become oxidized grey from being exposed to air, which may cause noses and hairstyles to disappear, and falling arms. However, the officials dismissed the claims. In Daily Planet Goes to China, the Terracotta Warriors segment reported the Chinese scientists found soot on the surface of the statue, concluding that the pollution introduced from coal burning plants was responsible for the decaying of the terracotta statues.

The Mausoleum of the First Qin Emperor at Lintong has been designated as a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Terracotta army made in two batches (Jennifer Viegas; 2-6-2007; News in Science: http://www.abc.net.au/science/news/stories/2007/1841166.htm)

The horses and warriors of China's terracotta army were made in different places, according to analysis of pollen found on the clay figures. The imposing faux army has mystified scholars since the 8099 clay warriors and horses were discovered in Emperor Qin Shihuang's mausoleum in 1974.The figures, meant to protect the emperor in the afterlife, were buried with him around 210-209 BC.

Now scientists, whose findings have been accepted for publication in the Journal of Archaeological Science, say at least one mystery about their origins has been solved.

"When the plants were flowering in the time of the Qin Dynasty 2000 years ago, the pollen flew in the air and fell in the clay, even if the pollen could not be seen with the naked eye," says lead author Ya-Qin Hu.

Hu, a scientist in the Institute of Botany at Beijing's Chinese Academy of Sciences, and colleagues crushed the collected terracotta fragments, washed them and spun the mix to separate

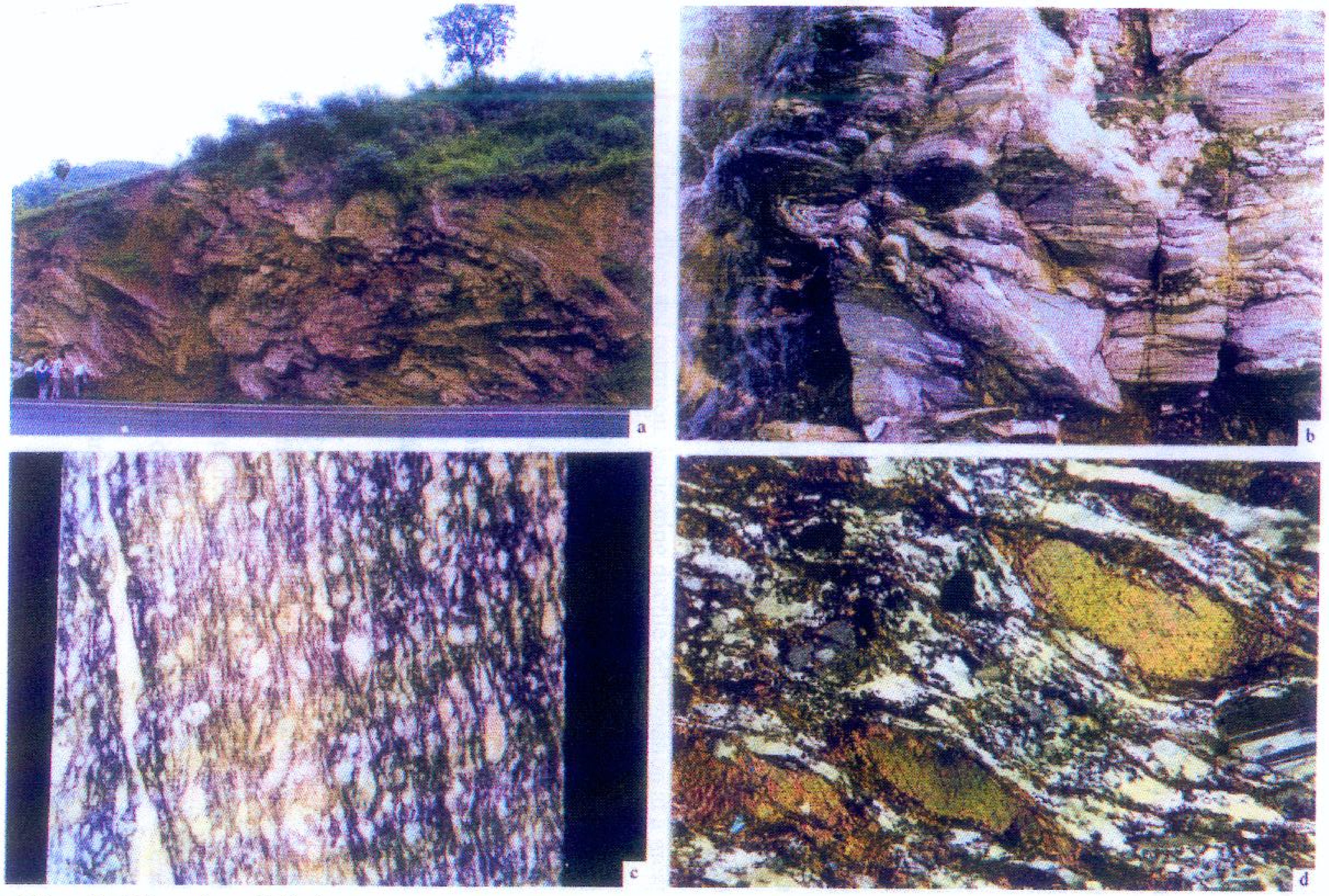

Figure 33. a. Bedding-plane folds in Cretaceous continental deposits, Shangzhou. b. Ductile shear zone and internal cleavages within the vertical plunging folds, Qinling Group, Weizhiling. c.-d. Melanges in the melange belt of Ningshan, and microscopic structures. From Zhou et al., 2002.

metamorphosed complexes. Metamorphism commonly reached amphibolite facies and locally gneissic facies. Migmatization and multi-stage deformation, metamorphism, and magmatism were intense. The age of Qinling Group ranges from 1.987 to 2.267 billion years. The parent rocks are sedimentary clastic and carbonate rocks intercalated with volcanic rocks, as a sedimentary-volcanic assemblage. Geochemical data of mafic volcanic rocks indicate a very high Pb value, suggesting a great difference from those in North China Block and a close resemblance with the Yangtze Block.

3. Ductile deformation of Paleo-Proterozoic Qinling Group

Five episodes of structural deformation were interpreted for Qinling Group (Fig. 34). The first is the formation of incumbent folds along bedding-parallel schistosity planes. Penetrative schistosity and gneissosity and associated joints were developed. Granitic invasion occurred. Boudinage structures of felsic dikes are common, indicating ductile deformation at a great burial depth.

The second episode is characterized by re-folding of the previous incumbent folds along the same axis to form close reversed incumbent folds, and penetrative axis-plane schistosity and joints. Ductile shearing associated with overthrusting also occurred, indicating plastic deformation in a solid state at a great burial depth. The first and second episodes also accompanied regional and dynamic metamorphism of the amphibolite facies. The ages of collisional granites and metamorphism events are concentrated around 1000-800 Ma and 1000-900 Ma, respectively, indicating the two episodes occurred before the Sinian. The P-T track analysis shows decreased pressure, indicating a burial depth of more than 35 km. Further

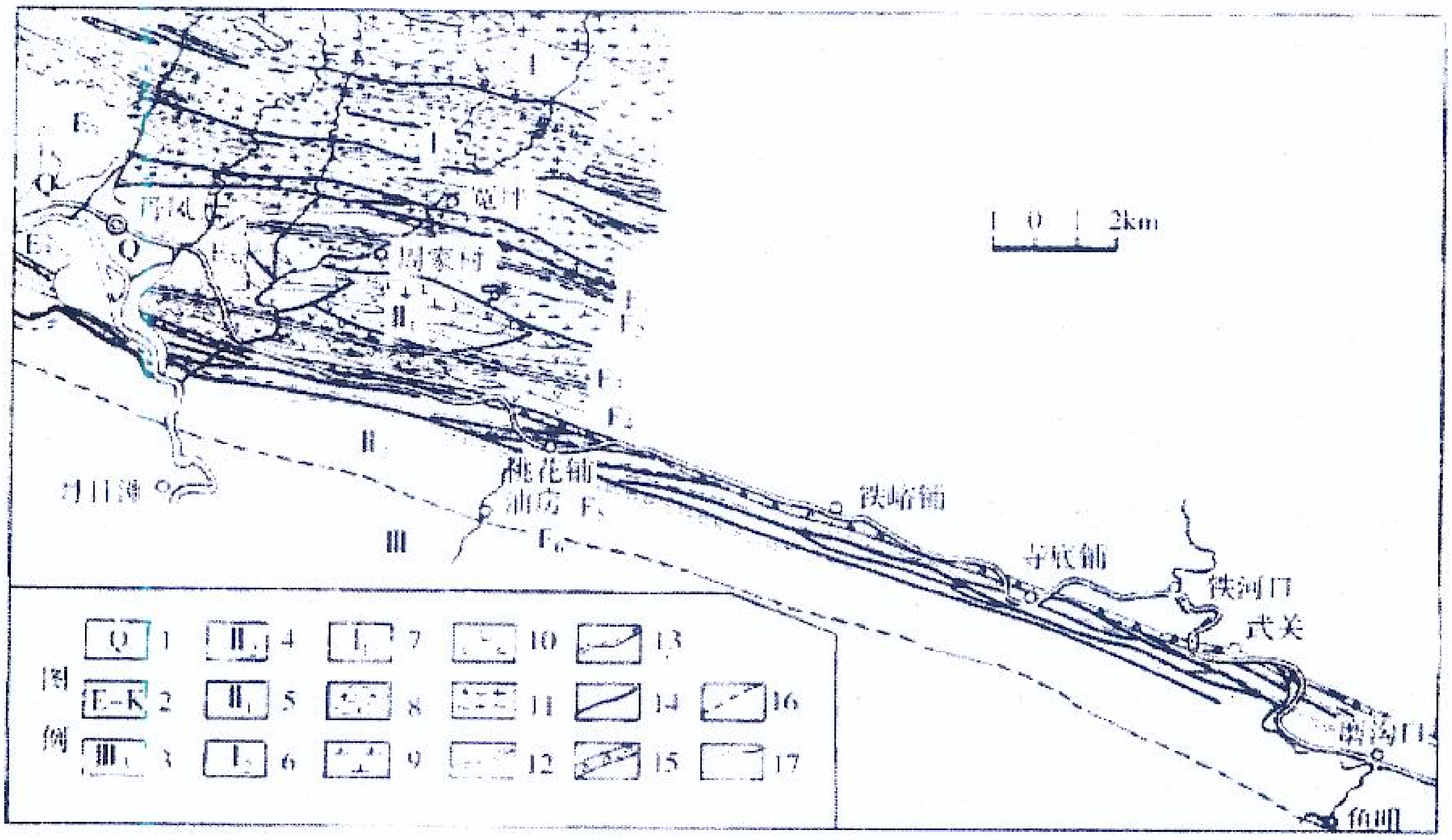

图 6-12　丹凤区段商丹带地质略图

（张国伟等，2001）

1. 第四系；2. 第三系－白垩系；3. 刘岭群；4. 变质沉积岩片组合带；5. 丹凤变沉积-火山岩带；6. 秦岭群上岩性段；7. 秦岭群下岩性段；8. 花岗片麻岩；9. 闪长岩；10. 辉长岩；11. 韧性剪切带；12. 脆－韧性断层；13. 平移断层；14. 断层；15. 脆性破碎带；16. 推测地质图线；17. 地质界线

Figure 34. Simplified geologic map of the Shang-Dan suture zone in Danfeng area. 1. Quaternary, 2. Tertiary-Cretaceous, 3. Liuling Group, 4. meta-sedimentary slate, 5. meta-sedimentary-volcanic rocks, 6. upper Qinling Group, 7. lower Qinling Group, 8. granitic gneiss, 9. amphibolite, 10. diabase, 11. ductile shear zone, 12. brittle-ductile shear zone, 13, strike-slip fault, 14, fault, 15, brittle fracture zone, 16. speculative geological contacts, 17. geological contacts. From Zhou et al., 2002.

analysis suggests that these episodes represent Paleo-Proterozoic oceanic plate subduction and ensuing continent-continent collision.

