinsuoguan.

June 23, 2007

- Xian to Zhaolaoyu (Zhaolao Canyon) (Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**)

Stop 5: Zhaolaoyu

- Sedimentology of Middle Ordovician shallow-water carbonate platform deposits in Zhaolaoyu.
- Sedimentology, stratigraphy, and structural geology of Upper Ordovician deep-water carbonate gravity-flow deposits.

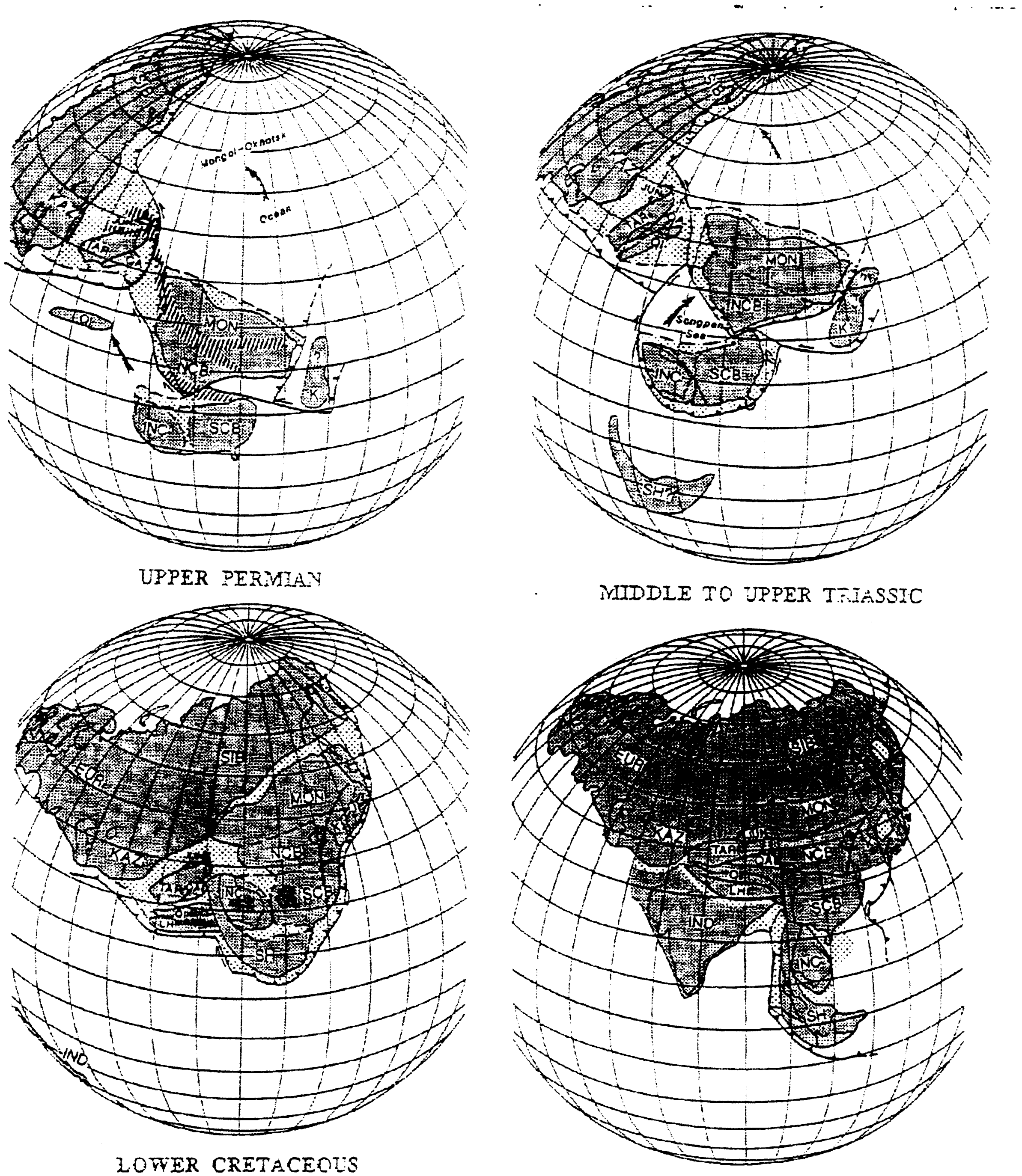


Figure 3: Global plate reconstructions based on paleomagnetism (modified from Enkin et al., 1993) Showing position of various tectonic blocks (plates of Asia).

June 24, 2007	• Break in Xian (Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**)

Geologic Field Traverse Leg 2 - Qinling Orogenic Belt

June 25, 2007	• Xian to Luonan (**overnight in Luonan; Luonan Hotel**) Stop 6: Luonan • Upper Archean metamorphic complex of Taihua Group in the minor Qinling, and the Huashan granitic intrusion. • Middle Proterozoic sedimentology of Gaoshanhe Group. • Middle Proterozoic sedimentology and structural geology of Fengjiawan Formation. Sedimentology of Sinian Luoquan Formation.
June 26, 2007	• Luonan to Xian (Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**) Stop 7: Luonan • Sedimentology of Permian nonmarine Luonanyaogou Formation. • Mineralogy, lithology, and structural geology of shallow metamorphic rocks of Neoproterozoic Taowan Group, and the Neoproterozoic-Permian unconformity.
June 27, 2007	• Xian to Shagoujie (**overnight in Guanhuojie; Guanhuojie Hotel**) • Observation along the old highway from Xian to Zhashui. Stop 8: Shagoujie • Frontal/bounding fault along the southern margin of Tertiary Weihe Graben and introduction to Weihe Graben. • Metamorphic complex of Lower Proterozoic Qinling Group in Weiziling. • Metamorphic deformation structures of Lower Proterozoic Qinling Group in Dabagou.
June 28, 2007	• Shagoujie to Zhashui (**overnight in Zhashui; Zhashui Hotel**) Stop 9: Shagoujie and Zhashui • Melanges of Shangdan Group in Shagoujie. • Sedimentology and structural geology of Middle-Upper Devonian rocks in Huanghualing.
June 29, 2007	• Stop 10: Zhashui to Xian (Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**) • Sedimentology and multi-stage structural deformation of Upper Devonian marine deposits, Longbozi (Dragon Neck) of Zhashui. • Sedimentology of shallow-water Cambrian-Ordovician platform

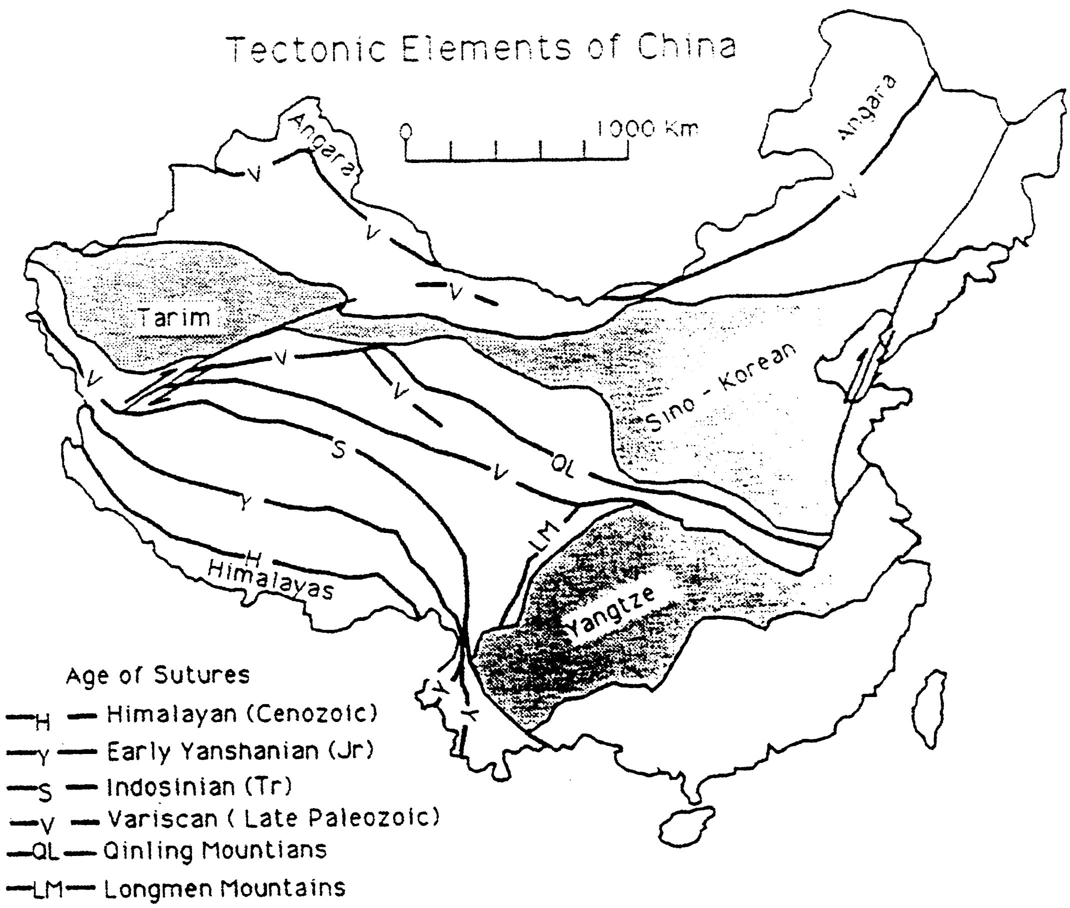


Figure 4. Regional tectonic elements of China. Ordos Basin is in the southwestern part of the Sino-Korean (or North China) Plate or Block.

deposits in Zhashui Cavern, and Middle-Upper Devonian mass and gravity deposits.
(Back to Xian via the 18-km Qinling Tunnel).

