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Geology of the Dian-Qian-Gui foldbelt, Southwest China

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ABSTRACT

This report on the geology of the Dian-Qian-Gui foldbelt, Southwest China, is based on sparsely available literature. The region is confined generally in latitudes 23°50' N to 25°00' N and longitudes 103°30' E to 107°00' E and covers the border areas of southeastern and eastern Yunnan, western and south-central Guizhou, and western Guangxi Provinces. The Nanpanjiang depression and the Baishai (Baise) basin are known to contain oil and gas deposits and are located in the central part and the southeastern part of the study region, respectively.

This foldbelt is one of the integral tectonic units of the South China fold system and borders the southern margin of the Yangzi (Yangtze) (Chang Jiang) paraplatform, which was formed during the Upper Proterozoic Yangzian (Yangtzeian) orogeny. By the end of the Caledonian orogeny, the South China fold system was well established.

In the study region, the initial depositional framework of Middle and Upper Proterozoic marine and continental sedimentary sequences was formed during the Lower Proterozoic Zhongtiaoian (Chungtiaoian) orogeny. Throughout most of the region, the Lower Paleozoic sedimentary sequences are incompletely preserved, but the stratigraphic record shows that the Upper Paleozoic marine platform deposits were well developed and extensive. These strata have been chosen to represent the type sections for South China from the Devonian through the Permian systems. In Lower Mesozoic time, the widespread Tethys Sea covered most of South China, and it retreated from this region during the Upper Triassic. In the southern part of the study region, Tertiary sea transgressions are recorded locally.

Coal deposits occur chiefly in the Lower Carboniferous, Lower and Upper Permian, and Upper Triassic sedimentary sequences. Locally, coal beds are mined.

Oil and gas deposits occur in the Upper Paleozoic and Lower Mesozoic carbonate and shale facies of shoreline and shallow shelf environments in the northeasterly-trending Nanpanjiang depression. Oil and gas deposits also occur in the Lower Tertiary detrital facies in the northwesterly-trending Baishai basin. The initial depositional framework of both the Nanpanjiang depression and the Baishai basin were formed during the Caledonian orogeny and were expanded, especially the Nanpanjiang depression, during the Variscan and Indosinian orogenies; later the Baishai was greatly expanded by rejuvenated faulting along the basin border during the Lower Tertiary Yanshanian (Yenshanian) orogeny. Subsequently, the Nanpanjiang depression was filled with very thick marine sequences of Devonian, Carboniferous, Permian, and Triassic reef and shale facies, in which the bioherms and carbonaceous shale are the favorable source rocks. The Baishai basin, however, was filled with thin marine sequences of Upper Paleozoic carbonate and shale facies, and thick continental and marine sequences of the Lower Tertiary fine detrital facies, in which the Lower Tertiary carbonaceous clayey detritus is considered to be the source rocks. In this study region, dome and syncline structures, and carbonate platform margins and algal banks, are believed to be generally favorable for oil and gas prospecting.

INTRODUCTION

General Statement

The Dian-Qian-Gui foldbelt, Southwest China, is confined within the borderlands of southeastern and eastern Yunnan, western and south-central Guizhou, and western Guangxi Provinces (figs. 1 and 2). Most of the region is located in the southeastern portion of the Yun-Gui plateau. The principal areas covered in this report are the Nanpanjiang depression in the central part and the Baishai basin in the southeastern part of the region. (figs. 1a and 2). Generally, Upper Paleozoic and Lower Mesozoic bioherms are well developed throughout the study region and have been considered probably to be the source beds for petroliferous deposits.

The study region is drained by the Nanpanjiang stream and Beipanjiang stream in the north and the Hongshuihe and Youjiang streams in the south. These streams are part of the upper-reach tributary streams of the Xijiang River, which, in turn, is one of the three principal tributaries of the Zhujiang (Pearl River) in Guandong Province. The climate ranges from moist temperate in the plateau uplands to subtropic in the dissected lowlands.