Several features characterize the third episode. First, subduction-collisional magmatism is indicated by calc-alkalic granites. Under this thermal regime, west-east-oriented broad to domal folds formed with the granites as the core. Correspondingly, penetrative new cleavages and joints formed. Afterwards, potassic granite formed, followed by widespread invasion of pegmatite dikes. In the late stage of this episode, south-verging overthrusting occurred. Under the unique thermal-dynamic conditions of this episode, regional and dynamic metamorphism occurred to form non-uniform amphibolite and ultra-amphibolite facies belts. Age of metamorphism centers around 450-400 Ma and that of subductional-collisional granites centers around 500-400 Ma. Thus, this episode of deformation and metamorphism belongs to the Caledonian Orogeny (Silurian-Devonian). It is postulated that the paleo-oceanic plate of Qinling ocean subducted northward, followed by continent-continent collision. These activities induced calc-alkalic magmatic activities, resulting in great thermal invasion and crustal thickening, and north-south overthrusting.

The fourth episode is represented by the ductile left-lateral strike-slip faulting along the Shangzhou-Danfeng suture zone 324-314 Ma. The antecedent structures of Qinling Group were altered. East-west-oriented vertical penetrative joint planes and superimposed vertically plunging folds accompanied by new joint planes with variable attitudes are the products of this episode in the south of Shangzhou. On the other hand, large-scale sinistral ductile shearing zone is the product in the north of the Shang-Dan suture zone (Fig. 33c, d).

The fifth episode is represented by the ductile reverse and overthrust shearing zone along the Shangzhou-Denfeng fault zone in 210 Ma. There are a series of secondary shearing zones and related folds.

In addition to the five episodes, the Qinling Group also experienced later brittle strike-slip faulting and block faulting and extension.

Stop 9 (June 28) – Zhashui:
Mélanges in Shaogoujie, Sedimentology and structural geology of Middle-Upper Devonian rocks in Huanghualing

1. Mélanges along the Shangzhou-Danfeng Fault Zone in Shaogoujie (Zhou et al., 2002, p. 197-200)

The Shang-Dan Fault Zone is a suture zone, as the southern boundary of the Northern Qinling Structural Belt, which is characterized by intense faulting of different types, in different stratigraphic levels, and in different ages.

In the vicinity of Stop 9, a 2-km exposure of the ductile shear zone of the Shang-Dan FZ will be observed (Fig. 35). Rocks (tectonites) include felsic mélanges, ultra-mélanges, and lenticular granitic mélanges, and discontinuous, irregular, elongate bands of pseudo-basaltic glasses. Four episodes of faulting of different types had occurred. First, the lenticular (eyeball-shaped) granitic mélange is 211 Ma in age, indicating the invasion time of original porphyritic granite. The rocks were subject to Indosinian (Triassic) overthrusting and associated strike-slip ductile shearing during the process of invasion. Other analysis indicates the formation of mélange occurred at a 10-15 km depth. Next, the age of granitic porphyritic mélange has an age of 126 Ma, when late Yanshanian (Cretaceous-Tertiary) thrusting ductile shearing occurred. Last, frictional heat generated by highly differential stress melted previous mélanges. The melts chilled quickly to form the pseudo-basaltic glass. It has an age of 45-100 Ma. This age corresponds to the timing of late brittle extension and translation in Late Cretaceous and Tertiary, as supported by extensional rifting of Late Cretaceous and Tertiary basins and brittle fault breccias.

The observations and interpretations of the movement of the Shang-Dan FZ (suture zone) suggest intense ductile to ductile-brittle overthrusting mainly along the fault zone during the

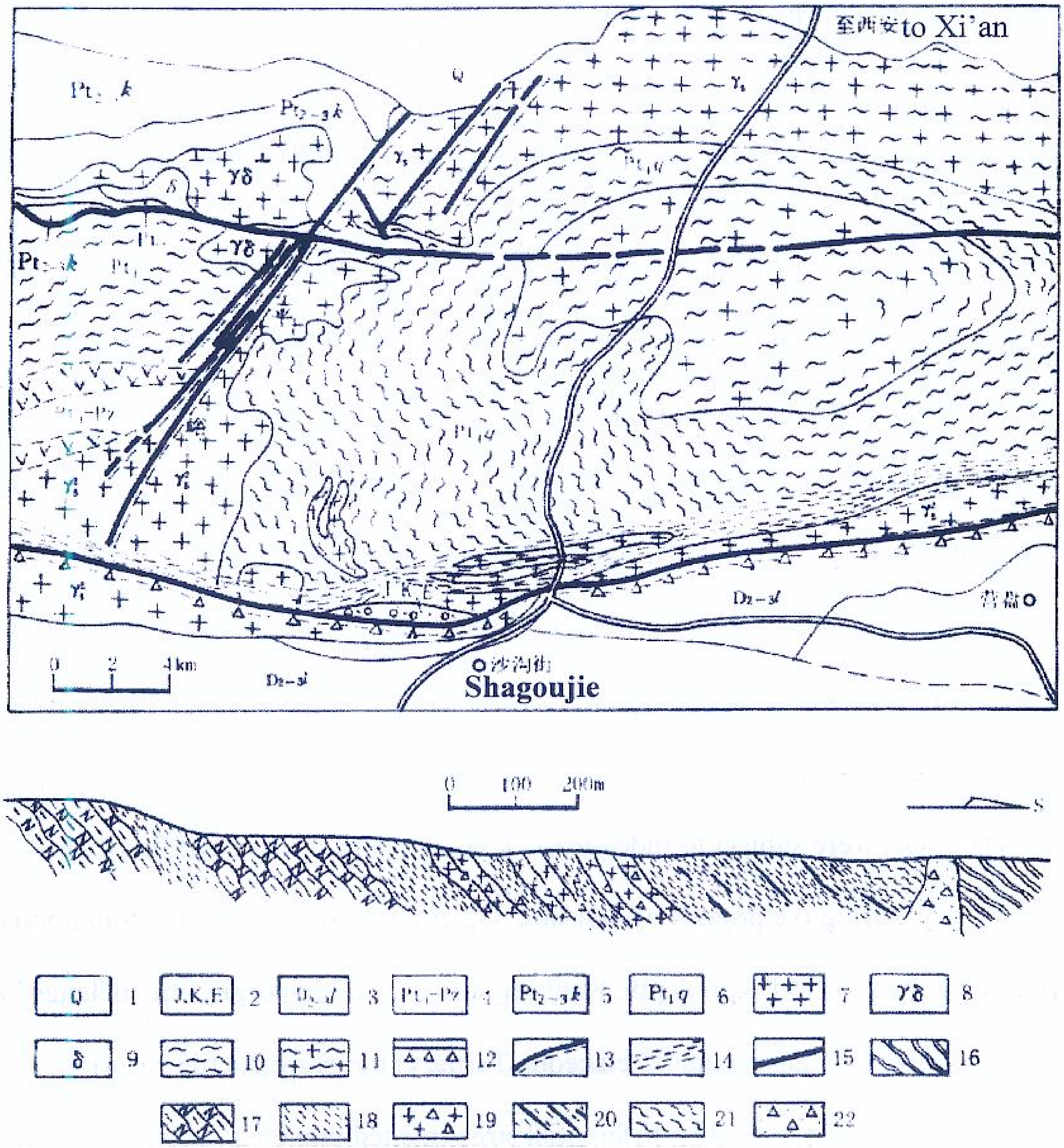

图 6-13 宁陕沙沟街商丹带区域地质图和糜棱岩带剖面图

（张国伟等，2001）

1. 第四系；2. 第三系－白垩系、侏罗系；3. 泥盆系刘岭群；4. 丹凤群变沉积-火山岩；5. 宽坪群；6. 秦岭群；7. 花岗岩；8. 花岗闪长岩；9. 闪长岩；10. 片麻岩；11. 花岗片麻岩；12. 脆性或脆韧性平移断层；13. 脆韧性断层；14. 韧性剪切带；15. 假玄武玻璃岩；16. 泥盆系板岩；17. 斜长角闪岩；18. 韧性剪切带；19. 碎裂花岗岩；20. 糜棱岩；21. 构造片岩；22. 碎裂岩

Figure 35. Geological map of Shang-Dan suture zone, Shagoujie, Ninshan area, and cross sections of melange zone. 1. Quaternary, 2. Tertiary-Cretaceous, Jurassic, 3. Devonian Liuling Group, 4. meta-sedimentary-volcanic Danfeng Group, 5. Kuanping Group, 6. Qinling Group, 7, granite, 8. granitic diabase, 10. gneiss, 11. granitic gneiss, 12. brittle or brittle-ductile strike-slip fault, 13, brittle-ductile fault, 14, ductile shear zone, 15, pseudo-basaltic glass, 16. Devonian slate, 17, plagioclase amphibolite, 18. ductile shear zone, 19, chilled granite, 20. melange, 21. tectonic slate, 22. fractured rocks. From Zhou et al., 2002.

Yanshanian Orogeny, forming a complex combination of faults in different tectonic sequences at different times (Fig. 36).

2. Sedimentology and structure of Middle-Upper Devonian Rocks in Huang Hua Ling (Zhou et al., p. 103-107)

Middle-Upper Devonian marine sedimentary rocks overlie unconformably the Lower Paleozoic metamorphosed sedimentary-volcanic rocks. They are mainly restricted to the Southern Qinling Structural Belt (Fig. 37). The rocks were deposited in highly partitioned small basins and have different characteristics, and are subdivided into three tectonic-sedimentary belts/zones, i.e. northern, middle, and southern belts, within the Southern Qinling Structural Belt.