June 30, 2007	• Tour of Xi'an • (Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**)
July 1, 2007	• Tour of Xi'an • Banpo Neolithic Villiage and Museum near Xian. • (Overnight at **Xian Northwestern University College of International Cultural Exchange – Dormitories**)
July 2, 2007	• Depart Xi'an; arrive Beijing • **Overnight in Beijing (Yuan Shan Hotel; address: 2 Yumin Road, Deshengmenwai, Beijing).**
July 3, 2007	• Group tour to Great Wall and the Thirteen Ming Dynasty Tombs • **Overnight in Beijing (Yuan Shan Hotel; address: 2 Yumin Road, Deshengmenwai, Beijing).**
July 4, 2007	• Free time in Beijing to visit such places as Tiananmen Square, the Great Wall and the Forbidden City • **Overnight in Beijing (Yuan Shan Hotel; address: 2 Yumin Road, Deshengmenwai, Beijing).**
July 5, 2007	• Free time in Beijing • **Overnight in Beijing (Yuan Shan Hotel; address: 2 Yumin Road, Deshengmenwai, Beijing).** • Depart Beijing; arrive U.S.
July 6, 2007	• Depart Beijing; arrive U.S.

Within and between the tectonic blocks of China there are a great variety of types of marine and terrestrial sedimentary basins. These include the Nanpanjiang and Sichuan basins in the South China block, the Songliao and Bohai basins in Northeast China, the Ordos Basin in central north China, and the Junggar and Tarim Basins in northwest China (Fig. 5). Some of these basins, such as the Ordos were the site of marine sedimentation in vast epicontinental seas that transgressed tectonically stable cratons. In other cases such as the Nanpanjiang basin of south China or the Ordos Basin, tectonic convergence and associated tectonic loading resulted in rapid foreland basin subsidence. The Tarim, and Junggar, basins can be considered famous examples of terrestrial intermontane basins formed as depressions enclosed on all sides by rising mountain systems. The Mesozoic phase of development of the Ordos Basin can also be considered to be an intermontane basin with terrestrial (fluvial and lacustrine) sedimentation. Finally, the Songpan-Ganzi basin in central China (Figs. 3, 5) is a world class example of a remnant basin formed between colliding continents by the incomplete "fit" between the colliding North China, South China and Tibetan tectonic blocks.

Our field area of the Ordos Basin and the Qinling Orogen of central China occurs at the critical junction between two tectonic blocks or continents that collided thus producing the Qinling Orogen, and in the Ordos Basin that records a Paleozoic history of epicontinental marine deposition on the North China block and Mesozoic terrestrial deposition as tectonic collisions resulted in the uplift of mountain ranges surrounding the basin. Our field area therefore will allow us to examine and consider geologic features illustrative of the general geologic setting of China.

Syllabus for Wichita State University

Instructors:
Wan Yang, associate professor, Wichita State University
Dan Lehrmann, professor, University of Wisconsin, Oshkosh
Dingwu Zhou, professor, Shangdong University of Science and Technology
Other instructors, to be determined

Course goal:

This course is designed for undergraduate and graduate students at all levels, who are interested in geology but may or may not be geology majors. The main goal of this course is to learn and practice skills of field observations of sedimentary, metamorphic, and igneous rocks, structural features, and stratigraphy. Preliminary interpretations of sedimentary environments, tectonics, and many other geologic features will be taught at different levels. Students should master the basic skills of geologic field work, some basic concepts of sedimentology, stratigraphy, petrology, structural geology, and tectonics.

The secondary goal of this course is to learn and comprehend the ancient and modern Chinese history and culture, and relate and compare them to the western culture.

Textbook:
Yang, W., Lehrmann, D., 2007, Field Geology Course – Part One: The Geological Corridor from Ordos Basin to Qinling Orogen, North-Central China: Wichita State University and University of Wisconsin, Oshkosh.

Supplementary readings to be assigned.

Course Requirements and Grading:

Active participation in individual and team observations and discussions of geological, archeological, and cultural features.

Field sketch and photograph geological, archeological, and cultural features.

Field measurement of stratigraphic sections and preliminary interpretations of geological features. Complete required drafting of measured sections and required write-ups of observations and interpretations.

Complete a short report on selected archeological and cultural subjects. The report should be typed with 12-point font, double spaces, and not exceed 5 pages not including photos and figures.

Geological part of the course will count for ¾ of the course grade and archeological and cultural part will count for ¼ of the course grade. The percentage of grade assignment is as follows:

1. Course notebooks (geological, archeological, and cultural) will be graded for its organization and content – 30%.
2. Geology field exercises – 40%.
3. Cultural report as specified above – 25%.
4. Class participation – 5%.

Syllabus for the University of Wisconsin-Oshkosh
FIELD GEOLOGY IN CHINA, SUMMER 2007; 51-360: 3 CREDITS

Instructors: Dr. Wan Yang, Wichita State University; Dr. Dan Lehrmann, University of Wisconsin, Oshkosh. Dr. Dingwu Zhou, Shangdong University of Science and Technology.

Emergency contact information:

- Dr. Lehrmann's cell phone number within China____________________.
- Lehrmann's e-mail address: lehrmann@uwosh.edu
- Telephone code to the U.S: 001_
- Primary UW Oshkosh Emergency Contact: University Police available 24-7; 920-424-1216 or 1212
- Office of International Education: 1-920-424-0775 graff@uwosh.edu; mylreab@uwosh.edu , stukenbk@uwosh.edu; mchughm@uwosh.edu
- Office of the Provost & Vice Chancellor: 1-920-424-0300
- U.S. Hotline for American Travelers: 1-202-647-5225
- UW Oshkosh Counseling Center: 1-920-424-2061

Text: Geological corridor from Ordos Basin to Qinling Orogen in North-central China

Other Supplies: Field book (hard-back, waterproof), Handlens, pencils, pens, colored pencils, calculator, protractor, camera. (Also attached packing list).

Grading: Grades will be based on: a) evaluation of your field notebooks; b) evaluation of your field exercises; and c) your overall attitude and performance on the trip. You will be instructed on how to keep a good field notebook in a meeting prior to our departure for the trip.

Course Objectives: Your objectives for this course should, at a minimum, include the following:

- To open your mind to Chinese culture, language, and way of life.
- To learn about history and archeological sites in China.
- To learn how to make and record geological observations in the field and to systematically record them in notes and on a map.
- To learn how to interpret field observations in terms of the origins of rocks, structures, landforms and the geological history that they represent.
- To accomplish the above objectives via written geological field book and completed exercises (including small geological maps, geological sketches, and geological problem sets)
- To gain an understanding of the tectonics, sedimentary environments, and hydrocarbon systems of the Qinling Mountains and Ordos Basin.

General Geology of the Ordos Basin and the Qinling Orogenic Belt

The Ordos Basin encompasses approximately 250,000 km^2 in Shaanxi and Shanxi provinces of north central China (Fig. 6). The Ordos has been considered one of the most important oil, gas, and coal producing basins in China (Sun et al., 1989). Oil is produced from Early Paleozoic marine strata and from Mesozoic lacustrine, deltaic, and fluvial strata. Coal is produced from Carboniferous and Mesozoic deltaic strata (Sun et al., 1989). Currently the Ordos region is a plateau held up by the famous Quaternary Loess (eolian glacial silt).

Precambrian rocks underlying the basin are Archean granulites and greenstones and weakly deformed Middle –Late Proterozoic marine clastic and carbonate strata up to 1500 m thick, interpreted to be sedimentary cover over the Archean basement or aulacogen filling successions (Fig. 7; Sun et al., 1987; Li et al, 1995). Latest Proterozoic (Sinian, Ediacaran) varved and breccia sediments may be glacial tillite deposited on the North China block near the end of the Proterozoic (Zhou et al., 2002). Early Paleozoic (Cambrian to Middle Ordovician) strata in the Ordos Basin range up to 400 m thick and consist of compositionally mature marine carbonates and quartzose sandstones (Fig. 7). The widespread deposition of these facies as well as the compositional maturity reflect tectonic stability and marine deposition of a vast, primarily shallow-marine epicontinental sea that stretched across the North China craton. Middle Ordovician strata are overlain by a regional unconformity. Late Ordovician through Early Carboniferous strata are missing due to erosion and/ or non-deposition (Fig. 7). The tectonic causes of this unconformity are uncertain, but it must represent widespread uplift across the region. During the Upper Paleozoic (Carboniferous to Permian), marine conditions returned and

Preface

Geologists are historians of the Earth. We decode, interpret, and reconstruct the history of the Earth and the evolution of its systems by reading the geologic history book, that is, the rock records. Thus, it is essential for students in geology to constantly practice and sharpen their skills in field observations. This field course provides such an opportunity by traversing the geological corridor from Ordos Basin to Qinling Orogen in north-central China. Geological records spanning the Archean to Holocene ages will be observed and studied in a 10-day field expedition. The fields of sedimentary, igneous, and metamorphic petrology, stratigraphy, tectonics, structural geology, paleontology, paleoclimatology, and mineral resources in diverse geological settings will be covered. Course participants, beginning or experienced alike, shall benefit from and be satisfied with the intriguing puzzles and histories presented by the spectacular rock exposures.