Regional Setting

The study region is generally limited by latitudes 22°50' N to 25°00' N and by longitudes 103°30' E to 107°00' E. It covers about 60,000 square kilometers. This region is chiefly situated in the western part of the Dian-Qian-Gui-Xiang foldbelt, which is one of the integral tectonic units of the South China fold system (Huang and others, 1980). The northern part of the study region, however, covers part of the southern Yangzi (Yangtze) (Chang Jiang) paraplatform. Throughout the region, the Upper Paleozoic and Lower Mesozoic sedimentary sequences are well developed, as compared with similar stratigraphic sequences elsewhere throughout China (fig. 2).

The principal topographic feature is the Yunnan-Guizhou plateau, which meets the western extension of Nanling Range in the east and the western Guangxi dissected lowlands in the south. The altitude of the plateau generally ranges from 1,800 to 2,500 m, and, locally, this plateau contains remarkable karst features.

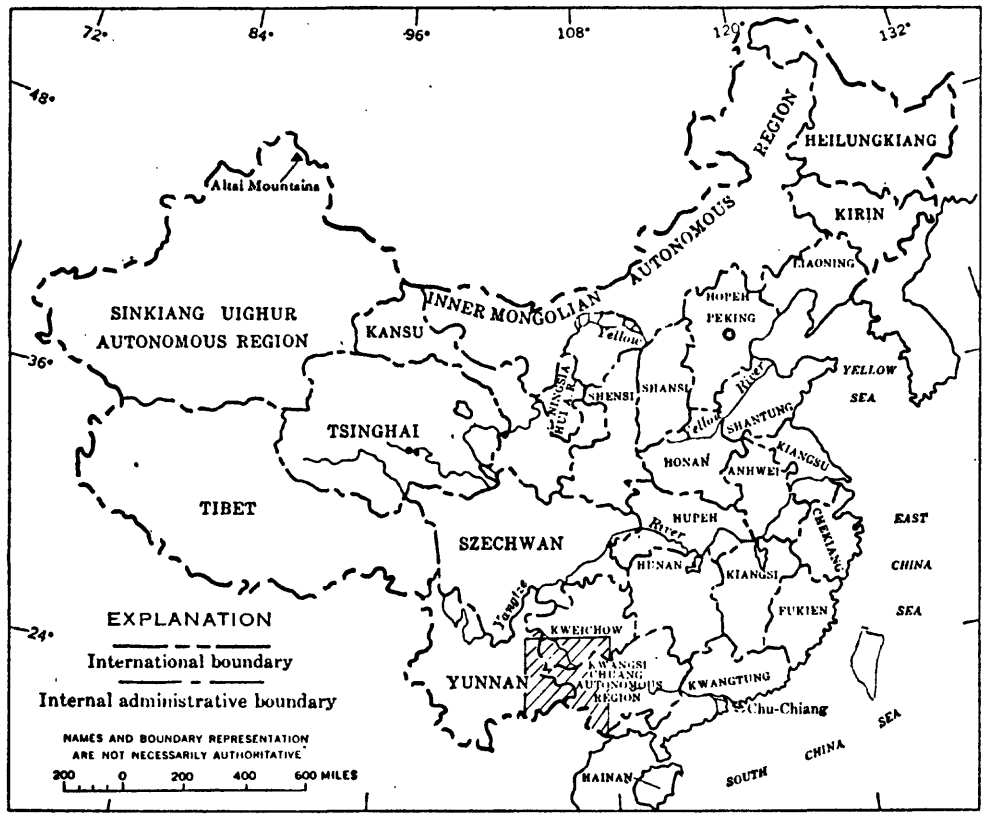

Figure 1. Index map of China showing location of the area of report (provincial names are in the Wade - Giles spelling; adopted and modified after K.Y. Lee, 1970; U.S. Geological Survey Bulletin 1312 - N, Figure 1, p. N2).