Stop 9 is in the northern belt. Here the Middle-Upper Devonian Liuling Group is several thousand meters thick with a basal parallel unconformity over Cambrian-Ordovician rocks. The Liuling Group is composed mainly of siliciclastic rocks with limited carbonate rocks. Conglomerate is present in the basal part, whereas the majority is fine-medium feldspathic-quartzose sandstone, siltstone, muddy siltstone, mudrock, and thin limestone. Fossils are from carbonates, and siliciclastic rocks are devoid of fossils. Some sandy limestones containing skeletal fragments are intercalated with turbidites and, thus, were probably transported through sediment gravity flows.

The Liuling Group is composed of the following depositional systems:

1) Shoreface system: Fine to medium-grained feldspathic quartz sandstone and quartz sandstone are thin to thick bedded, cross or planar bedded. There is minor siltstone.
2) Storm-influenced shelf system: It includes massive sandstone, hummocky cross stratified sandstone, siltstone, muddy siltstone, and mudrock.

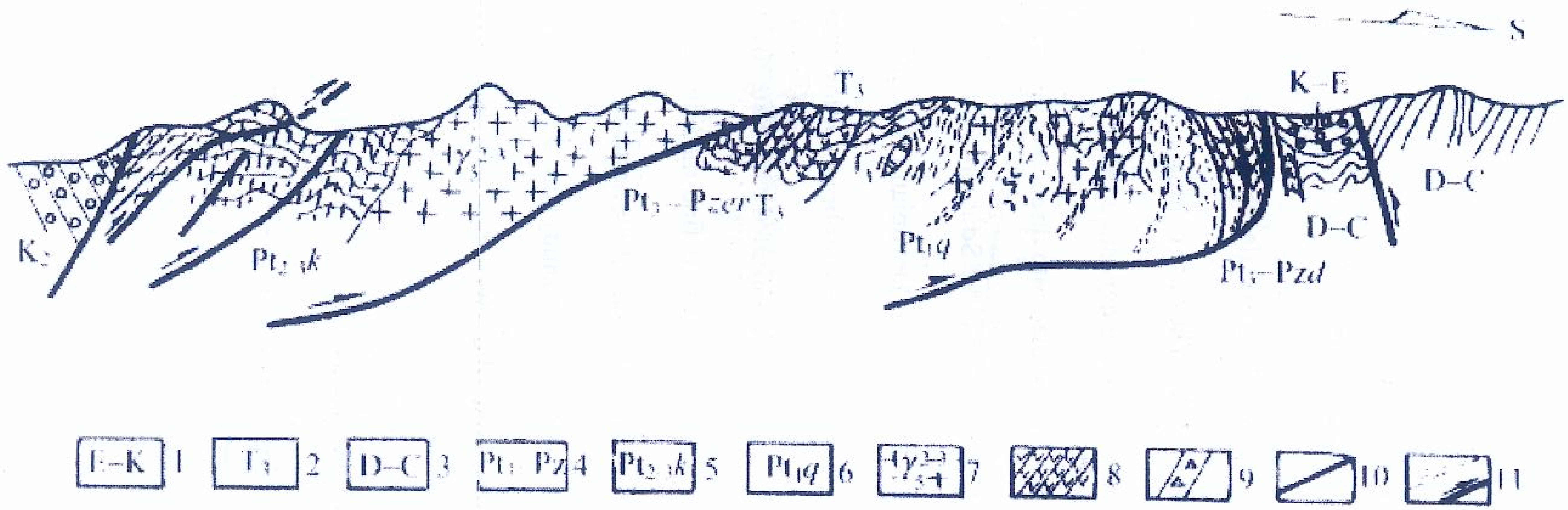

图 6-14　北秦岭叠瓦状逆冲推覆构造系统剖面图

（张国伟等，2001）

1. 老第三系—白垩系；2. 上三叠统；3. 泥盆系—石炭系；4. 丹凤群变沉积-火山杂岩（Pt_3—Pzd）、二郎坪群变沉积-火山岩（Pt_3—P_{zer}）；5. 中新元古界宽坪群；6. 古元古界秦岭群；7. 花岗岩；8. 火山岩与花岗岩；9. 脆性断层角砾岩；10. 断层；11. 韧性剪切带和逆冲推覆断层

Figure 36 Cross section of imbricated overthrust systems in Northern Qinling Structural Belt. 1. Paleogene-Cretaceous, 2. Upper Triassic, 3. Devonian-Carboniferous, 4. meta-sedimentary-volcanic Danfeng Group (Pt3-Pzd) and Erlangping Group (Pt3-Pzer), 5. Meso-Neo-Proterozoic Kuanping Group, 6. Proterozoic Qinling Group, 7. granite, 8. volcanic and granitic rocks, 9. brittle fault breccia, 10. fault, 11. ductile shear zone and overthrust fault. From Zhou et al., 2002.

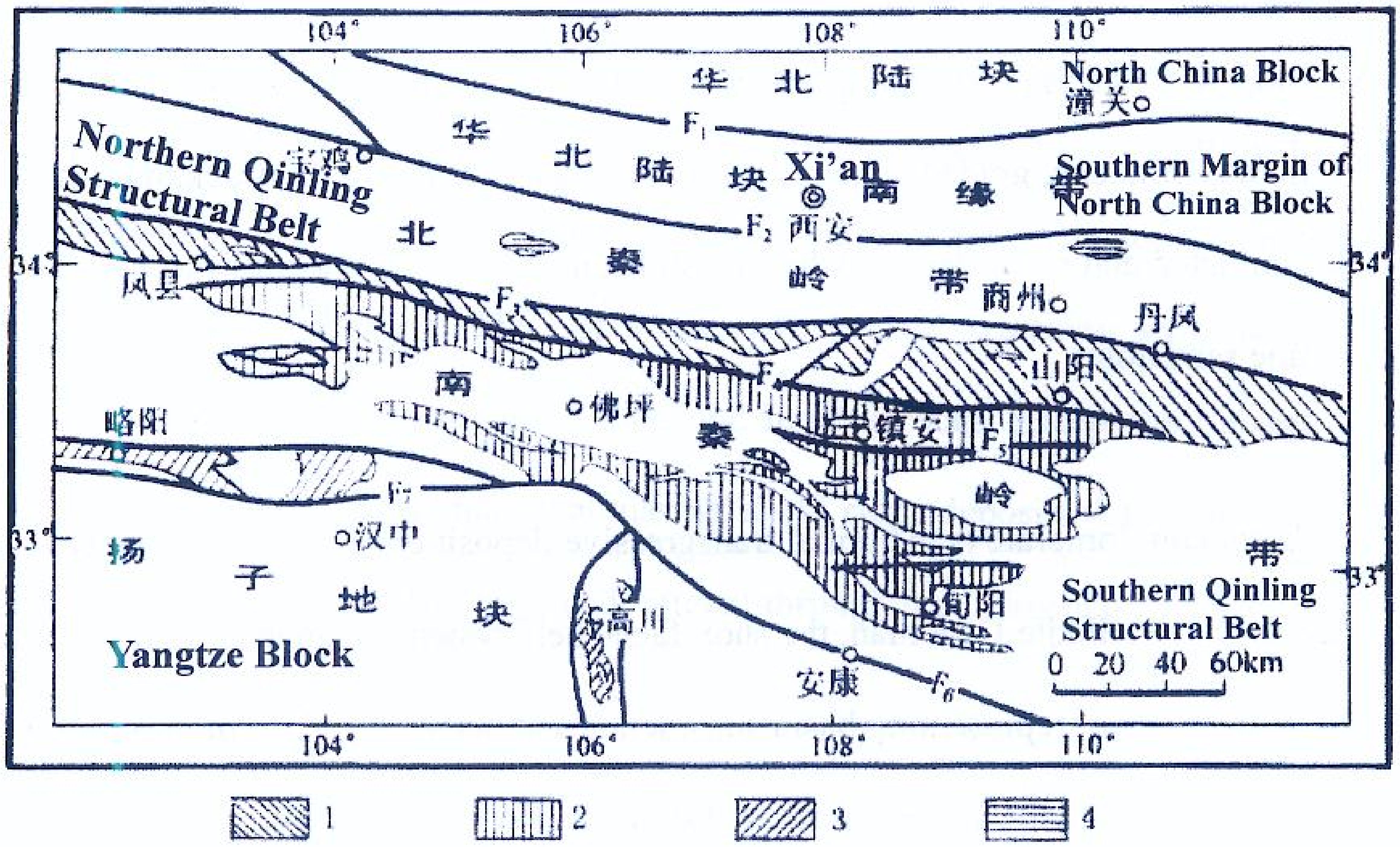

图 4-29　秦岭泥盆系的分布与构造简图

（据梅志超等改绘，1999）

1. 南秦岭北带泥盆系；2. 南秦岭中带泥盆系；3. 南秦岭南带泥盆系；4. 北秦岭泥盆系(?)；F_1. 秦岭北界断裂；F_2. 宝鸡–洛南–栾川断裂；F_3. 商丹缝合带；F_4. 山阳–凤镇断裂；F_5. 镇安–板岩镇断裂；F_6. 安康断裂；F_7. 勉略缝合带

Figure 37. Distribution and structures of Devonian rocks in Qinling Orogen. 1. Devonian in northern belts of Southern Qinling Structural Belt, 2. central belt, 3. southern belt, 4. Devonian (?) rocks in Northern Qinling Structural Belt, F1-northern bounding fault of Qinling, F2-Baoji-Luo'nan-Luanchuan fault zone, F3-Shang-Dan suture zone, F5-Shanyang-Fengzheng Fault Zone, F5-Zhengan-Banyan Fault Zone, F6-Ankang Fault Zone, F7-Mianlue suture zone.

3) Tide-influenced shelf system: It includes simple and complex cross-bedded sandstones, planar bedded sandstone, and thin-bedded mudrock and siltstone.

4) Shelf-slope system: It includes massive sandstone, cross-bedded sandstone, thin-bedded fine sandstone, planar-bedded sandstone, thin interbedded siltstone and mudrock and massive siltstone showing collapsing structures.

5) Slope-abyssal plain system: parallel and ripple laminated siltstone and fine sandstone, muddy siltstone, graded siltstone laminae, massive siltstone/mudrock, dark gray parallel-laminated and cross-bedded silty limestone, and a small amount of medium-thick-bedded fine sandstone.

The basal conglomerate is the initial transgressive deposit during the early phase of basin subsidence. In the Middle Devonian, the shoreface-shelf systems change upward into slope-abyssal plain systems, representing basin subsidence and deepening. Common soft-sediment deformation features in the shoreface-shelf systems and syndepositional faults and turbidites in shelf-slope systems suggest that basin subsidence was controlled by syndepositional faulting. Subsidence decreased in Late Devonian, causing an environmental change from deep to shallow water depths. Shallow-water deposits dominate and the depositional area also decreases upward, indicating basin contraction. Nevertheless, Upper Devonian deposits are up to 3000-4000 m thick, suggesting subsidence continued and sediment supply from both the north and south were copious.