Rocks do not have borders. A new generation of geoscientists shall be open-minded to and take advantage of the globalization of world economy and culture in the 21st century. The skills to communicate with and learn from scientists and peers of different academic, cultural, and ideological backgrounds are critical to a person's successful professional career. We hope that this international expedition will be a life-long experience in geology, culture, and history for the participants.

This collaborative field course has been the fruit of cooperation among many parties and individuals. We appreciate the support and hospitality from our host – Department of Geology, Northwestern University in Xian, China. Mr. Mingxin Yu has been instrumental in originating and planning the field course. Professor Dingwu Zhou,

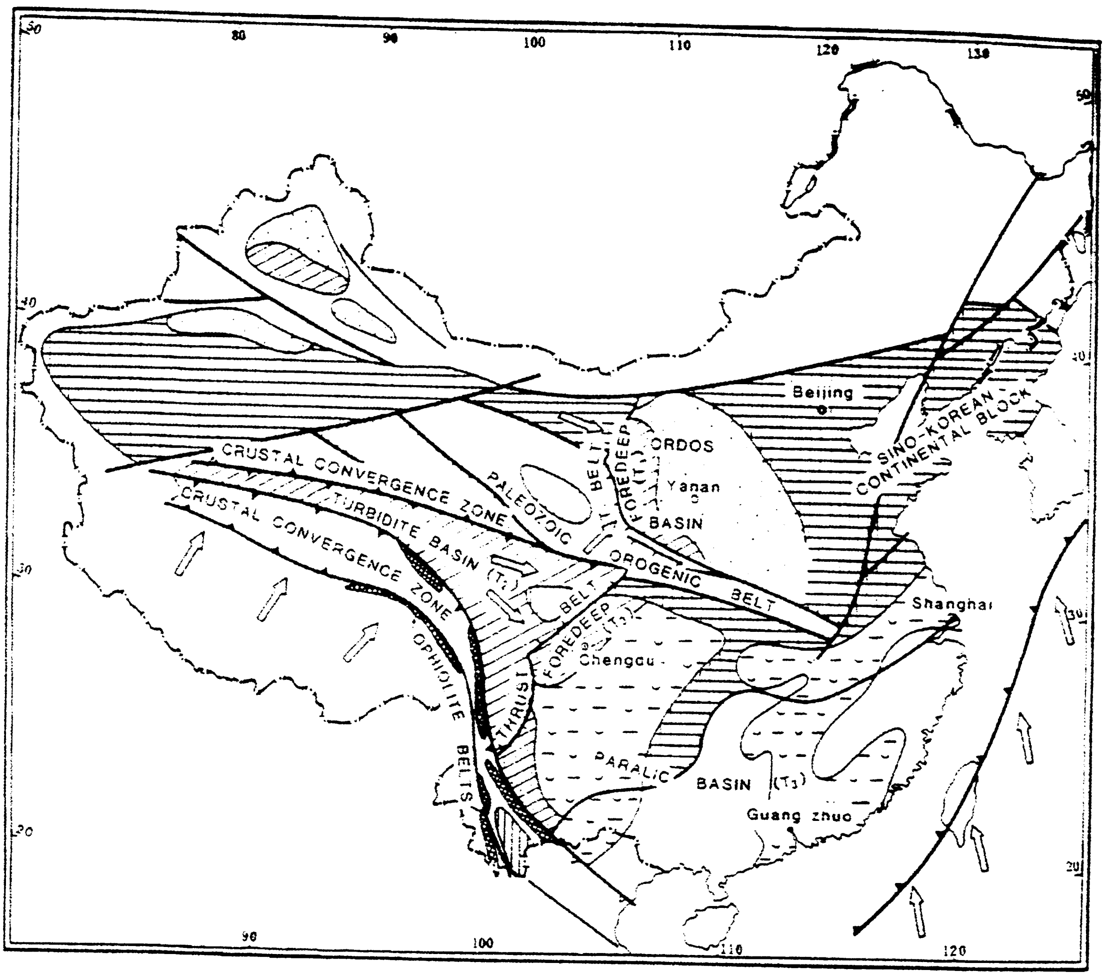


Figure 6. Tectonic map of China in the plate tectonic context.

now at Shangdong University of Science and Technology, provided support in course materials and instructions that are critical to the success of the course. Dr. Hong Hua and Dr. Chengli Zhang's help and cooperation ensured a smooth and successful execution of the course. Student volunteers of Northwestern University made the trip enjoyable and memorable. We also thank Dr. Bradley Ritts of Indiana University, Dr. Amy L. Weislogel of University of Alabama, and Dr. Natasha Vidic of University of Wisconsin, Oshkosh, for providing their publications, data, and collections in preparation for this field guidebook. We gratefully acknowledge the support from the university administration, geology departments, and fellow colleagues in Wichita State University and University of Wisconsin, Oshkosh. Finally, it is the effort, determination, and curiosity of the student participants that made this course possible, fruitful, and fun.

Wan Yang
Dan Lehrmann
May, 2007

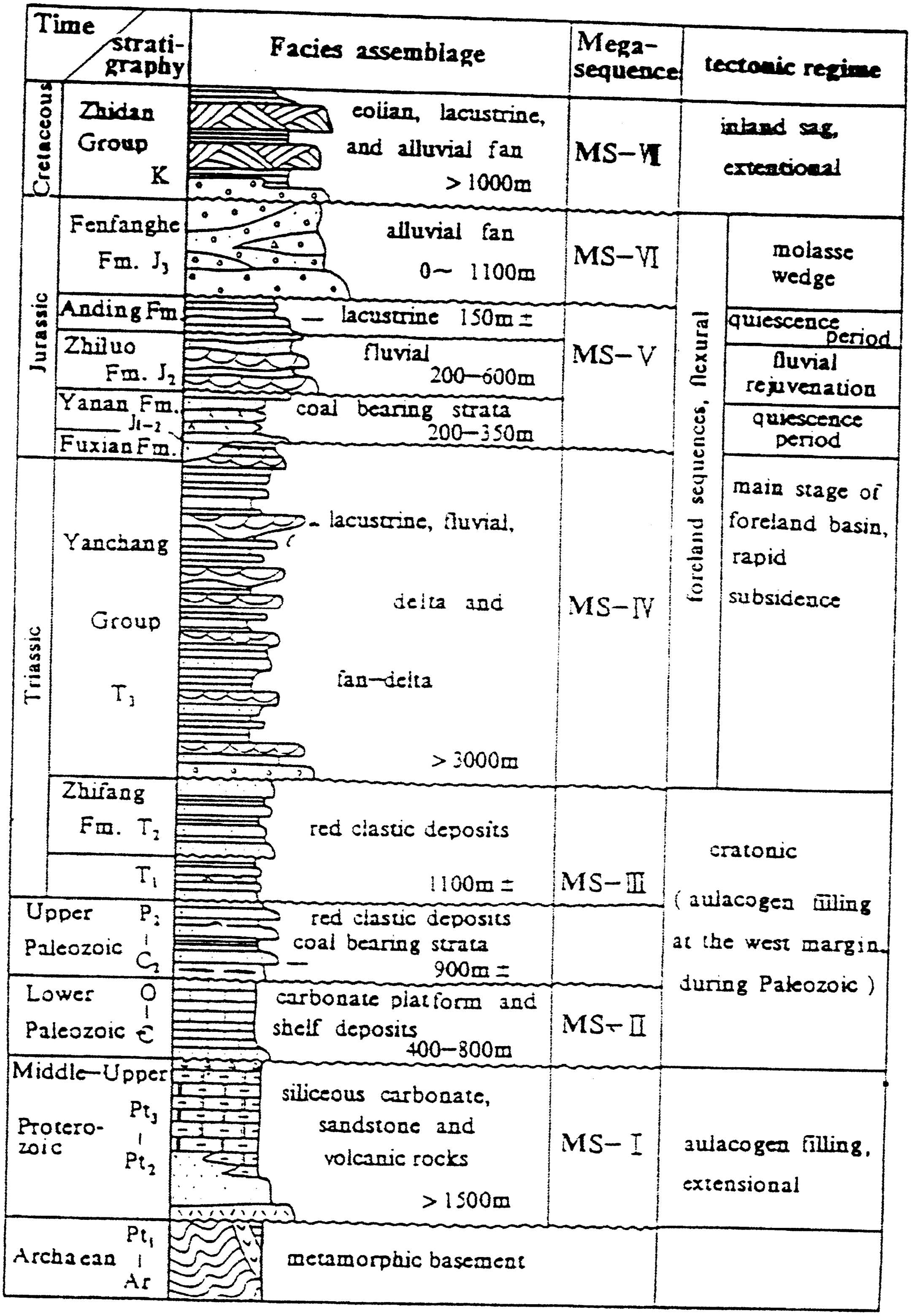
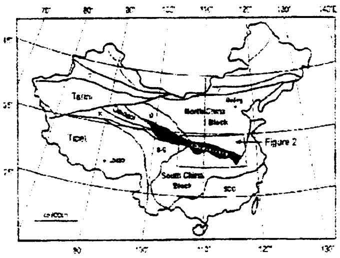


Figure 7. General stratigraphic chart of Ordos Basin, North China Block.

resulted in the deposition of cyclothemic deltaic deposits with substantial accumulations of coal (Fig. 7).