Area of the report

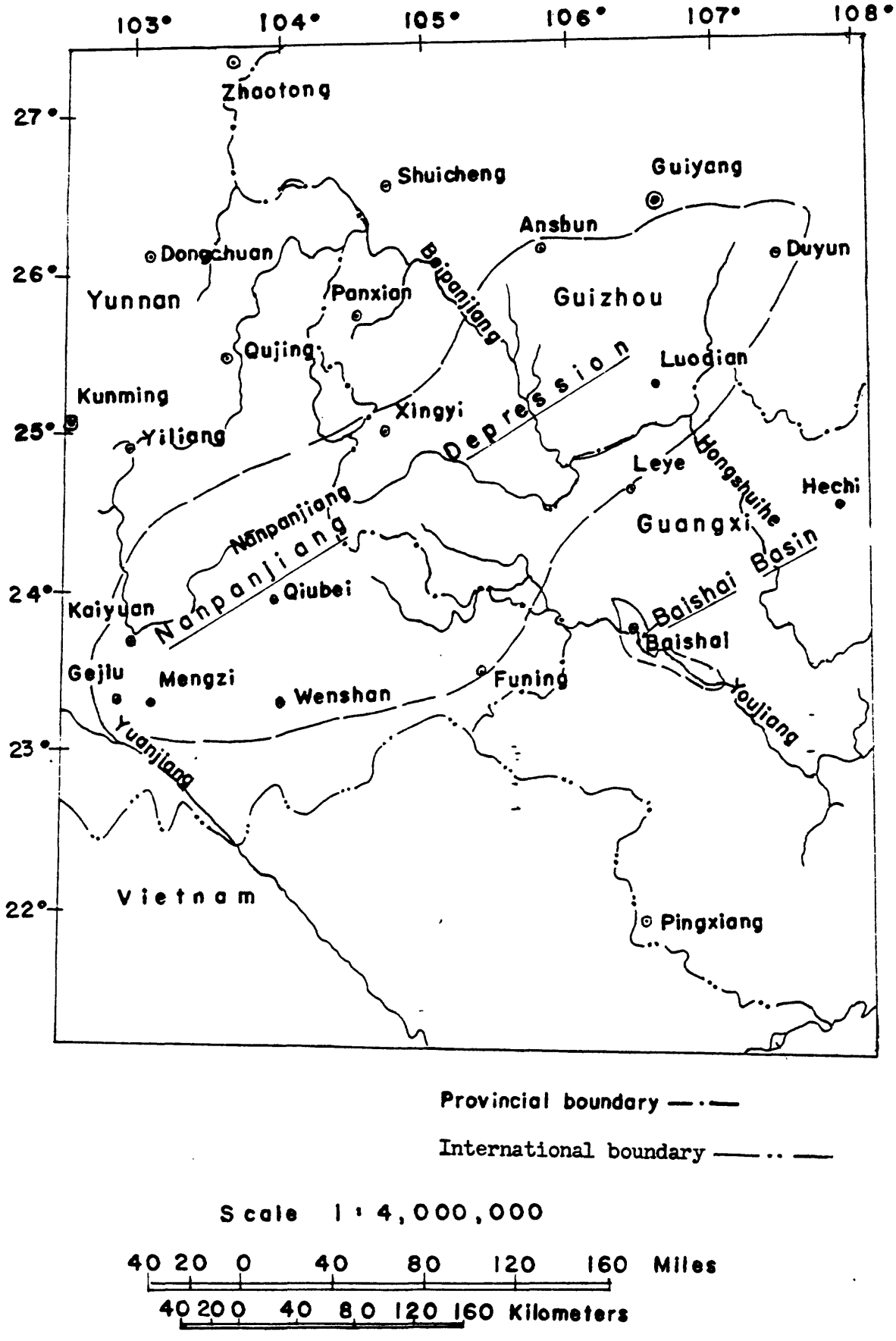

Figure 1a.--Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location of Nanpanjiang depression and Baishai Basin.