Stop 10 (June 29) – Zhashui to Xian:
Sedimentology and multi-stage structural deformation of Upper Devonian marine deposits, sedimentology of shallow-water Cambrian-Ordovician platform deposits in Zhashui Cavern, and Middle-Upper Devonian mass and gravity deposits.

1. Sedimentology and multi-stage structural deformation of Upper Devonian marine deposits in Longbozi (Dragon neck) (Zhou et al., 2002, p. 209-213)

This stop is in the Southern Qinling Structural Belt. The Southern Qinling Structural Belt is in contact with the Northern Qinling Structural Belt along the Shang-Dan FZ (or suture zone) to the north and with the Yangtze Block of Southern China Plate along the Mianlue-Chengkou-Fangxian-Xiangfan FZ (or suture zone). The Upper Paleozoic-Mesozoic tectonic sequence includes Devonian, Carboniferous, Permian, Triassic, and Jurassic rocks. Except the Jurassic deposits, the other ones are dominantly marginal marine, shelf, slope deposits with limited abyssal plain deposits. Thin-skinned tectonics is dominant through the Indosinian (Triassic) and Yanshanian (Cretaceous-Tertiary) orogenies.

Stop 10 is situated in the central part of the central Southern Qinling Structure Belt (Fig. 38). Middle and Upper Devonian, Carboniferous, and Lower and Middle Triassic are continuous marine deposits. Middle Devonian is in a parallel unconformable contact with underlying Cambrian-Ordovician open platform deposits, and is in an angular unconformable contact with underlying Precambrian volcanic and intrusive rocks. Middle Devonian depositional environments change from continental to marginal-marine and shallow-marine, and deep-water in Late Devonian to Early Carboniferous, and finally to shallow-marine environments from Middle to Late Carboniferous, Permian to Triassic.

Four tectonic episodes can be identified in this area:

- Episode 1: Multiple-stage continuous extension and subsidence caused by syndepositional normal faulting controlled Middle Devonian sediment gravity deposits

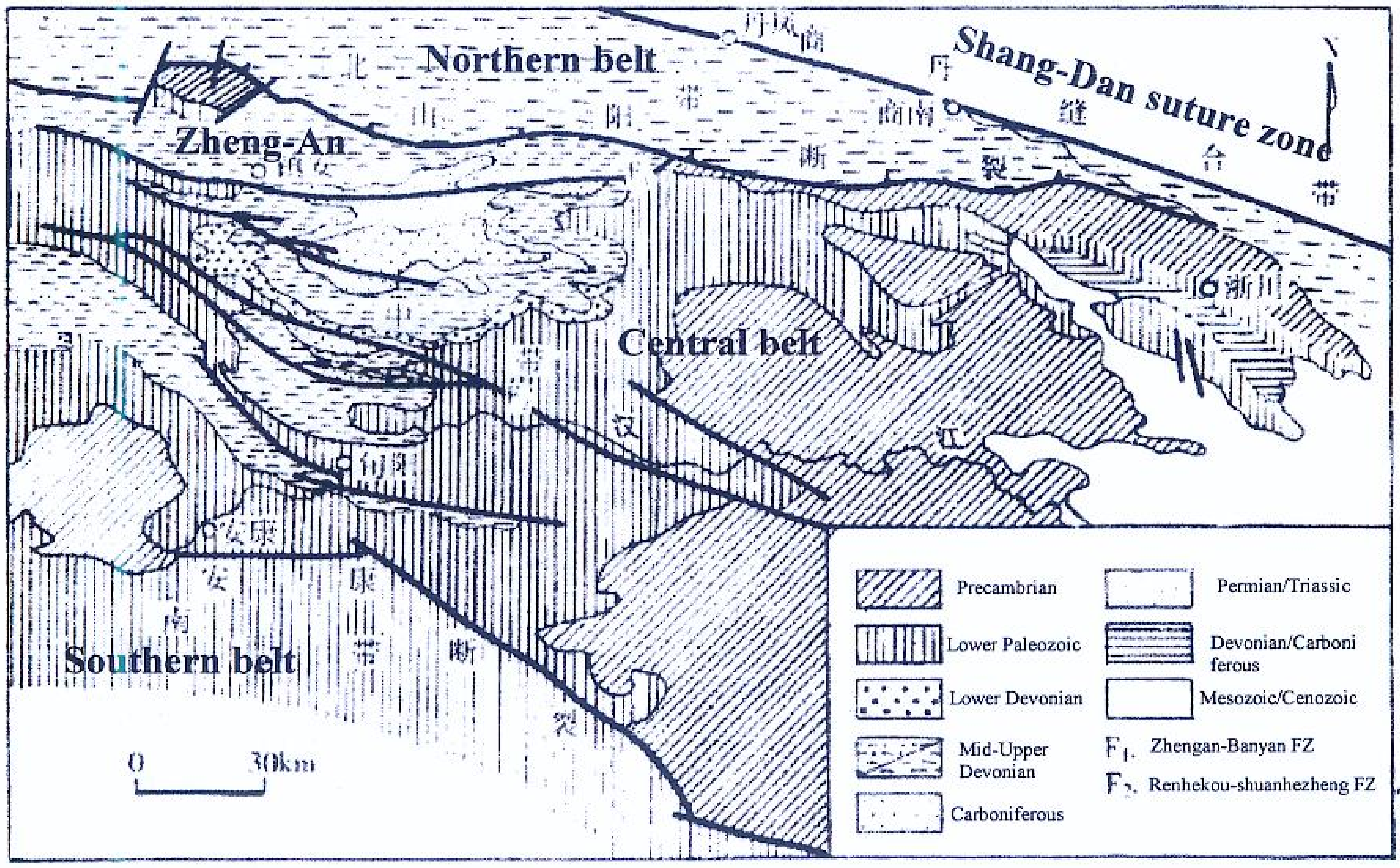

图 6-22 南秦岭中段地质略图

（据张国伟等，2001 改绘）

Figure 38. Simplified structural map of central belt of Southern Qinling Belt. From Zhou et al., 2002.

- (Fig. 18a, b, c, d), and evolution from nonmarine, marginal marine, shelf, and basinal environments.
- Episode 2: Inversion of preexisting normal faults formed south verging reverse faults. Overthrusting occurred along some fault zones to form large-scale ductile thrusting nappes. As a result, several orders of faults and different types of complex folds were generated in the Sinian-Middle Triassic sedimentary cover (Fig. 39). This episode of deformation was estimated to the Indosinian Orogeny on the basis of youngest rocks (Lower and Middle Triassic) deformed and radiometric ages of tectonites (203-197 Ma).
- Episode 3: This episode was interpreted from observations in this stop. Upper Devonian Jiuliping Formation is exposed in Longbozi area. Two left-lateral ductile-brittle shear zones are present over a distance of 7 km (Fig. 40), of which the Longbozi zone is about 700 m wide. Strike-slip shearing is indicated by penetrative cleavages developed on the broad open folds with a near-horizontal hinge line. The strike of the shear zone is 290-300°, dip is about 85° to NNW. Asymmetrical vertically plunging folds (Fig. 41a) are common with an axial orientation of 290° and a plunging angle of 75-90°; so are rootless vertically plunging folds within the cleavage zones. The geometry and dynamics of asymmetrical folds and the oblique array of deformed lenses indicate left-lateral strike-slip within the shear zone. Furthermore, the development of folded and slaty cleavages, and microscopic mica along cleavage planes suggest shearing occurred in a ductile-brittle state at a shallow burial depth.
- Episode 4: A series of large-scale overthrusting sheets formed by brittle reverse faulting and overthrusting. Accompanying block faulting modified preexisting structures. Basement rocks and Meso- and Neo-Proterozoic and Paleozoic rocks were incorporated

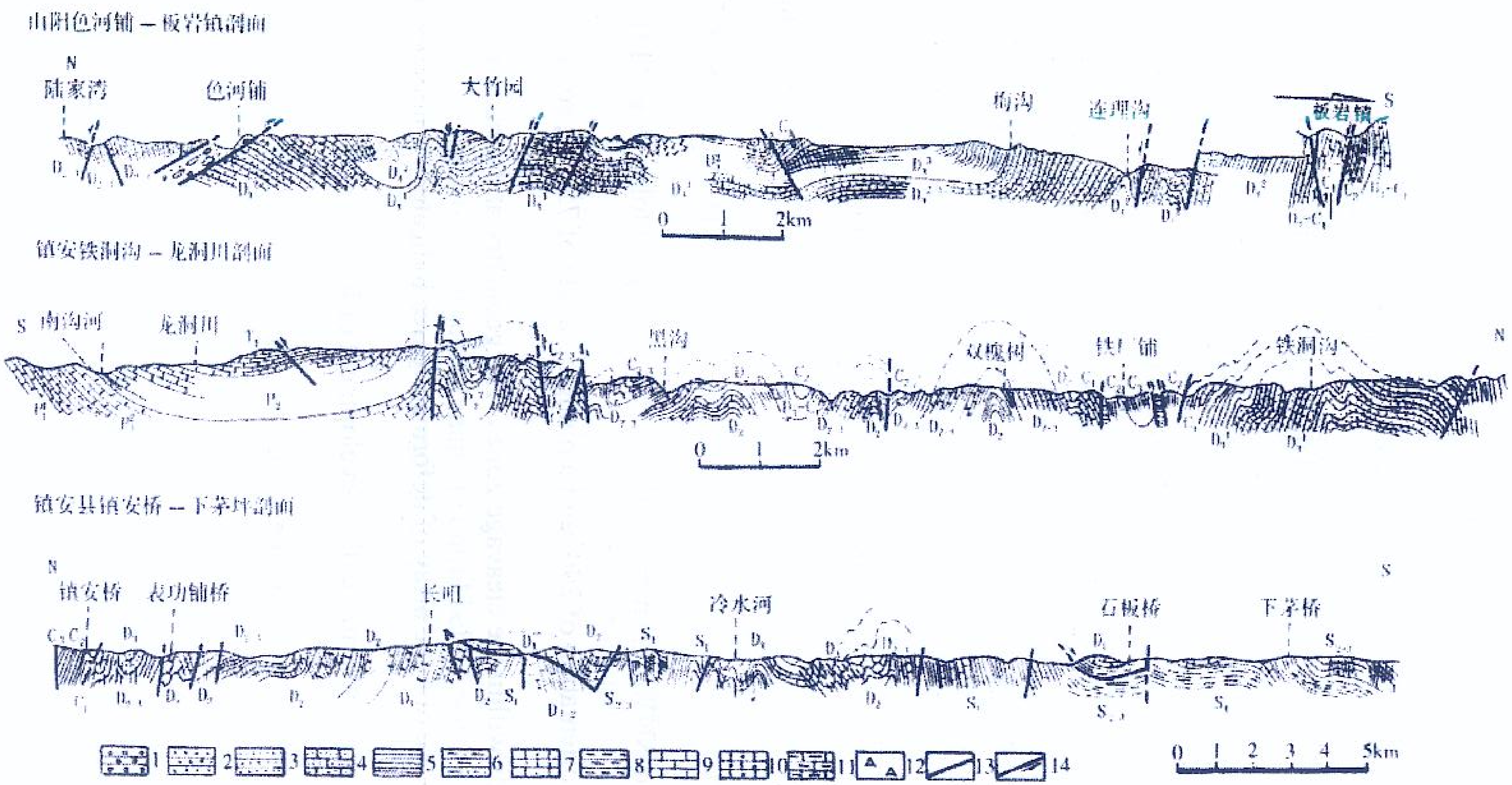

图 6-25　南秦岭中带(山阳-镇安)沉积盖层(S－T)构造变形剖面

(许志琴,1988)

1.砾岩;2.砂岩;3.粉砂岩;4.钙质粉砂岩;5.板岩;6.砂质板岩;7.砂质灰岩;8.碳质板岩;9.灰岩;10.砾状灰岩;

11.泥质灰岩;12.爆破角砾岩;13.断层;14.冲断层

Figure 39. Structural map of sedimentary cover (Silurian-Triassic) in the central belt of Southern Qinling Structural Belt. 1. Conglomerate, 2. sandstone, 3. siltstone, 4. calcareous siltstone, 5, slate, 6. sandstone slate, 7. sandy limestone, 8, carbonaceous slate, 9. limestone, 10. conglomeratic limestone, 11. argillaceous limestone, 12. explosive breccia, 13. fault, 14. reverse fault. From Zhou et al., 2002.