The onset of the Mesozoic represents a dramatic change in tectonic development and style of sedimentation in the Ordos Basin. During this time the seas retreated and the basin shifted to terrestrial (lacustrine, deltaic, and fluvial) sedimentation as the basin became sharply differentiated by rapid subsidence in the basin and uplift of Qinling, Helen, and Langshan-Daqingshan, and Taihangshan mountains surrounding the basin on the south, west, north, and east respectively (Fig. 6; Darby and Ritts, 2002). Triassic strata consist of upwards of 3000 m of lacustrine, fluvial and alluvial strata. Organic rich Triassic lacustrine strata in the center of the basin form important source rocks for hydrocarbon reservoirs. Uplift of mountains peripheral to the basin and especially south of it, and the shift to non-marine sedimentation can be attributed to the tectonics of the collision between the North and South China blocks along the Qinling suture zone. Similarly, fluvial and lacustrine sedimentation persisted through much of the remainder of the Mesozoic and Cenozoic characterized by the development of several unconformity bound tectono- sedimentary sequences (Fig 7) driven by subsequent tectonic collisions in the Tibet/ Himalaya region (e.g. Qiantang, India collisions).

The Qinling belt is the traditional dividing line between north and south China and is considered to be the suture zone between these plates (Figs. 8, 9). Although this is agreed, there has been a great deal of controversy about the timing of the docking between the North and South China blocks and the precise position of the faults (suture zones) bounding the two plates. Much of this controversy reflects the extreme structural and stratigraphic complexity of the zone and complication of the Qinling range by subsequent Mesozoic and Cenozoic tectonism resulting from the collision of India and associated tectonic blocks (Meng and Zhang, 2000).



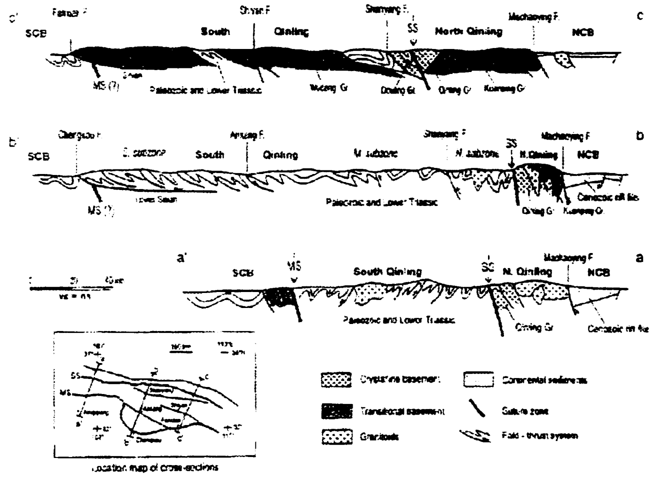


Fig. 3 Three geologic cross-sections across the Qinling orogen. Note that the South Qinling is dominated by a thin-skinned thrust system detached above the Lower Silurian, whilst the North Qinling displays thick-skinned style. The Mianlue ophiolitic complex might be covered by thrust sheets in most localities along the southern boundary (sections b–b′ and c–c′). NCB = North China block, SCB = South China block; vs = vertical scale; hs = horizontal scale.

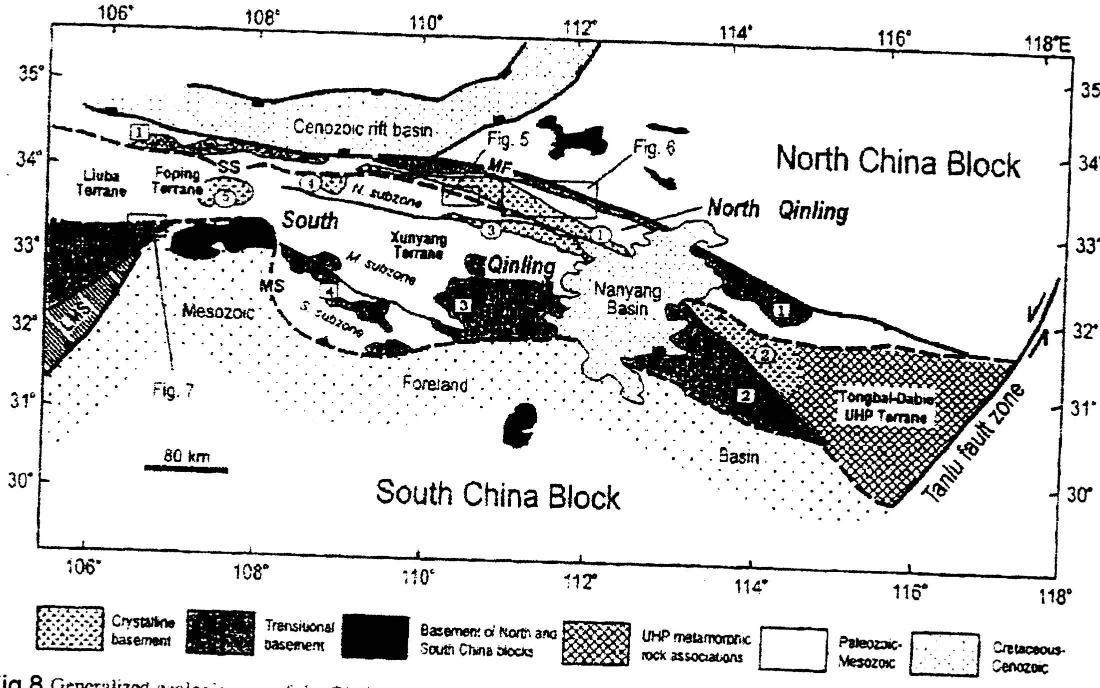


Fig 8 Generalized geologic map of the Qinling, showing its regional tectonic setting, internal divisions and distribution of two types of basement. Numbers in circles indicate amphibolite and granulite facies assemblages comprising crystalline basement: 1 = Qinling Group; 2 = Tongbai Group; 3 = Douling Group; 4 = Xiaomoling Group; 5 = Foping Group. Numbers in squares represent greenschist or low-amphibolite facies assemblages making up transitional basement: 1 = Kuanping Group; 2 = Shuixian Group; 3 = Wudang Group; 4 = Yunxi Group and Yiaolinghe Group; SS = Shangdan suture; MS = Mianlue suture; MF = Machaoying Fault; LMS = Longmenshan orogen.