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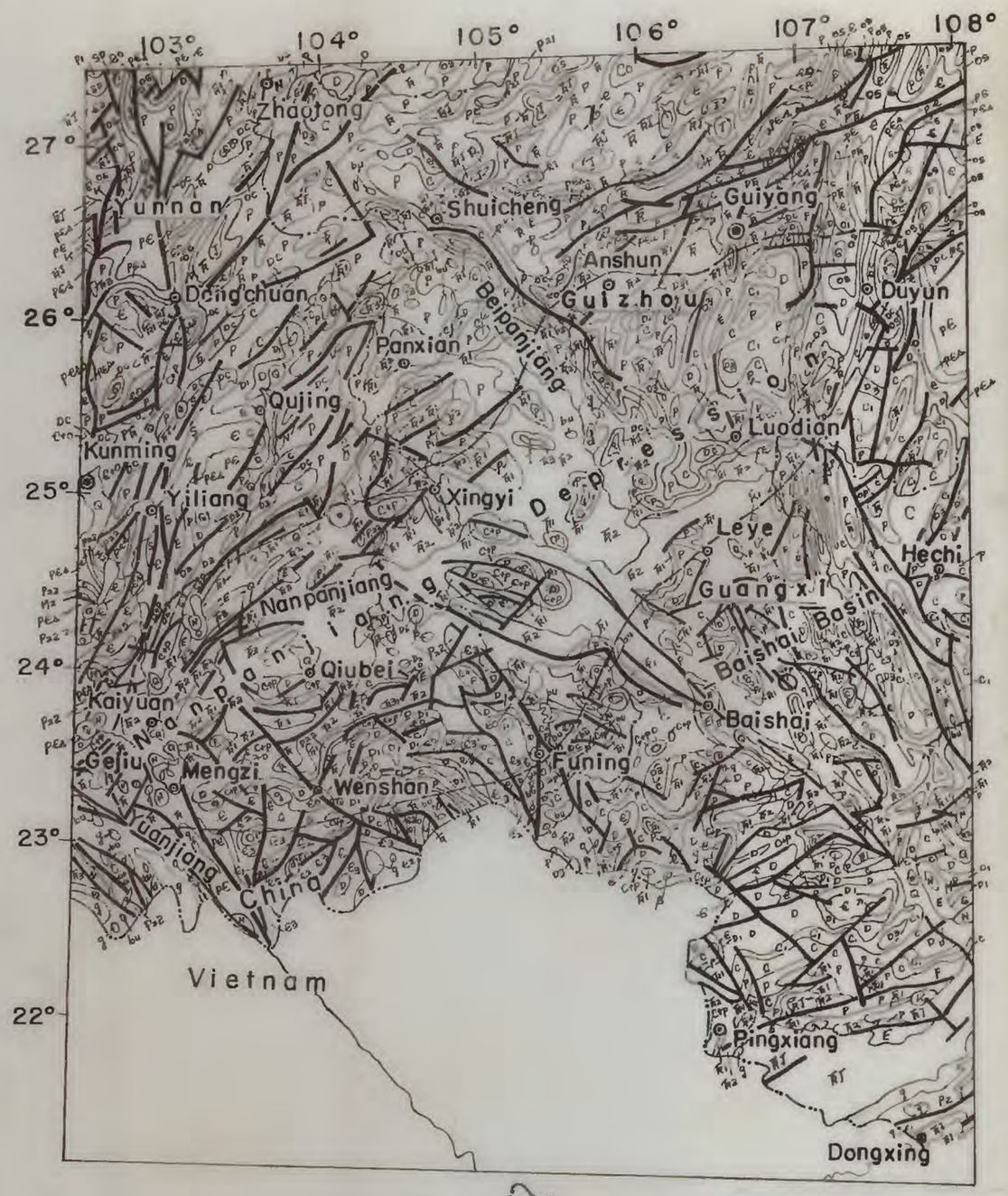

Scale 1 : 4,000,000

40 20 0 40 80 120 160 Miles

40 20 0 40 80 120 160 Kilometers

Figure 2. Generalized geologic map of the Dian-Qian-Gui foldbelt, Southwest China (adopted after the Chinese Academy of Geological Sciences, 1976, Geologic Map of the People's Republic of China; 1 : 4,000,000)

EXPLANATION

Quaternary

- Q — Alluvium

Tertiary

- N — Neogene (Upper Tertiary)
- E — Eogene (Lower Tertiary)

Cretaceous

- K — Undifferentiated Cretaceous rock.