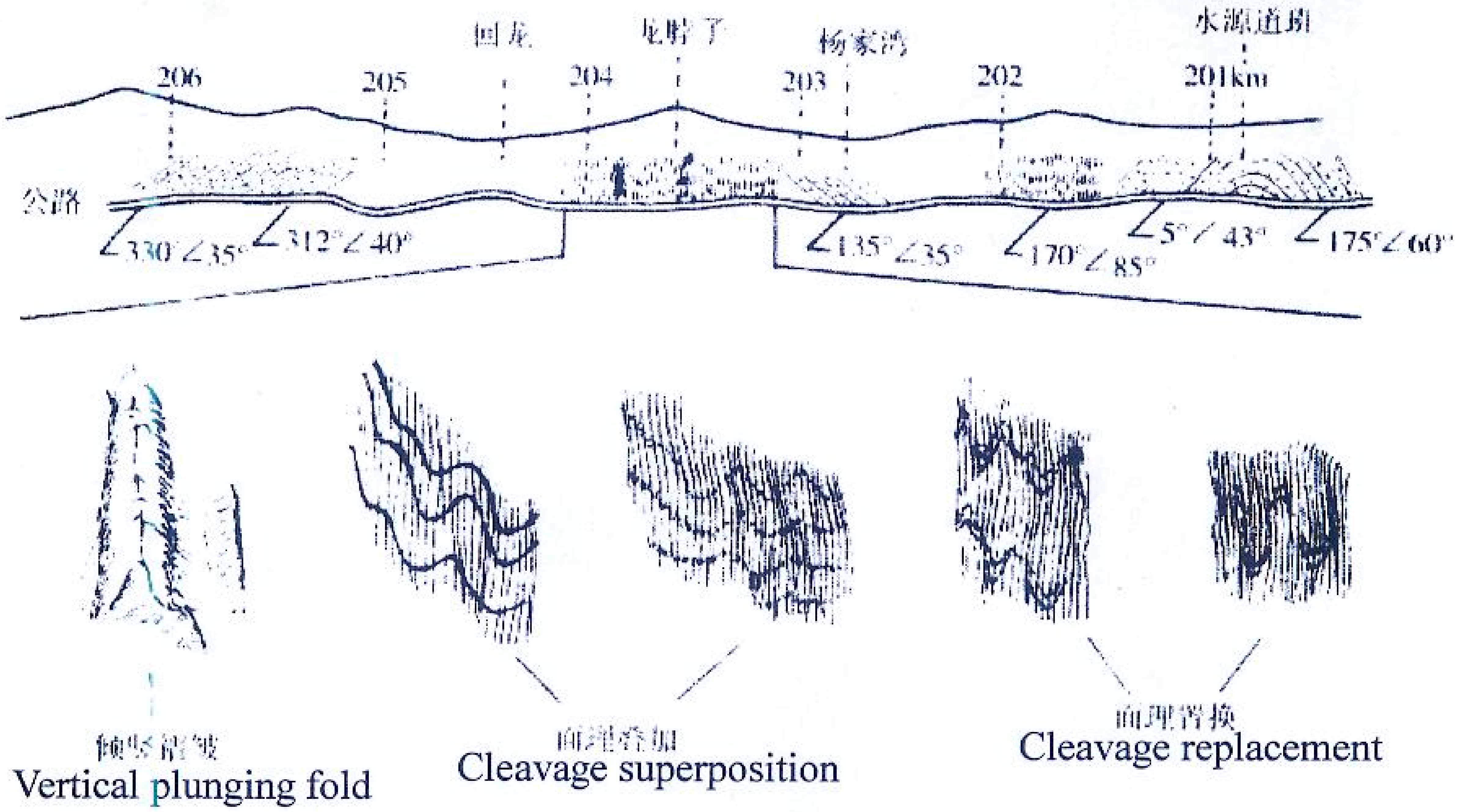

图 6-26　镇安回龙龙脖子地区的左行走滑剪切带

Figure 40. Sinistral (left-lateral) strike-slip shear zone in Longbozi and Huilong area, Zhengan. From Zhou et al., 2002.

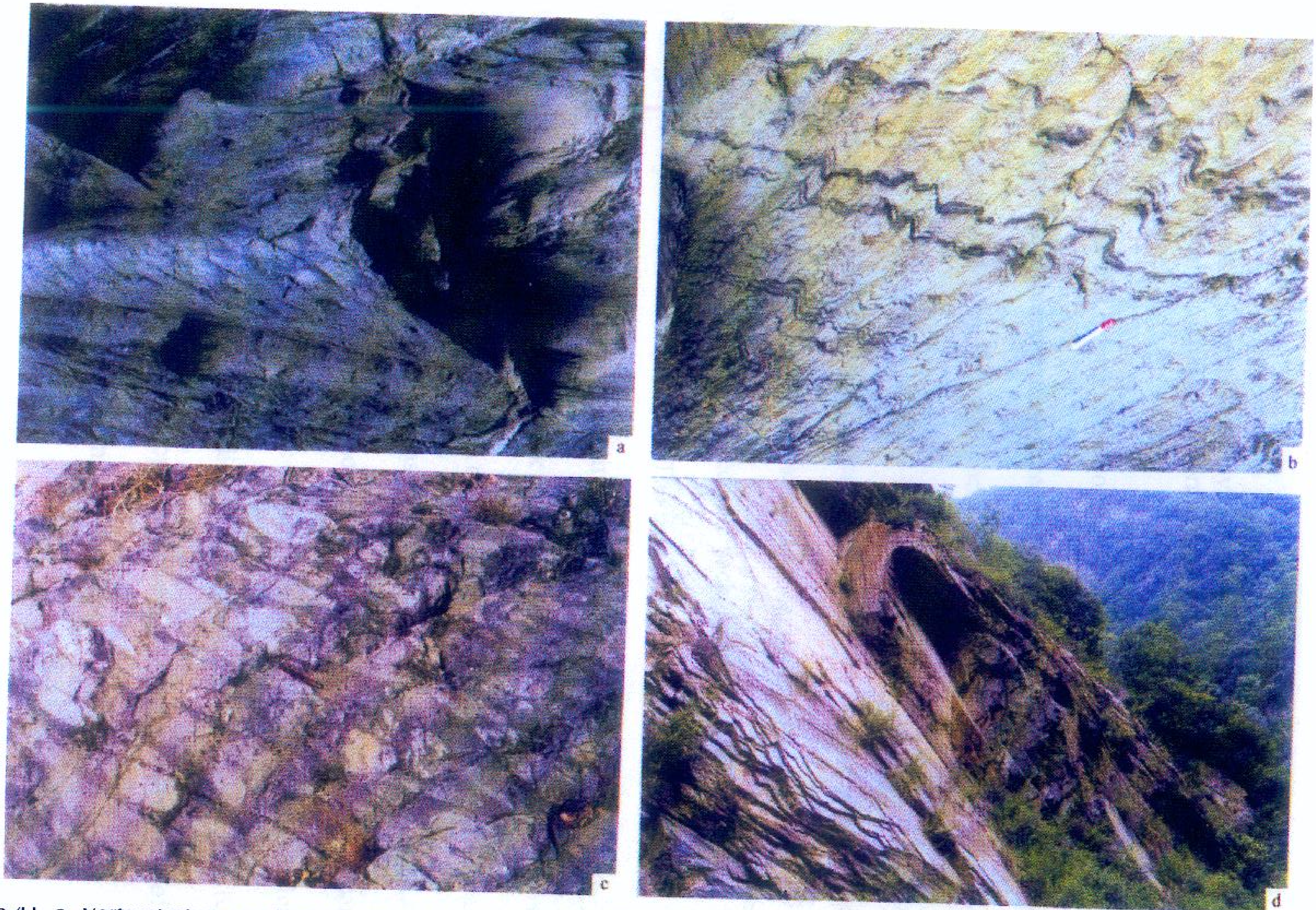

Figure 41. a. Vertical plunging fold in Huilong and Longbozi area, Zhengan. b. Cleavage replacement in the same area. c. Deformed conglomerate at basal Devonian, Shaliangzhi, Zhouzi. d. Isoclinal folds in Devonian sandstone, Dengwozhan, Zhouzi. From Zhou et al., 2002.

in the thrusts. In the vicinity of Zhashui (Fig. 42), Sinian and Cambro-Ordovician rocks were thrusted over on Upper Devonian strata, forming nappe outliers.

2. Sedimentology of shallow-water Cambrian-Ordovician platform deposits and Middle-Upper Devonian sediment gravity deposits in Zhashui Cavern (Zhou et al., 2002, p. 107-113).

The Devonian rocks in Stop 9 belong to the northern belt of the Southern Qinling Structural Belt. Devonian rocks in this stop are situated in the central belt. The Devonian rocks here were deposited in two small basins. Devonian rocks in the Zheng An Basin in the north will be the focus of this stop.

Middle and Upper Devonian rocks in Zhengan Basin overlie the Upper Paleozoic rocks unconformably. They were deposited in a rift basin, where sedimentation was controlled by syndepositional faults under a regional extensional tectonic background from late Middle to Late Devonian. Transgression proceeded from the south. The basal estuarine sandstone and conglomerate grade upward into siliciclastic and peritidal carbonate rocks, and further into carbonate platform deposits. The fan deltaic complex conglomerate deposits of the uppermost Devonian suggest uplifting of a northern source area or a sea level fall, when the basin was an extension of the basins to the south. However, the basin became partitioned in middle-late Late Devonian, when activities of both the northern and southern bounding faults intensified to cause great subsidence of the Zhengan Basin. Stratigraphic architecture and paleocurrent data indicate that sediments were transported down slope perpendicular to basin axis, and then along the basin axis, typical of sedimentation in grabens. The development of turbidites suggests steep dip of the bounding faults. Overall, Devonian deposits show an upward-deepening trend.