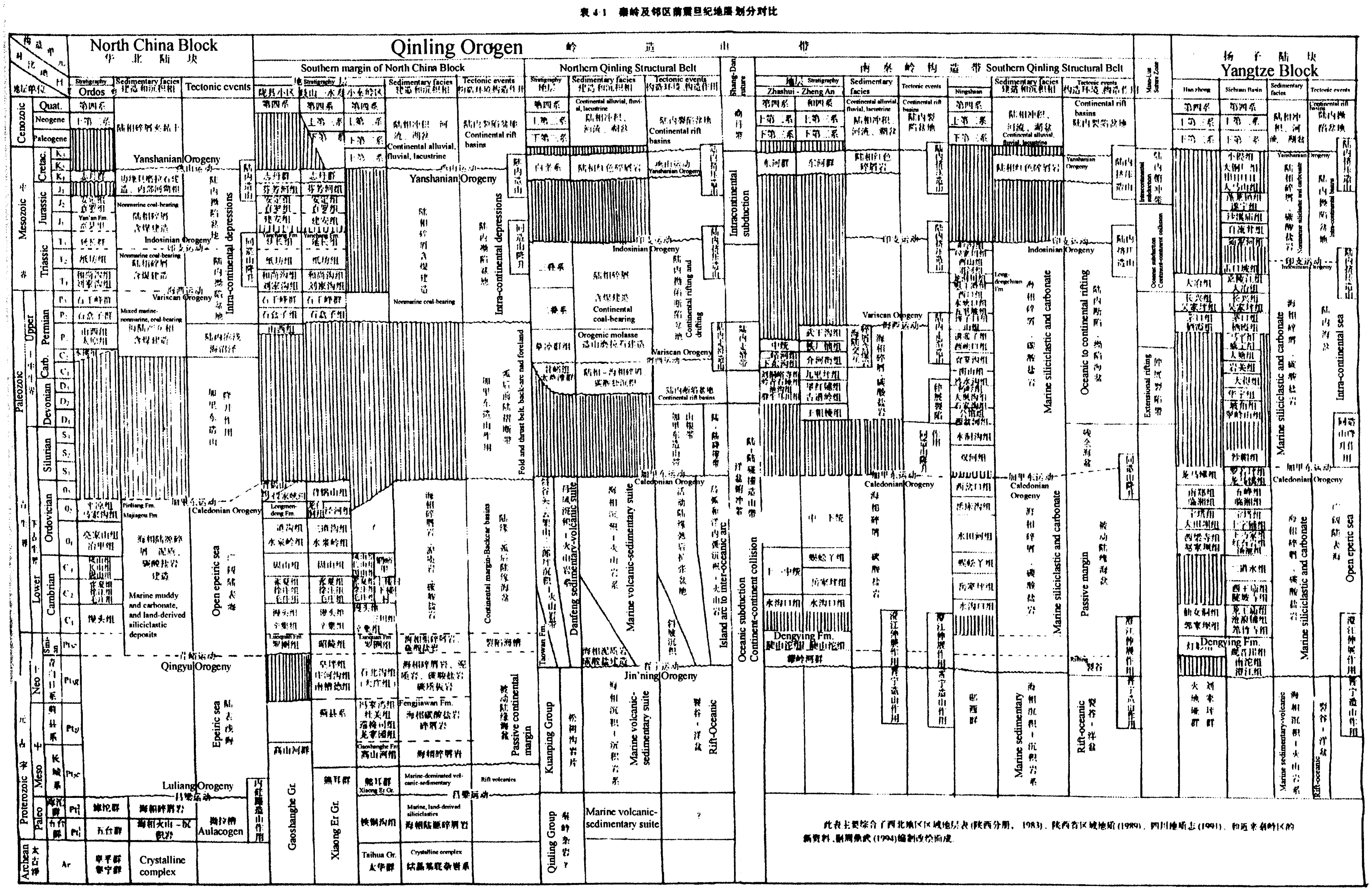


Figure 9. Stratigraphic chart of Ordos Basin, Qinling Orogen, and Yangtze Block. From Zhou et al. (2002).

Several authors have suggested that the South China plate collided with the North China plate along the Qinling-Dabie suture during the Late Triassic (Klimetz, 1983; Sengör, 1987; Enkin et al., 1993; Enos, 1995). Controversy regarding whether the North and South China blocks docked instead during the Early Paleozoic (cf. Mattauer et al., 1985; Zhang et al., 1997) seems to have been reconciled with a tectonic model that includes earlier docking of a terrane along the northern Qinling followed by Late Triassic docking of South China along the southern Qinling-Dabie (cf. Sun and Li, 1998 and Meng and Zhang, 1999, 2000).

Meng and Zhang (1999) subdivide the Qinling orogen into a northern and southern zones separated by the Tienshui-Shangdan and Mianlue (Chengkou) faults interpreted to be suture zones (Fig. 8). The North Qinling occurs between the North China craton and the Tienshui-Shangdan fault to the south whereas the South Qinling occurs between the Tienshui-Shangdan and Mianlue faults (Fig. 8). The Mianlue fault bounds the South Qinling and the South China tectonic block.

The North Qinling and South Qinling have vastly different stratigraphic successions and tectonic styles (Fig. 9; Meng and Zhang, 1999). The South Qinling has a stratigraphic succession more similar to that of the South China block and is characterized by thin-skinned thrust faults detached above the basement. The Mianlue fault is interrupted by an arcuate projection (Fig 8), to the east of this feature thrusts are south vergent, to the west they switch to north vergent (Meng and Zhang, 1999). The northern Qinling has high-angle faults that involve basement, has a sedimentary sequence more similar to the north China block, and contains Paleozoic Ophiolites and Devonian granitic intrusions. Meng and Zhang (1999) interpreted the South Qinling to have been a terrane (microcontinent) that rifted from the south china block and move forward to collide with the North Qinling in the Devonian along the Tienshui-Shangdan suture (Fig. 8). This was later followed by Triassic docking of the South China block with the South Qinling during the Triassic along the Mianlue suture (Fig 8). Devonian docking of the South Qinling terrane is supported by Devonian granitoid intrusions in the North Qinling and biostratigraphy. Triassic docking of South China is supported by ages of granitoid intrusions in the South Qinling, paleomagnetic reconstructions, metamorphic ages in the Qinling-Dabie ultra-high-pressure metamorphic belt, and the presence of ophiolites along the Mianlue suture (Meng and Zhang, 1999).

GEOLOGICAL TRAVERSE LEG-1 ORDOS BASIN JUNE 19-24 (Figs. 10, 11).

Stop 1 (June 19) – The City of Yan'an: Jurassic Nonmarine Deposits, Boatashan Sandstone of Yan'an Formation (Zhou et al., 2002, p. 129-133)

The Jurassic outcrop in this stop is situated in the central Ordos Basin on the western part of the North China Block/Plate. The Lower and Middle Jurassic are composed of continental siliciclastic coal-bearing fluvial and lacustrine deposits (Fig. 12a).

The Ordos Basin evolved from a marine cratonic basin to a continental basin in Late Triassic, due to regional differential subsidence and uplift within the North China Plate. The Upper Triassic Yanchang Formation recorded a complete cycle of lake basin expansion and contraction. A regional dentritic drainage system was well developed during the beginning of Early Jurassic. Fluvial sandstones. 20-260 m thick, were deposited covering ~30,000 km^2. A few red beds suggest short periods of arid climate.

Early-Jurassic peneplanation in the Ordos Basin was accompanied by gradual climatic change to warm and wet conditions. Paleogeography is characterized by lakes, swamps, and streams with thick vegetation, resulting in accumulation of abundant coals (Fig.13). Climate changed again to hot and arid conditions in late Middle Jurassic. Reddish brown fluvial sandstones were deposited first, followed by lacustrine mudrocks and limestones.

In the Yan'an area, the Jurassic deposits evolved from bed load-dominated braided stream systems to suspension-load dominated meandering streams and lacustrine systems. The Baotashan Sandstone of the upper Lower Jurassic Yan An Formation consists of typical braided stream deposits. The braided systems consist of medium to coarse grained sandstones and basal conglomeratic sandstones and conglomerate lenses, and show upward-fining and thinning trends.