Jurassic

- J — Undifferentiated Jurassic rock.
- TrJ — Undifferentiated Triassic and Jurassic rocks.

Triassic

- Tr 3 — Upper Triassic
- Tr 2 — Middle Triassic
- Tr 1 — Lower Triassic
- Tr — Undifferentiated Triassic rock.

Permian

- Mz — Undifferentiated Mesozoic rocks.
- PTr — Undifferentiated Permian and Triassic rocks.
- P2 — Upper Permian
- P1 — Lower Permian
- P — Undifferentiated Permian rock.

Carboniferous

- C+P — Undifferentiated Carboniferous and Permian rocks.
- C 3 — Upper Carboniferous
- C 1 — Lower Carboniferous
- C — Undifferentiated Carboniferous rock.

Devonian

- DC — Undifferentiated Devonian and Carboniferous rocks.
- D 3 — Upper Devonian
- D 2 — Middle Devonian
- D 1 — Lower Devonian
- D — Undifferentiated Devonian rock.

Silurian

- SD — Undifferentiated Silurian and Devonian rocks.
- S — Undifferentiated Silurian rock.

Ordovician

- OS — Undifferentiated Ordovician and Silurian rocks.
- O 1 — Lower Ordovician
- O — Undifferentiated Ordovician rock.
- €O — Undifferentiated Cambrian and Ordovician rocks.

Cambrian

- €3 — Upper Cambrian
- €2 — Middle Cambrian
- €1 — Lower Cambrian
- € — Undifferentiated Cambrian rock.

Precambrian

- Pz 2 — Undifferentiated Upper Paleozoic rocks.
- Pz 1 — Undifferentiated Lower Paleozoic rocks.
- P€s — Undifferentiated Sinian rocks.
- P€ — Undifferentiated Precambrian rocks.

Igneous Rocks

- g — Granite
- d — Diorite
- bu — Basic and ultrabasic rocks.
- λ — Rhyolitic flows
- β — Basalitic flows
- Outline of depression
- Faults
- Deep hole
- Details unknown

Purpose, method, and scope of the report.

The primary purpose of this report is to provide a digest of available literature on the geology of energy-mineral deposits in the Dian-Qian-Gui foldbelt to aid geologists of the U.S. Geological Survey who participate in the study of coal, petroleum, and natural gas deposits throughout this region. Most of the geologic information is synthesized from individual published reports, and bedrock geology is generally available to ascertain general processes of sedimentation in the sedimentary sequences. In particular areas, detailed information on basic geology is not available, such as in the Nanpanjiang depression and the Baishai basin.

This report covers one of the target project areas in the U.S.-People's Republic of China technical exchange agreement. No attempt is made to estimate the mineral resources of the region. Throughout the illustrations, index maps are given to indicate the approximate location of local names and areal coverage of individual figures. The Chinese Pinyin system is used for transliterating Chinese names, which are followed in some case by the Wade-Giles system in parentheses for better understanding of cited references.

STRATIGRAPHY

The stratigraphy of the Dian-Qian-Gui foldbelt consists of a sequence of marine and continental Proterozoic, Paleozoic, Mesozoic, and Cenozoic sedimentary rocks; Proterozoic metamorphic rocks; and Paleozoic and Mesozoic intrusive rocks (Chinese Academy of Geologic Sciences, 1973, p. 92-96, p. 135-139, p. 139-144, and p. 197). Generally, the marine sequences of the Devonian, Carboniferous, Permian, and Triassic sedimentary rocks are extensively distributed and exposed throughout the region (fig. 2). The discussion of stratigraphy proceeds in accord with the regional distribution, which includes southeastern and eastern Yunnan province, western and south-central Guizhou Province, and western Guangxi Province (table 1; for location of provinces see fig. 1).