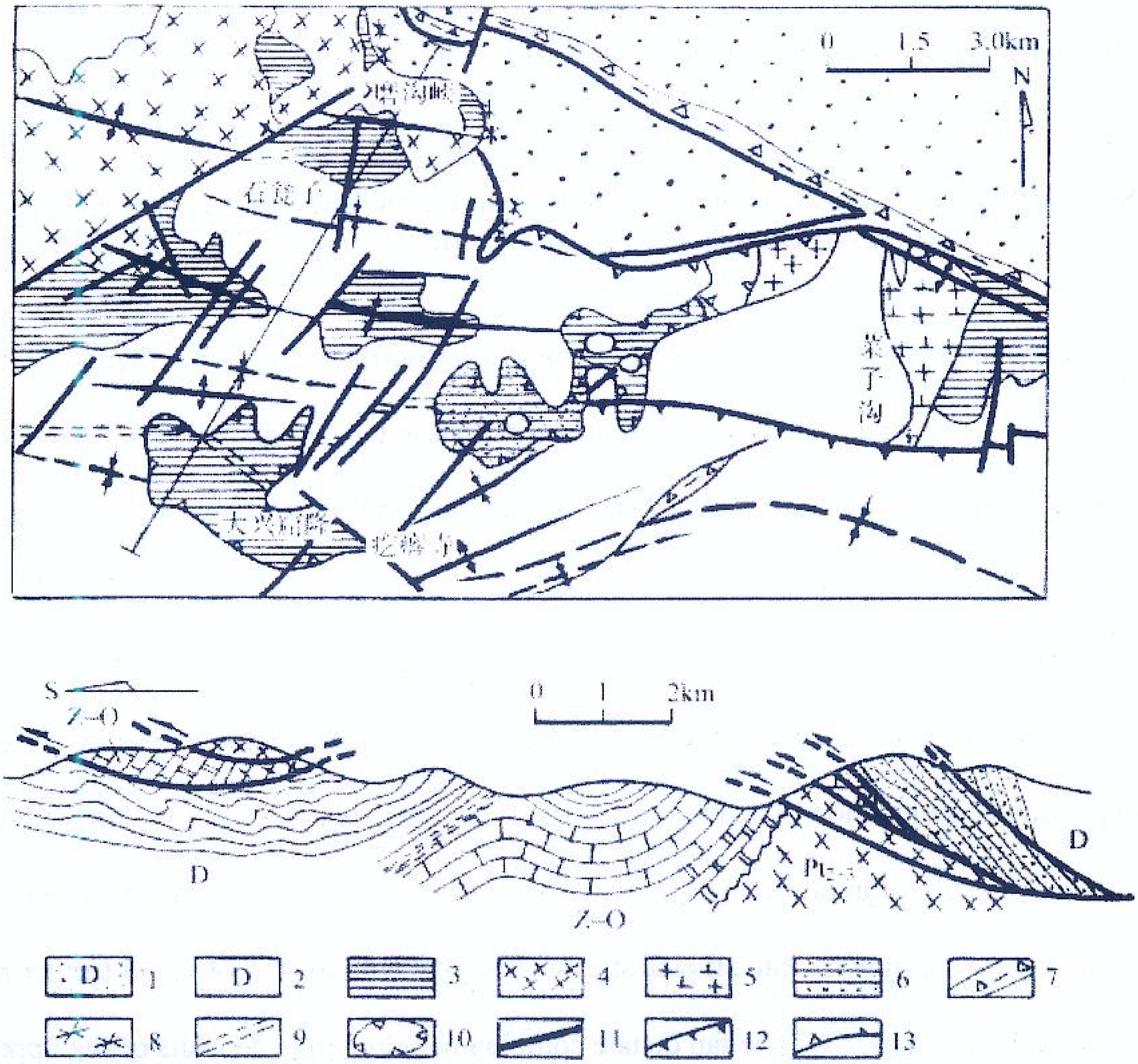

图 6-27 柞水磨沟峡－疙瘩寺地区构造图

（据陕西省区域地质调查队 1:5 万石嘴子幅地质图，1990，略有改动）

1. 北区泥盆系；2. 南区泥盆系；3. 震旦系－奥陶系；4. 小磨岭杂岩和加里东－海西期闪长岩体；5. 花岗岩、闪长岩；6. 推覆混杂构造岩；7. 碎裂岩；8. 糜棱岩；9. 韧性、脆韧性断层；10. 飞来峰；11. 脆性平移断层；12. 逆冲断层；13. 推覆构造主界面

Figure 42. Structural map in the Gouxia-Gedashi area of Zhashui. 1. Northern Devonian, 2. Southern Devonian, 3. Sinian-Ordovician, 4. Xiaomoling complex and Calidonian-Variscan diabase, 5. granite, diabase, 6. overthrusting tectonite, 7. fractured rocks, 8. melange, 9. ductile and brittle faults, 10. tectonic outlier, 11. brittle strike-slip fault, 12, reverse fault, 13. main surface of overthrusting structure. From Zhou et al., 2002.

Middle and Upper Devonian sediment gravity flow deposits are well exposed in the vicinity of the Zhashui Caverns. The Middle Devonian Longdonggou Formation consists of dolomitic sandy conglomerate and fine-grained conglomerate and intercalated calcareous siltstone at the base, sandy limestone intercalated with calcareous sandy conglomerate, dolomitic sandstone, and calcareous siltstone in the lower part, and grayish green and variegated conglomerate intercalated with purple silty slate in the upper part. The overlying Upper Devonian Er-Tai-Zi Formation contains sandy limestone, breccia-bearing limestone intercalated with silty slate, lime mudstone, and skeletal limestone in the lower part, and medium-thick-bedded crystalline limestone in the upper part. The two formations have a total thickness of nearly 500 m.

Equivalent to the Middle Devonian Longdonggou Formation to the south is the Gudaoling Formation. It is several to 100 m thick, consists of siliciclastic and carbonate rocks of a shelf system, whereas the Longdonggou is tidal flat and fan delta nearshore system. The tidal system of the Longdonggou consists of channel-shaped sandstone, sandy conglomerate, or cyclic deposits of lenticular oolitic limestone and nodular limestone and thin-medium-bedded siltstone, mudrock, and dolomite. The fan deltaic deposits include thick-bedded sandstone and conglomerate cycles. The Conglomerate is rich in matrix and is chaotic. Clasts are Proterozoic granulite, granite, amphibolite, and gneiss, and some Cambro-Ordovician limestone and dolomite. Sandstone is dominantly feldspar-quartz sandstone, with cross and graded beddings and basal scour surfaces. The deposits are wedge-shaped overall and pinch out basinward. They interfinger with nearshore or shelf deposits.

The Upper Devonian Hong-Pu Formation, laterally equivalent Er-Tai-Zi Formation, is 400-1000 m thick in the south. It consists of silty mudrocks intercalated with thin-medium-bedded limestones of a shelf system. On the other hand, Ertaizi in the north consists mainly of carbonate build-ups and slope carbonate rocks. The buildups are composed of thick to massive-bedded wackestone and reefal limestone, with a maximum thickness of 200-300 m, 20-30 km long, and several kilometers wide. Slope carbonates are limestone mudstone, thin-bedded silty limestone intercalated with chaotic limestone breccia and collapsing blocks. Collapsing/sliding breccias occur as sheets, commonly more than 4 m thick and are laterally persistent. The breccias are matrix supported; clasts are dark gray to grayish black limestone and lime mudstone, 2-20 cm in size, with maximum of 1 m in size. The clasts are platy, well-rounded semi-spheroidal, or angular where associated with sliding folds. Internal faulting, soft-sediment deformation, and toe upturning are associated with the folds. Clasts are frequently oriented parallel to bedding plane but are dominantly randomly oriented. Some bivalves and other shallow-water skeletal fragments are present in the matrix, suggesting sediments were derived from shallow-marine platforms. These deposits have sharp base and top. The basal surface is relatively flat or erosional, deformed with erosional marks. The top is wavy.

Regionally, the Devonian in Zhengan Basin has different systems from south to north and an east-west orientation. Sedimentary evolution was controlled mainly by tectonics, along with sea-level changes and sediment supply. Extensional subsidence provided accommodation space and controlled provenance, resulting in an overall upward fining and deepening succession (Figs. 43, 44, 45).

3. Sedimentology of shallow-water Cambrian-Ordovician platform deposits in Zhashui Cavern (Zhou et al., 2002, p. 88-92).

The Southern Qinling Structural Belt was a restricted basin in Early Cambrian, because it was a topographic low surrounded by islands and underwater highs (Fig. 46). At the beginning of