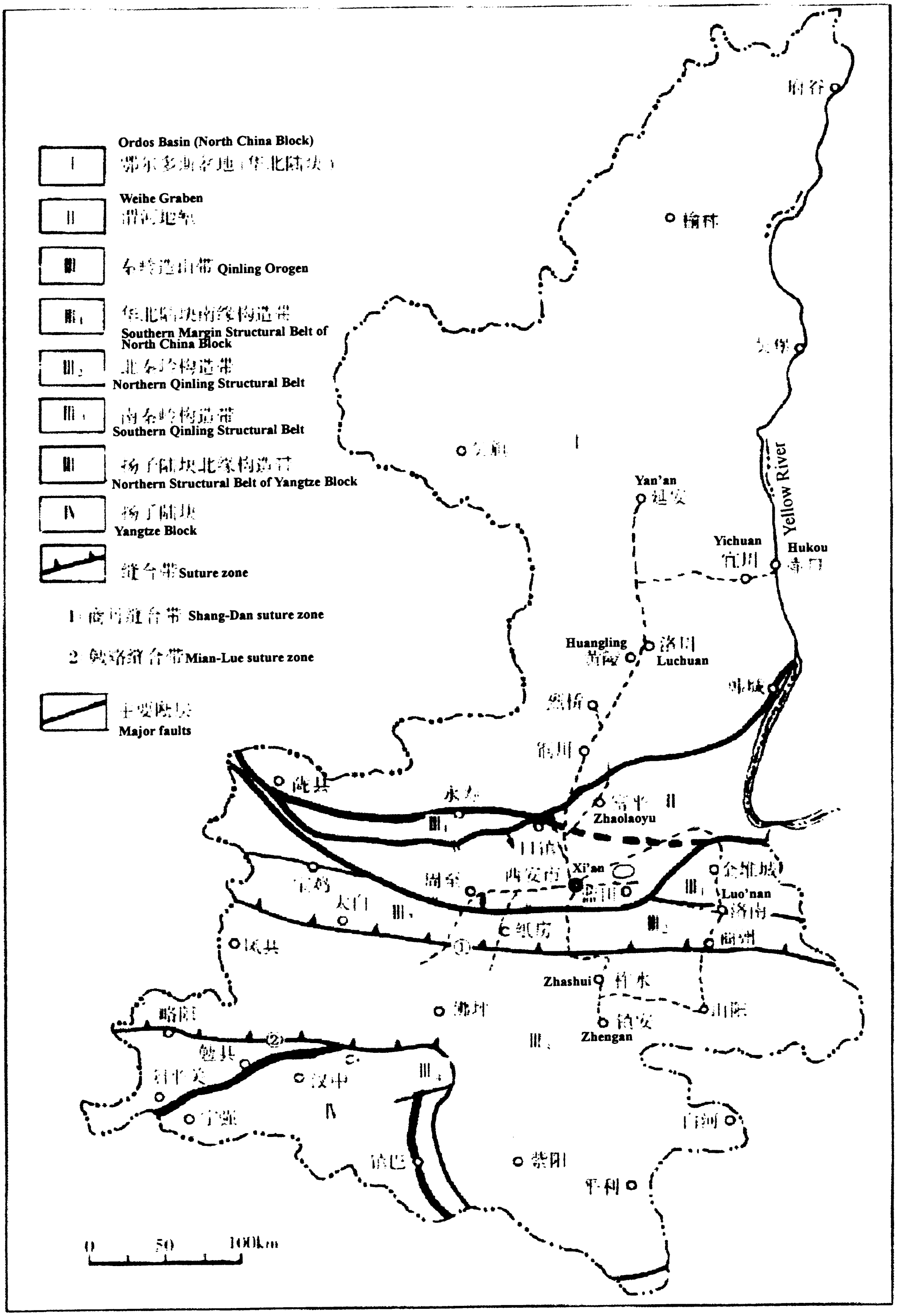


图 3-2　鄂尔多斯盆地－秦岭造山带地质走廊野外地质考察路线图

Figure 10. Field traverses in the Ordos Basin-Qinling Orogenic Belt corridor. From Zhou et al., 2002.

图3-1 秦岭造山带及邻区地质略图
(据李廷栋1997主编亚欧地质图改绘)
1:5000 000

Figure 11. Simplified geologic map of Qinling Orogen and its vicinity. From Zhou et al., 2002.

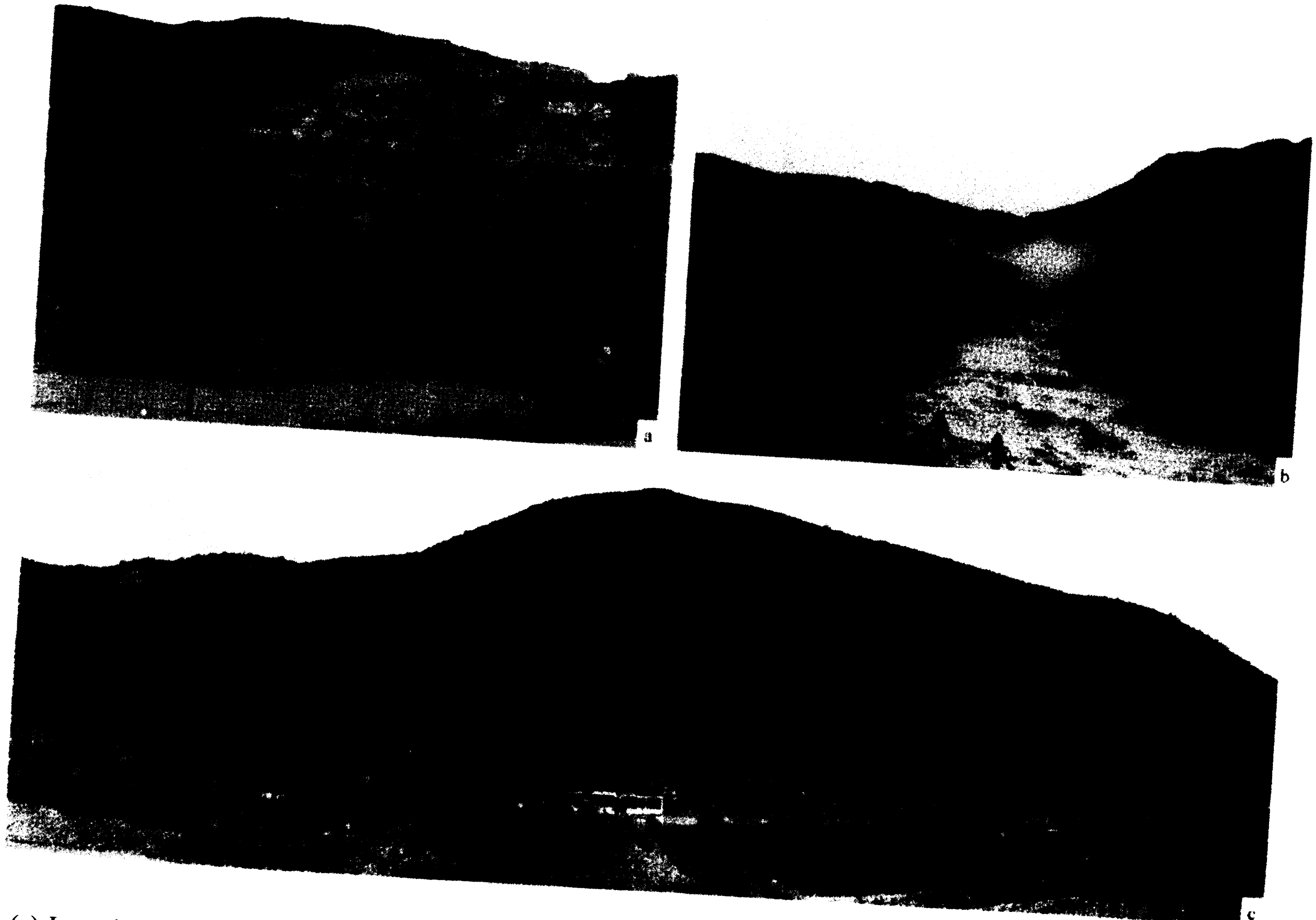


Figure 12. (a) Jurassic lacustrine deposits near Yanan. (b) Upper Triassic fluvial deposits and water fall and fluvial deposits, Hukoou, Yellow River. (c) Upper Triassic continental deposits and sedimentary structures, Huangling.

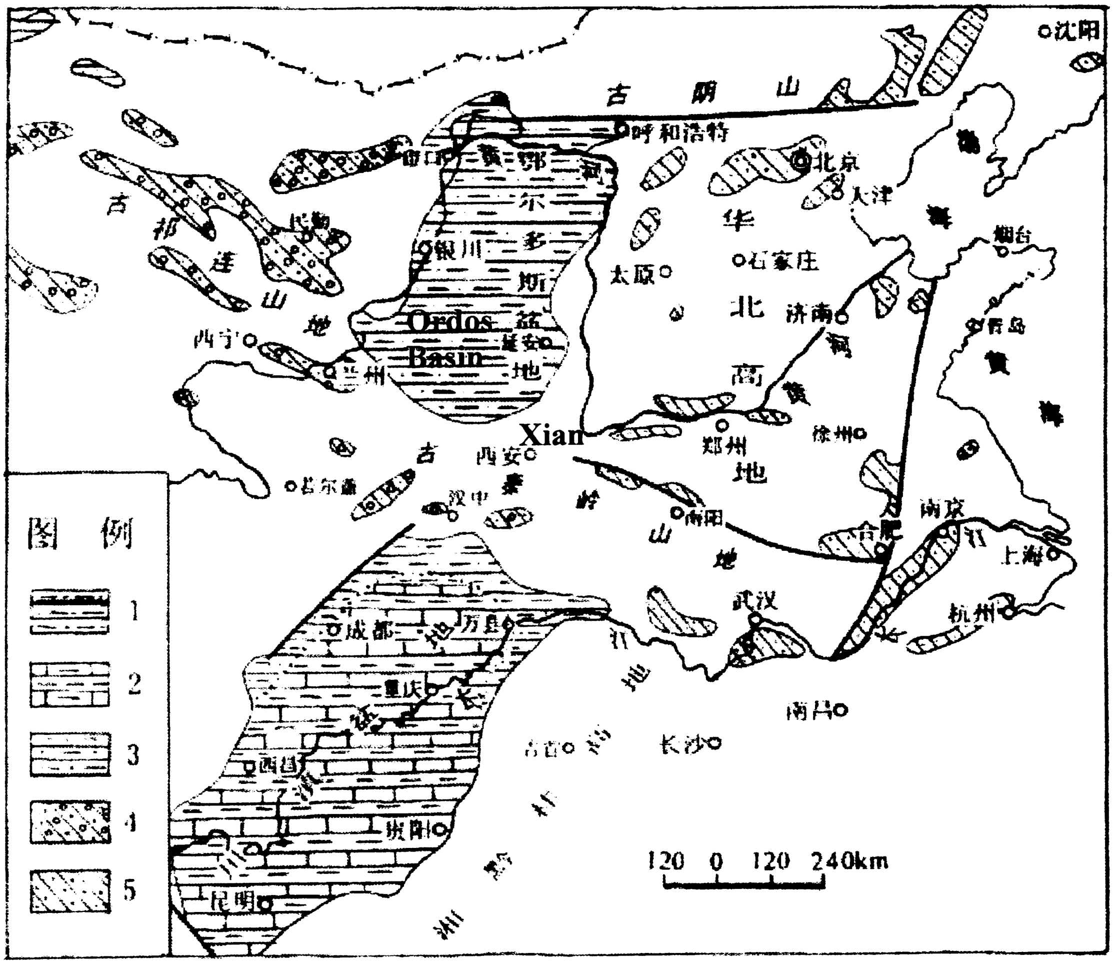


图 4-39 中国中东部早侏罗世古地理图

（据王鸿祯等修改，1985）

1. 内陆开阔盆地河湖碎屑及泥质组合；2. 内陆开阔盆地湖泊泥质及泥灰质组合；3. 内陆开阔盆地河湖砂质及泥质组合；4. 山间盆地类磨拉石组合；5. 断陷盆地碎屑组合

Figure 13. Early Jurassic paleogeography of east-central China. 1. Fluvial-lacustrine siliciclastic deposits in intra-continental basins; 2. lacustrine muddy and calcareous deposits in intra-continental basins; 3. fluvial-lacustrine sandy and muddy deposits; 4. molasses in intermontane basins; 4. siliciclastic deposits in rift basins. From Zhou et al., 2002.