Precambrian-Proterozoic

During most of Precambrian time, the Dian-Qian-Gui foldbelt was emergent. The deposition of Middle and Upper Proterozoic detrital and carbonate rocks has been recorded throughout this region (figs 3 and 4; table 1) (Institute of Geology, Academia Sinica, 1956 and 1958) (Chinese Academy of Geological Sciences, 1973).

Proterozoic

The Proterozoic rocks of this region are of Middle and Upper Proterozoic age (table 1).

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Table 1. Stratigraphic correlation of the Dian-Qian-Gui foldbelt, Southwest China

(after Institute of Geology, Academia Sinica, 1956 and 1958; Chinese Academy of Geological Sciences, 1973 and 1979; and Wang and Liu, 1980)

Era	System	Series	Southeastern Yunnan	Eastern Yunnan	Western Guizhou	South-central Guizhou	Western Guangxi
CENOZOIC	Quaternary	Holocene	Alluvium Residual detritus	Alluvium Residual detritus	Alluvium Residual detritus	Alluvium [illegible].	Alluvium Residual detritus [illegible] deposits
		Pleistocene	Red clay Maru beds, clay, sand & gravel. 1-20 m.	Lacustrine deposits Travertine cavern deposits, ls-breccia & clay. Red clay.	Glacial-fluvial deposits, clay, sand & gravel.	[illegible] gravel. 2 m. Glacial till	Glacial-fluvial deposits. 3-12 m. Till Cavern accumulation
	Tertiary	Upper Tertiary	Xinglongzhai Fm, clay, congl & ss. 7-12 m. Buzhaoba Fm, ss, congl & sh. 60-300 m.	Ciyang Fm, ml, clay, sand, gravel, & lignite. 90-165 m.			[illegible] Series, ml, clay, siderite & oil sand, Clay, siderite, Ml, clay & lignite. 1,000 m.
		Lower Tertiary		Caijiachong Fm, ml, ls, & siltstone. 200 m. Lunan Fm, ss, ml, & ls. 350 m.	New Red Beds Series ls & congl. 10 m.	New Red Beds Series, sh, ss & congl. 160 m.	Yongle Series, Red Beds, oil-sh & coal (Gongkang Fm Baise Basin (Nadu Fm (Dongjun Fm (Lingma Fm
MESOZOIC	Cretaceous				Old Red Beds Series(?), ss & sh. 200 m.	Old Red Beds Series, sh, ls., clay & ss. 200-600 m.	[illegible] Series, sh, ss & congl. 1,000-1,300 m. Volcanic Rock Series, basaltic flow, ss and breccia. 300-900 m.
	Jurassic	Lower Jurassic		Shimen Series, ss & sh. 100-300 m. Lufeng Series, mudstone, sh, siltstone & ss. 1,000 m.	Xiangxi Series, ss, sh & coal. 40-600 m.	Xiangxi Series, ss & sh. 300-400 m.	
	Triassic	Upper Triassic	[illegible] Fm ([illegible] Fm), ss, sh, & coal. 250-700 m. Dingdong Fm (Jiaodingshan Ls), sh, & ls. 250-300 m.	Palongao Fm (Huobachong Fm), ss, sh, & coal. 300-700 m. Dingdong Fm (Gaomiao Ls), ls, sh & ss. 400 m.	Erqiao Fm, ss, sh & mudstone. 300 m. Huobachong Fm, sh, ss, & coal. 700 m. Bannan Fm, sh, ml & minor coal. 400 m.	Palongao Fm. 40-700 m. Pingdong Fm. 300 m.	Silo Series, sh, ss, & coal. 1,000 m+