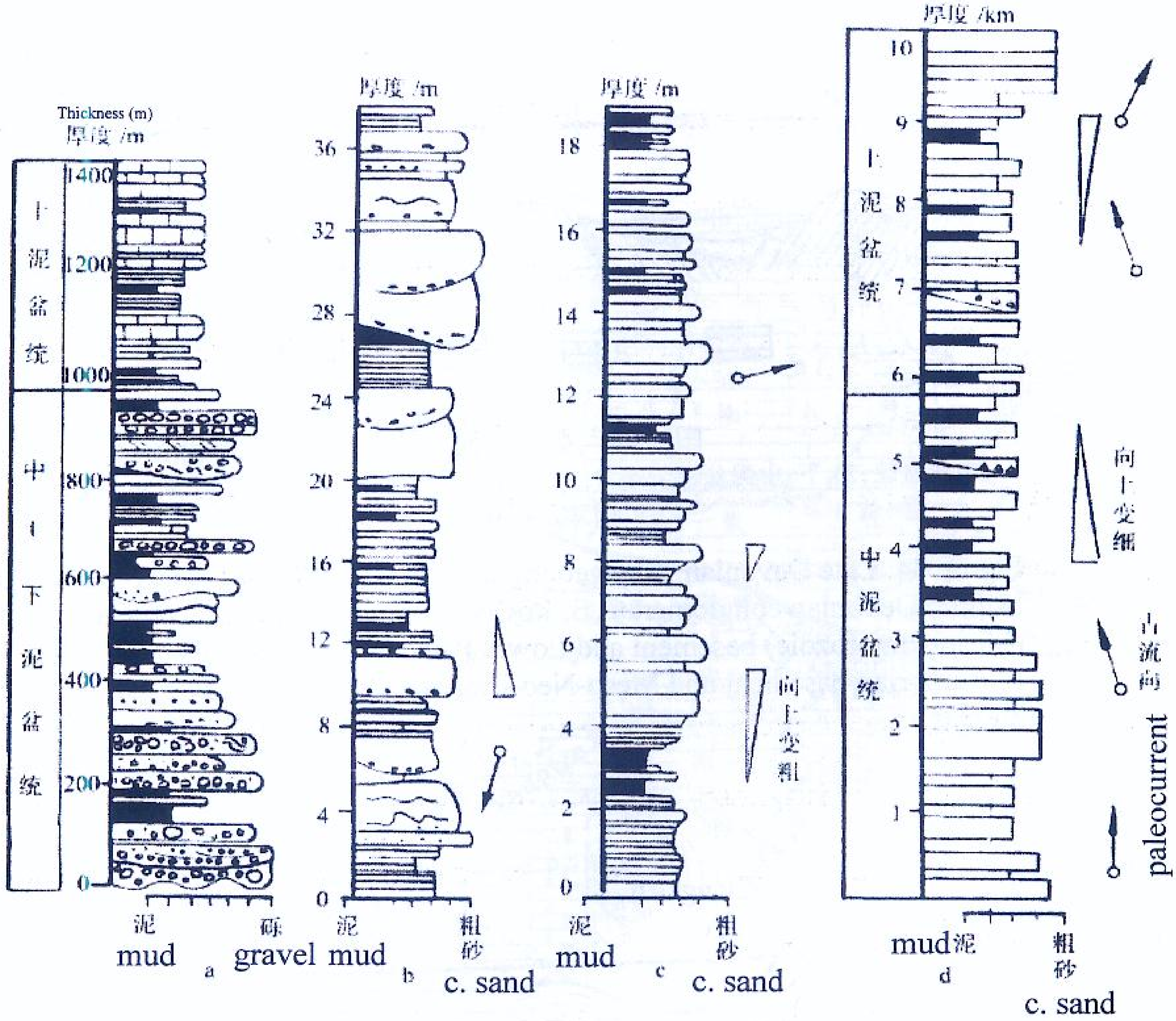

图 4-31　南秦岭泥盆系的沉积序列
（孟庆任，1994）
a. 南带略阳盆地南缘的沉积序列；b. 中带上泥盆统九里坪组浊积体系的水道-天然堤沉积序列；c. 叶状体序列；d. 北带柞水地区中-上泥盆统的沉积序列

Figure 43. Devonian sedimentary successions in Southern Qinling Structural Belt. a. Southern margin of Lueyang Basin, southern belt. b. Upper Devonian channel-levee succession of turbidite systems, Jiuliping, central belt. c. Succession of lobate systems. d. Middle-Upper Devonian successions, Zhashui, northern belt. From Zhou et al., 2002.

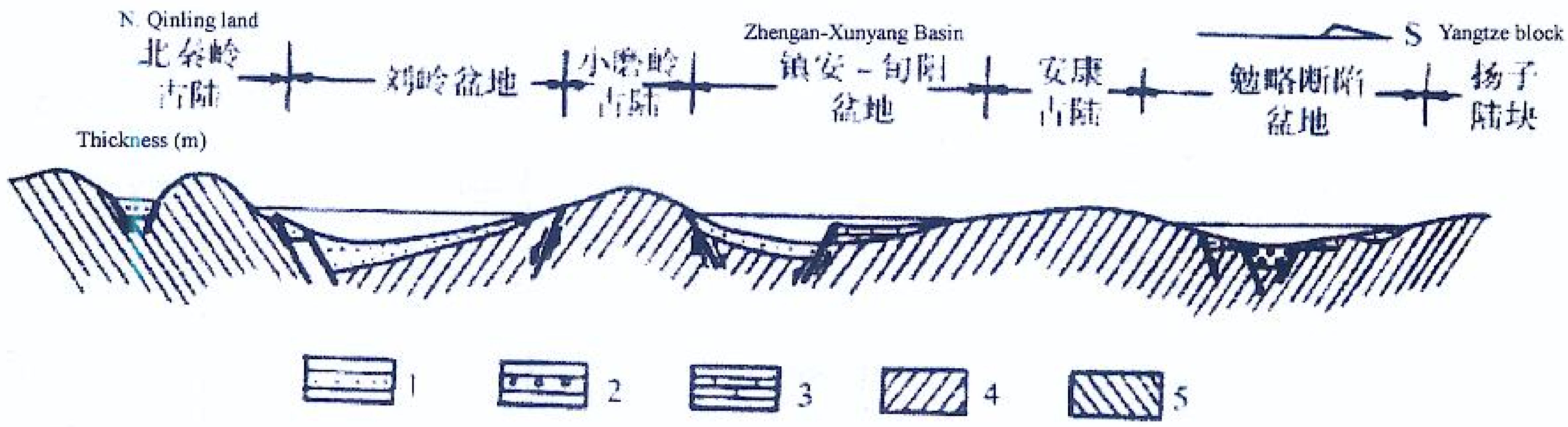

图 4-33 秦岭晚泥盆世古地理格局示意图

1. 中泥盆统;2. 下-中泥盆统杂砾岩;3. 下-中泥盆统碳酸盐岩;4. 晋宁期基底及早古生代盖层;5. 早前寒武纪基底及中晚元古宙盖层

Figure 44. Late Devonian paleogeography, Qinling. 1. Middle Devonian, 2. Lower-Middle Devonian conglomerate, 3. Lower-Middle Devonian carbonate rocks, 4. Jingnian (Meso-Proterozoic) basement and Lower Paleozoic sedimentary cover. 5. Early Precambrian basement and Meso-Neo-Proterozoic sedimentary cover. From Zhou et al., 2002.

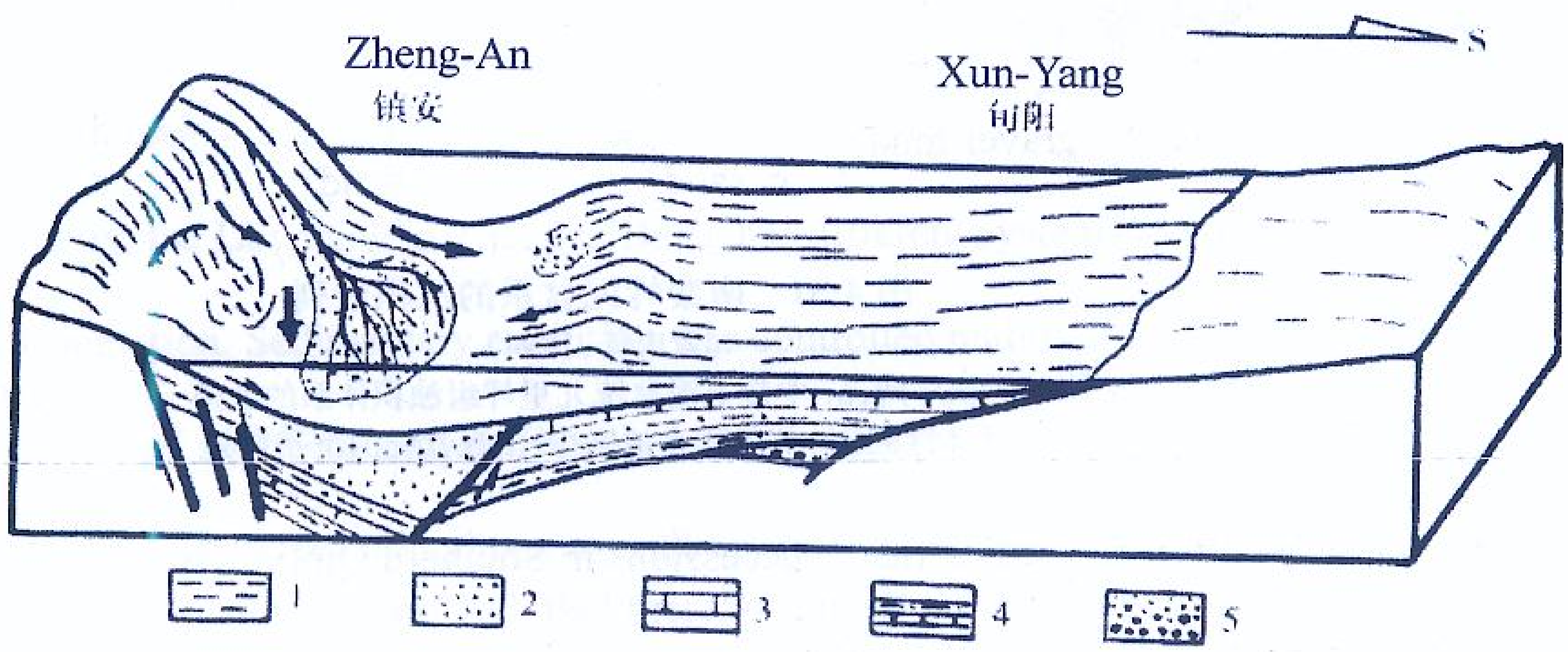

图 4-34 南秦岭中带泥盆纪的沉积作用与构造演化示意图

1.D_3^1 斜坡沉积;2.D_3^1 浊积岩;3.D_3^1 台地碳酸盐岩;4.D_2－D_3^1 混合大陆架沉积;5.D_1 潮缘沉积

Figure 45. Sedimentation and structural evolution during Devonian, central belt of Southern Qinling Structural Belt. 1. D^1_3-slope deposit, 2. D^1_3-turbidite, 3. D^1_3-platform carbonate rocks, 4. D2-D^1_3-mixed shelf deposits, 5. D_1-peritidal deposits. From Zhou et al., 2002.