Overbank deposits are rare, poorly developed, and laterally discontinuous. Individual braided stream successions have a lenticular geometry with a flat top and concave base. Lateral and vertical stacking of sandstone-dominated braided stream successions displays an overall sheet-like geometry. Individual channel fills are well connected due to repeated channel cutting and filling.

Meandering stream systems are present in the uppermost part of the Baotashan Sandstone. They consist of thick-bedded to massive, interbedded sandstone, siltstone, and silty mudrocks. Channel fills are lenticular with high-relief basal surfaces. Channel-fill sandstones display characteristic point-bar sequences, with basal channel-lag lenses overlain by large-scale cross-bedded sandstones, which, in turn, are overlain by small-scale cross-bedded siltstones and fine sandstones.

Stop 2 (June 20) – Hukou (Kettle Spout) and Yichuan: Sedimentology and stratigraphy of nonmarine Triassic deposits (Zhou et al., 2002, p. 121-129)

This stop focuses on the Upper Triassic Yanchang Formation (Fig. 14). The Yanchang Formation is 1,141.5 m thick at this stop and consists of 4 members and 10 beds, comprising a meandering stream-lacustrine-meandering stream cycle (Fig. 12b). The sandstones in this formation are major petroleum reservoir rocks.

The regional Late Triassic paleogeography of the Ordos Basin is characterized by alluvial and fluvial environments along the edge and lacustrine environments in the center (Fig. 15). Meandering stream systems at this stop have a high-relief erosional base, overlain by an upward succession of channel lag, large and medium-scale trough cross-bedded sandstones, tabular cross-bedded sandstones, parallel laminated and small-scale cross-bedded sandstones, capped by overbank fine-grained deposits.

Lacustrine deposits include littoral non-deltaic successions and deltaic successions. The non-deltaic littoral deposits consist of interbedded sandstone and shale. Sandstones are highly bioturbated, well bedded, 5-20 cm thick and 2 m thick at the maximum, and laterally extend for ~100 m. Sandstone bodies are lenticular with a flat base and convex top. Lacustrine deltas in this location were fed by meandering streams. Regionally, these deltas are extensive, more than 100 km long along depositional dip and 15-30 km along depositional strike, covering 1,000s to 10,000s of km^2. They have a lobate or bird-foot geometry. Delta plain, delta front, and prodelta subenvironments are well developed. Sandstones are relatively fine-grained with a high textural and mineralogical maturity. A commonly accepted interpretation is that the framework sandstones of these deltas are composed of subaqueous distributary channel-fill sandstones that

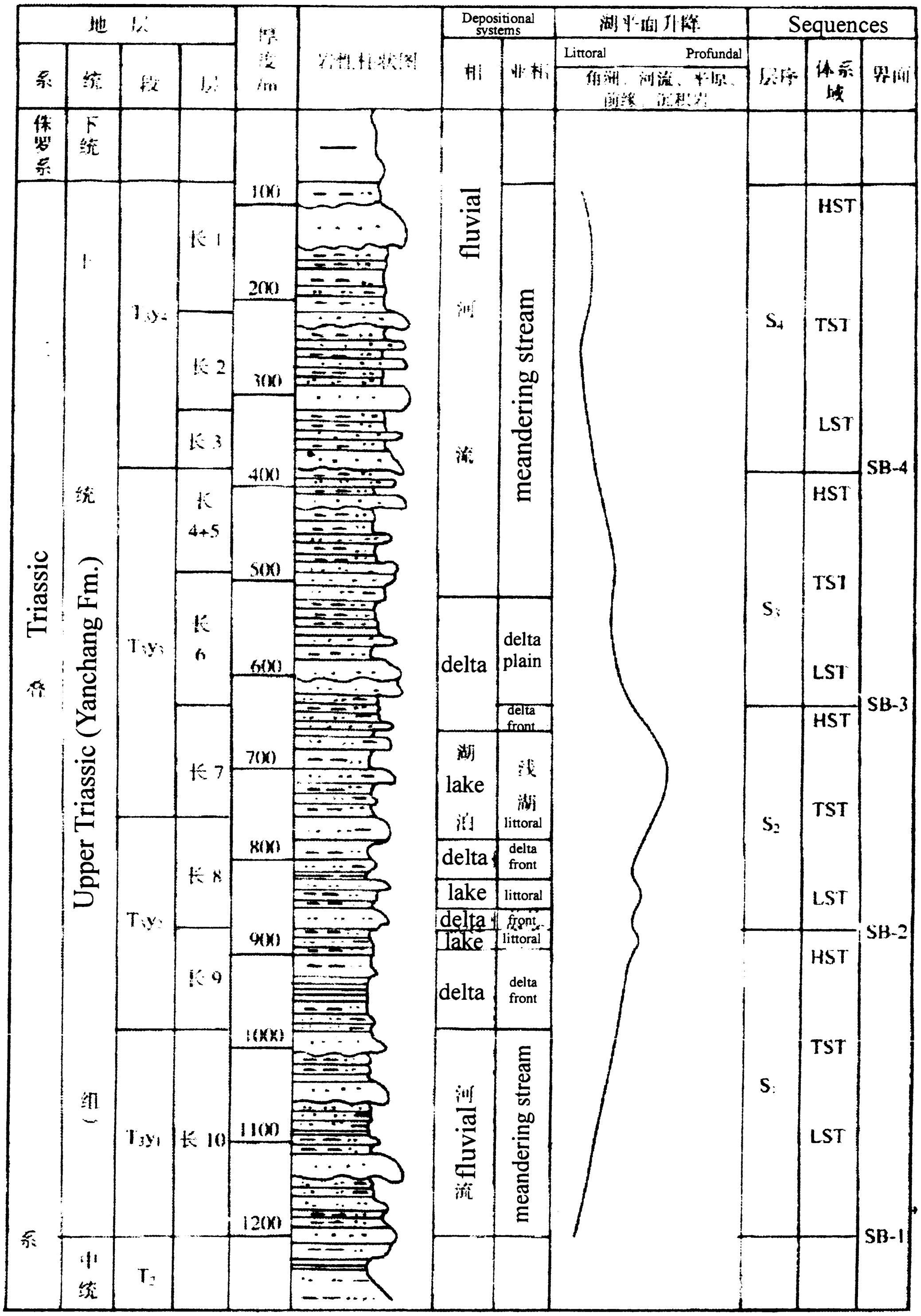


图 4-41 宜川仕望河剖面上三叠统延长组沉积相-层序地层柱状剖面图

Figure 14. Chrono- and litho-stratigraphy, litho-column, depositional environments, lake level, and sequence stratigraphy of Upper Triassic Yanchang Formation, Shiwanghe Section, Yichang. From Zhou et al., 2002.