		Middle Triassic	Falang Fm, ls, sh & ss. 200 m. Guanling Fm, ls & dol-ls. 800-1,000 m.	Gejiu Fm (Falang Fm), ls & ml. 50-200 m. Hongyi Fm (Guanling Fm), ls, dol & sh. 20-170 m.	Falang Fm, ls, sh & ss. 1,000 m. Guanling Fm, ls & sh. 700-1,600 m.	Qingyan Fm (Undiff. Falang & Guanling Fms), ls & sh. 610 m.	Pingerguan Series, sh, ss & ls. 510-800 m.
		Lower Triassic	Red Beds Series, sh, ml & ls. 100-200 m.	Yelang Series, sh, ss & ls. 150-400 m.	Yelang Series: Yongningzhen Fm, sh, ml & ls. 900 m. Feixianguan Fm, ss, sh & ml. 200-800 m	Yelang Series: Yulongshan Ls. 160-500 m. Shabaowan sh. 10-35 m.	Luolou Fm, ss, sh, ls & ml. 800 m.
PALEOZOIC	Permian	Upper Permian	Loping Series, ls. Coal Series	Loping Series, ls. 50-250 m. Emeishan basalte 9-1,000 m.	Dalong Fm, sh & ls. 2-60 m. Changxing Ls. 30-100 m. Longtan Fm, sh, ss, ls & coal. 10-400 m.	Loping Series: Dalong Fm. 35 m. Changxing Ls, ls & coal 50-120 m. Longtan Fm, sh, ss, ls & coal. 560 m.	Dalong Fm. 15 m. Heshan Fm. 60-200 m.
		Lower Permian	Yangxin Series, ls & basal congl. 100 m.	Maokou Ls. 150-400 m. Qixia Ls. 50-300 m.	Maokou Ls. 200-600 m. Qixia Ls. 650 m. Coal-bearing Fm. 2-180 m.	Yangxin Series: Maokou Ls. 40-250 m. Qixia Ls. 120 500 m. Coal-bearing Fm. 50 m.	Maokou Ls. 250-900 m. Qixia Ls. 150-200 m.
	Carboniferous	Upper Carboniferous	Hutian Series: Maping Ls, ls, sh & coal. 300 m.	Hutian Series: Maping Ls, ls, sh & coal. 10-100 m. Weining Group, 30-300 m.	Hutian Section: Maping Ls, ls, sh & coal. 40-600 m. Weining Group. 900 m.	Hutian Series: Maping Ls. 30 m. Longmenzhai Ls. 15-400(?) m.	Hutian Series: Maping Ls. 230-300 m. Huanglong Ls. 150 m.
		Lower Carboniferous	Fengninian Series: Weixian Fm, ls, sh, & ss. 500 m. Dusai Fm, ls.	Fengninian Series: "Upper Ls", ls, chert, ml & sh. 8 m. Shangsi-Jiusi Fm, sh, ls & ss with coal. 23-35 m. Baizuo Fm, ls, sh & breccia. 20-400 m	Fengninian Section: Weining Ls, ls, chert, ml & sh. 200-600 m. Fengning Ls, ls, sh & coal. 100-350 m.	Fengninian Series: [illegible] Ls. 15-400 m. Shangsi Fm, ls, sh & ss with coal. 300-450 m. Jiusi Fm, ls, sh, ss & coal. 10-300 m. Tangbagou Fm, sh, ss, ls & coal. 100 m. Gelaohe Fm, ls, dol & sh. 300 m.	Fengninian Series: Xinshoujie Ls. 30 m. Luocun Fm, sh & ls. 200 m.
	Devonian	Upper Devonian	Yidade Fm, ls, ml & sh. 350(?) m.	Yidade Fm, ls & sh. 30-350 m.	Yidade Fm, ls, ml & sh. 350(?) m.	[illegible] Series: Yaosuo Ls, ls & sh. 140-340 m. Wangchengpo Fm, ls, sh & ss. 100-230 m.	Shiti Ls. 150-200 m. Bailuo Fm (Guilin Ls), ls & sh. 200(?) m.