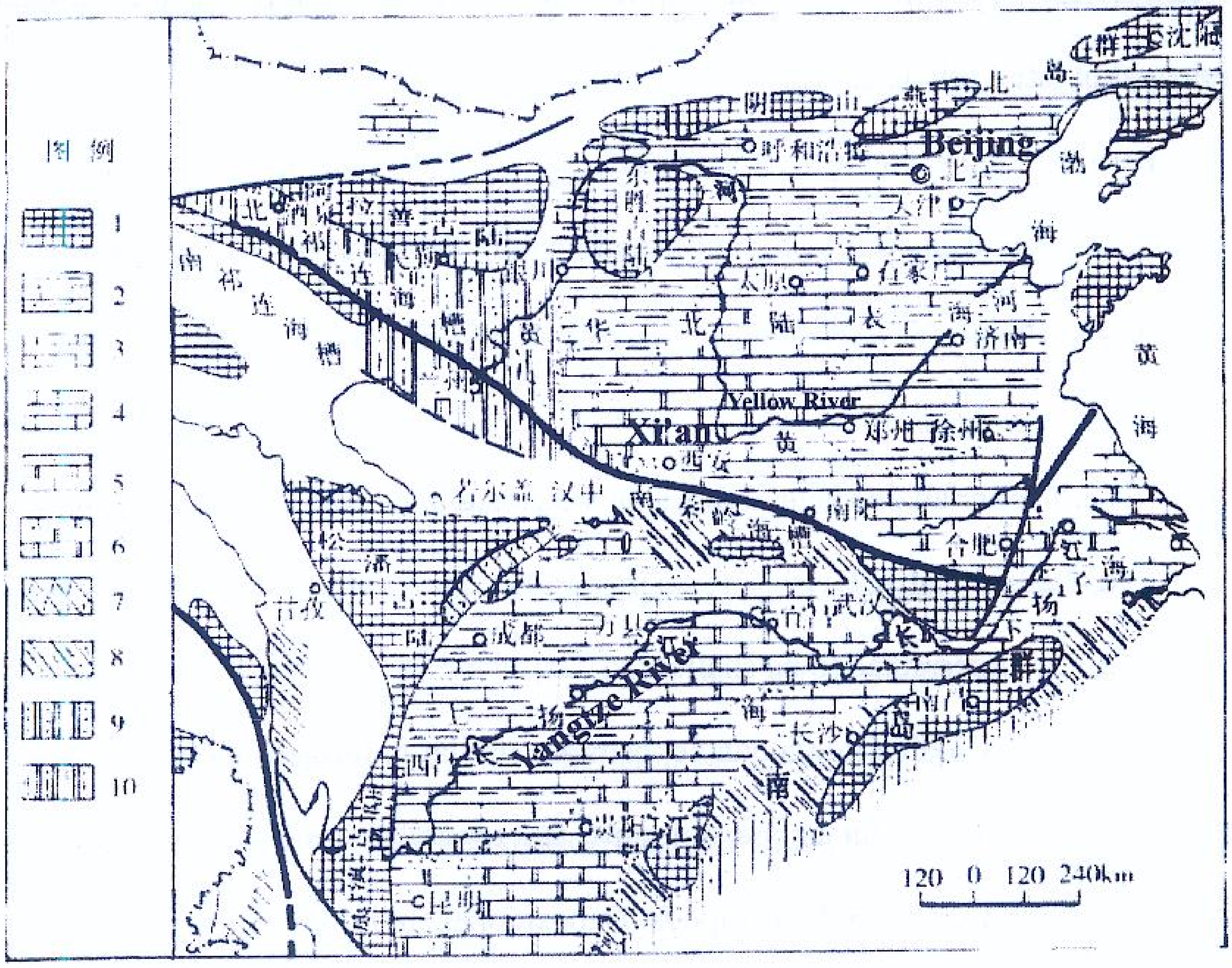

图 4-11　中国中东部中—晚寒武世古地理图

（王鸿祯等修改，1985）

1.古陆;2.滨浅海碳酸盐及粉砂质组合;3.深浅海碳酸盐组合;4.滨浅海含石膏泥质及含镁碳酸盐组合;5.滨浅海含镁碳酸盐及粉砂泥质组合;6.滨浅海含镁碳酸盐组合 ;7.凝灰质碎屑组合;8.半深海泥质及碳酸盐组合;9.半深海泥砂质复理石及类复理石组合;10.半深海含碳酸盐硅质泥砂质组合

Figure 46. Middle-Late Cambrian paleography, east-central China. 1. Land, 2. littoral-shallow marine carbonate rock and siltstone, 3. deep-shallow marine carbonate, 4. littoral-shallow marine gypsum and dolomitic deposits, 5. littoral-shallow marine dolomite and siltstone, 6. littoral to shallow marine dolomite, 7. tuffaceous siliciclastics, 8. slope muddy and carbonate deposits, 9. slope muddy-sandy flysh and para-flysh deposits, 10. slope carbonate-bearing siliciclastic mud and sand deposits. From Zhou et al., 2002.

Cambrian, this area experienced brief erosion and ensuing fast subsidence into relatively deep water, where siliceous rocks were deposited. Afterwards, regression started and water depth decreased. Thus, a shallow-water platform gradually appeared and peritidal environments dominated in late Early Cambrian.

Peritidal environments persisted into Middle Cambrian with a limited shelf environment. Dolomitic limestone and dolomitic algal laminites are the dominant deposits with local purplish red sandstone, shale, and chert nodules. Fenestrae and parallel laminations are common; fossils are rare.

Upper Cambrian deposits in this area are crystalline limestones, which were commonly dolomitized diagenetically. Fossils are mainly planktonic trilobites. The depositional environments are interpreted to be shallow to deep shelf.

Upper and Middle Ordovician deposits are similar to those of the Cambrian, and consist of thick-bedded dolomitic limestone, dolomite, and crystalline limestone with trilobites, cephalopods, brachiopods, and gastropods. Depositional environments are interpreted to be peritidal carbonate. Siliciclastic mud content increases and carbonate decreases to the south, gradually changing to the shallow platform and slope environments.

The Upper Ordovician is limited in its distribution. In the study area, the deposits are sandy mudrocks intercalated with argillaceous limestone, and limestone lentils, and in some cases, dolomitic lime mudstone. Corals are common. The depositional environment is interpreted to be shallow shelf. The area was completely exposed and eroded at the end of Silurian.

Summary

A scientific hypothesis originates from observations that cannot be satisfactorily explained by existing theories; and a scientific theory is being constantly tested by observations. Acute observational skills come from a curious, knowledgeable mind and are sharpened through practice. This is the central message from this field course.

Tectonic movement of the lithosphere is the key control on sedimentation, including deposition, nondeposition, and erosion, metamorphism, and igneous activities. In space, equant stable blocks are separated by linear active belts. In time, rock intervals are separated by unconformities to form tectonic sequences as observed throughout this course.

Interpreting the causes and processes and reconstructing the evolutionary pathways of tectonic, sedimentary, metamorphic, and igneous events and the earth as a whole on the basis of observations is the next more speculative step. This field course demonstrates the power of the plate tectonic theory. It provides a conceptual framework within which lithospheric movements and events can be better explained.

Many questions remain: For example, how complete is the geologic record, and is the Precambrian record less complete than the Phanerozoic record? What are the feedback mechanisms of sedimentation, metamorphism, and igneous activities on tectonics? How does one reconcile the apparent contradiction between the rock cycle and uni-directional and irreversible tectonic evolution (i.e. a fold can not be unfolded), and is the concept of "rock cycle" a fallacy? Will continental growth ever stop and what if it does not? Can the plate tectonic theory explain all observations, even Martian tectonics?

Keep expanding the list of questions and enjoy geology!

CULTURAL AND ARCHAEOLOGICAL STOPS WITHIN THE XIAN AREA (JUNE 16-17, 30; JULY 1)

Brief summaries from various internet sources. See also additional literature on these topics in travel guide books etc.

Lingtong – Terracotta warriors of the Qin Dynasty.

The Terracotta Army (http://en.wikipedia.org/wiki/Terracotta_Army). The Terracotta Warriors and Horses is a collection of 8,099 life-size Chinese terra cotta figures of warriors and horses located near the Mausoleum of the First Qin Emperor Qin Shi Huang. The figures were discovered in 1974 near Xi'an, Shaanxi province, China.

The Terracotta Army was buried with the first Emperor of Qin (Qin Shi Huangdi) in 210-209 BC (his reign over Qin was from 247 BC to 221 BC and over unified China from 221 BC to his death). Their purpose was to help rule another empire with Shi Huangdi in the afterlife. Consequently, they are also sometimes referred to as "Qin's Armies".

The Terracotta Army was discovered in March 1974 by local farmers drilling a water well to the east of Mount Lishan. (The precise coordinates are 34°23'5.71"N, 109°16'23.19"ECoordinates: 34°23'5.71"N, 109°16'23.19"E.) Mount Lishan is also where the material to make the terracotta warriors originated. In addition to the warriors, an entire man made necropolis for the emperor has been excavated

Construction of this mausoleum began in 246 BC and is believed to have taken 700,000 workers and craftsmen 38 years to complete. Qin Shi Huangdi was interred inside the tomb complex upon his death in 210 BC. According to the Grand Historian Sima Qian, the First Emperor was buried alongside great amounts of treasure and objects of craftsmanship, as well as a scale replica of the universe complete with gemmed ceilings representing the cosmos, and flowing mercury representing the great earthly bodies of water. Pearls were also placed on the ceilings in the tomb to represent the stars, planets, etc. Recent scientific work at the site has shown high levels of mercury in the soil of Mount Lishan, tentatively indicating an accurate description of the site's contents by Sima Qian.

The tomb of Qin Shi Huangdi is near an earthen pyramid 76 meters tall and nearly 350 square meters. The tomb presently remains unopened. There are plans to seal off the area around the tomb with a special tent-type structure to prevent corrosion from exposure to outside air. However, there is at present only one company in the world that makes these tents, and their largest model will not cover the site as needed.

Qin Shi Huangdi's necropolis complex was constructed to serve as an imperial compound or palace. It comprises several offices, halls and other structures and is surrounded by a wall with gateway entrances. The remains of the craftsmen working in the tomb may also be found within its confines, as it is believed they were sealed inside alive to keep them from divulging any secrets about its riches or entrance. It was only fitting, therefore, to have this compound protected by the massive terracotta army interred nearby.

The terracotta figures were manufactured both in workshops by government laborers and also by local craftsmen. It is believed they were made in much the same way that terracotta drainage pipes were manufactured at the time. This would make it a factory line style of production, with specific parts manufactured and assembled after being fired as opposed to crafting one solid piece of terracotta and subsequently firing it. After completion, the terracotta figures were placed in the pits outlined above in precise military formation according to rank and duty.

The terracotta figures are life-like and life-sized. They vary in height, uniform and hairstyle in accordance with rank. The colored lacquer finish, molded faces (each is individual), and real weapons and armor used in manufacturing these figures created a realistic appearance. Unfortunately, the weapons were stolen shortly after the creation of the army and the coloring has mostly faded. However, their existence served as a testament to the amount of labor and skill involved in their construction. It is also proof of the incredible amount of power the First Emperor possessed to order such a monumental undertaking as the manufacturing of the Terracotta Soldiers.

There is evidence of a large fire that burned the wooden structures once housing the Terracotta Army. The fire was described by Sima Qian, who described them as the consequences of General Xiang Yu, who raided the tomb less than five years after the death of the First Emperor, as that the effects of General Xiang's army included looting of the tomb and structures holding the Terracotta Army, as well as setting fire to the necropolis and starting a blaze that lasted for three months. Despite this fire, however, much of the remains of the Terracotta Army still survive in various stages of preservation, surrounded by remnants of the burnt wooden structures.

Today nearly two million people visit the site annually, and almost one-fifth is foreigners. The Terracotta Army now serves as both a phenomenal archaeological discovery as well as an icon of China's distant past recognizable the world over. The power and military achievement of the First Emperor Qin Shi Huang is evident in the massive and monumental achievements present throughout his tomb complex, most notably the 8,000+ terracotta figures eternally serving to protect their leader.

In 1999, it was reported that pottery warriors were suffering from "nine different kinds of mold", caused by raised temperatures and humidity in the building which houses the soldiers, and the breath of tourists. In addition, South China Morning Post reported the figures have