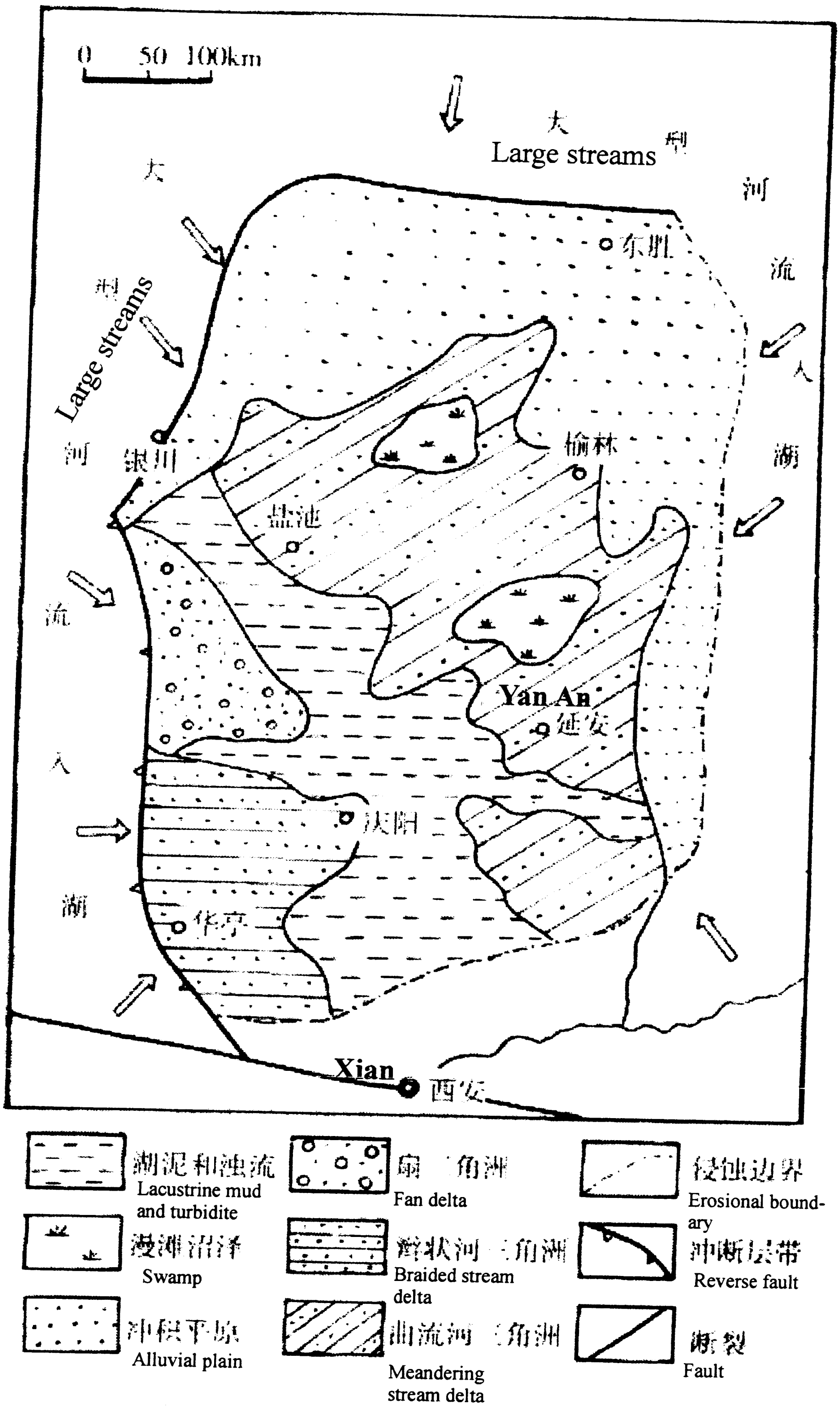


图 4-40 鄂尔多斯盆地晚三叠世延长组沉积体系分布略图

Figure 15. Distribution of depositional systems of Upper Triassic Yanchang Formation, Ordos Basin. From Zhou et al., 2002.

extend 100s of kilometers. This interpretation may be debatable. Deltas that prograded into deep lakes are thick, with a pronounced upward-coarsening and thickening trends.

Stop 3 (June 21) – Huangling and Luo Chuan: Sedimentology and paleoclimatology of Luo Chuan Loess Section (Zhou et al., 2002, p. 334-337)

Loess is widely distributed in China (Fig. 16). It occurs mostly in arid to semi-arid regions in northern China, ranging in elevation from 3,500 m to 100s m. Loess accumulation ranges from 300-500m in western China to 100-200 m in the Ordos Basin. Three distinct types of loess landscapes are evident in the Ordos Basin: plateaus, hills, and ridges. Plateaus are wide and flat plateaus. Where situated on fault blocks, they are in a form of mesas. Loess ridges are elongate, ranging from 100s m to 10s of km long, 10s-100s m wide, and 100-200 m high. Hills are rounded with a variable size, 100s-10s m in diameter and 100s m in height. Ridges and hills are controlled by bedrock morphology and stream erosion.

In the study area, loess deposits are commonly horizontal, composed of alternately stacked grayish yellow loess proper and brownish red paleosols. Most loess deposits are built up on Neogene red muddy sediments with a conformable contact.

The section to be observed is in Heimugou (Black Wood Canyon) of Luo Chuan (Fig. 12c). It has four stratigraphic units, with total 26 paleosols. Below is a brief description of the section (L- loess; S-paleosol):

Holocene loess and paleosol:

- L0. Light grayish yellow loess, friable, porous, 2 m thick.
- S0. Black paleosol. 1 m thick.

Late Pleistocene loess and paleosol:

- L1. Light grayish yellow loess, friable, porous. 7 m thick.

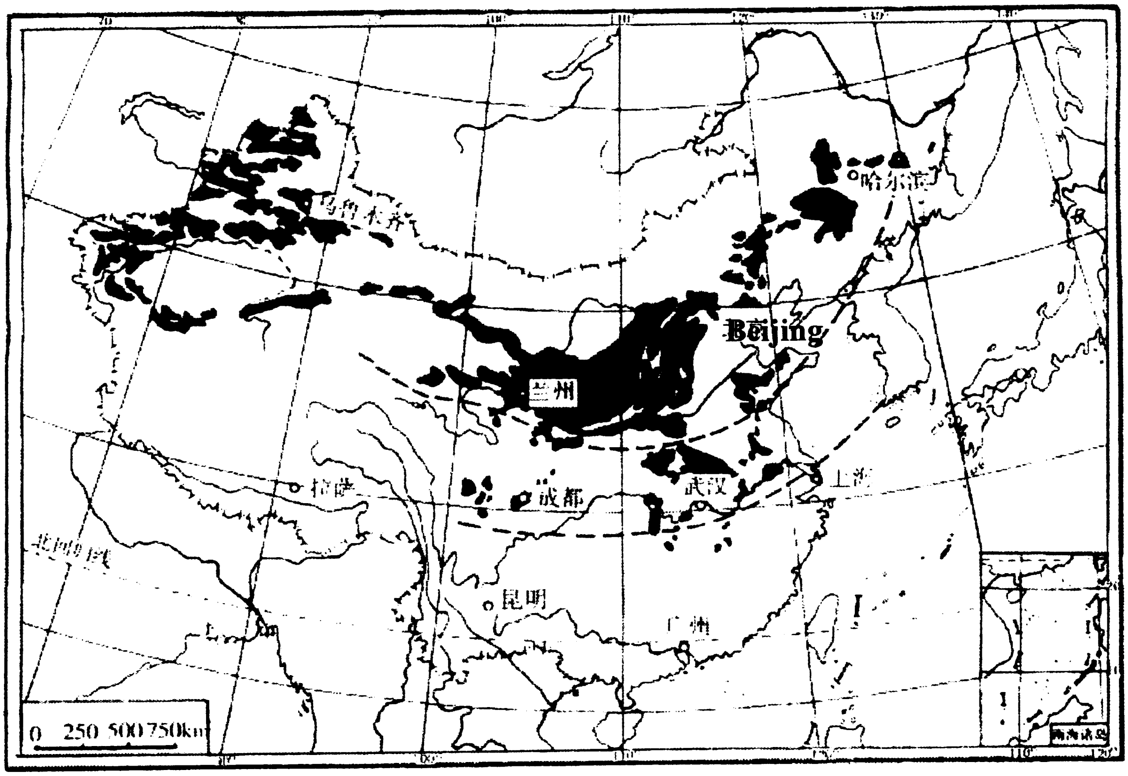


图 9-4 中国黄土分布示意图
（刘东生等，1985）

Figure 16. Loess distribution in China. From Zhou et al., 2002.

- S1. Light reddish brown paleosol. Pedogenic structure is well developed with calcitic nodules at base. 2 m thick.

Middle Pleistocene loess and paleosol:

- L2. Light grayish yellow loess, fairly friable, some large pores. 7 m thick.
- S2. Reddish brown paleosol. Two layers, evident pedogenic structures. Calcitic nodule layer at base. 2 m thick.
- L3. Light grayish yellow, moderately cemented, limited large pores. 4 m thick.
- S3. Reddish brown paleosol, calcitic nodule zone at base. 2 m thick.
- L4. Light grayish yellow loess, moderately well cemented, limited large pores. 4.5 m thick.
- S4. Reddish brown paleosol, calcitic nodule zone at base. 2 m thick.
- L5. Light grayish yellow, moderately well cemented, limited large pores. 5 m thick.
- S5. Reddish brown paleosol, vivid color, mature, prismatic peds and solumns, grainy texture. Three profiles, each of which has a calcitic nodule zone at base. 5 m.
- L6. Grayish brown loess, well cemented, rare pores. 5 m thick.
- S6. Reddish brown paleosol, two profiles separated by ~1-m thick loess. Calcitic nodule zone at base. 3 m thick.
- L7. Grayish brown loess, well cemented, rare pores. 2 m thick.
- S7. Reddish brown paleosol with a calcitic nodule zone at base. 2.5 m thick.

Early Pleistocene loess-paleosol. Total 79 m thick.