		Middle Devonian	Ls and sh. 400 m.	Gujing Fm, ls, sh & ss. 150-550 m. Pozi Fm, ls, chert, sh & breccia. 00-270 m. Longhuashan Fm, ss, sh & ls. 60-200 m.	Ml, ls, dol, & sh.	Dushan Series: Jiwozai Ls. 100-200 m. Songjiaqiao Ss. 150 m. Jipao Ls. 40-200 m. Bangzai Ss. 350 m.	Donggangling Ls, ls & sh. 400 m. Chabo Fm, ss, sh & ls. 100-150 m. Tangchongjiang Fm, sh, ls & chert. 250 m. Wuzhishan Fm, ls & chert. 55 m. Luohuotai Fm, ls, chert & sh. 87 m. Najiao Ls, ls, ml & sh. 250 m.
		Lower Devonian	Pojao sh. 100 m. (exposed thickness)	Cuifengshan Group	Ss and sh. (thinning to the east)	Sh, ss, ls & basal congl. 5-90 m.	Yipai sh, sh & ls. 300 m. Lianhuashan Fm, ss & sh. 100 m.
	Silurian	Upper Silurian		Yulongsi Fm, sh, ml & siltstone. 390 m. Miaogaoshan Fm, sh & ml. 700 m.	[illegible] Group, ss, sh & ls.	[illegible] Group, sh & ss. 400(?) m.	
		Middle Silurian		Guandi Fm, sh & ls. 120 m.	[illegible] Group, ss, sh & ls.	[illegible] Group, sh, ss & ls. 300-700 m.	
		Lower Silurian					
	Ordovician	Upper Ordovician					
		Middle Ordovician	Sh, ss & ls. 150-300 m.			Aijiashan Series: Baota Ls. 20-50 m. Yangzibei Fm, ls & sh. 120-170 m.	
		Lower Ordovician	Sh, ml, ls & ss. 160-1,000 m.	Hongshiya Series, sh & ss. 50-480 m.		[illegible] Series, sh, ls, ml & ss. 160-340 m.	
	Cambrian	Upper Cambrian			Dolomite	Loushanguan Ls, dol, dol-ls & sh. 250-500 m.	Sh, dol, ls & ml.
		Middle Cambrian	Tianlimo Fm and Longha Fm undifferentiated.	Shuanglongtan Fm, ls, dol & sh. 135-400 m. Douposi Fm, ls, sh & basal ss. 70 m.			
		Lower Cambrian	Ls, dol-ls, sh & ss.	Longwangmiao Fm, 120-130 m. Canglangpu Fm, sh & ss. 130-280 m. Qiongzhusi Fm, sh. 50-300 m. Meishucun Fm, sh & ss. 10-30 m.	Dolomite	Jindingshan Fm, ls & sh. 201 m. Mingxinsi Fm, sh & ls. 300 m. Niutitang Sh, sh & ss. 35-80 m.	Ls & dol.
PROTEROZOIC	Upper Proterozoic	Upper Sinian	Dengying Ls.	Dengying Ls, ls & sh. 600-900 m.	Dengying Ls. Doushantou Fm, ss. 450 m.	Dengying Ls. 100-600 m.	Doushantou Fm, ls, dol-ls, stone-coal.
		Lower Sinian	Chengjiang Series, sh, ss & congl.	Chengjiang Series, sh, ss & congl. 250-2,300 m.	Nantuo Fm, ss & tillite. 300 m.	[illegible] Series, sh & ss. 100-500 m.	Nantou Fm Fulu Fm Changan Fm 400 m.
	Middle Proterozoic		Kunyang System (Longshan System), phyllite, slate, quartzose, schist, ss & ls. 2,000-10,000 m.	Kunyang System, slate, phyllite, ls, schist & quartzose. 3,000-10,000 m.	Kunyang System, slate, phyllite, ls, quartzose & schist. 3,000-10,000 m.	Banxi Group, phyllite, slate, schist, ls & quartzose. 20,000 m.	Banxi Group, phyllite, slate, schist, ls & quartzose. 410 m.

Fm, formation; congl, conglomerate; dol-ls, dolomitic limestone; ls, limestone; sh, shale; ss, sandstone; dol, dolomite; ml, marl.

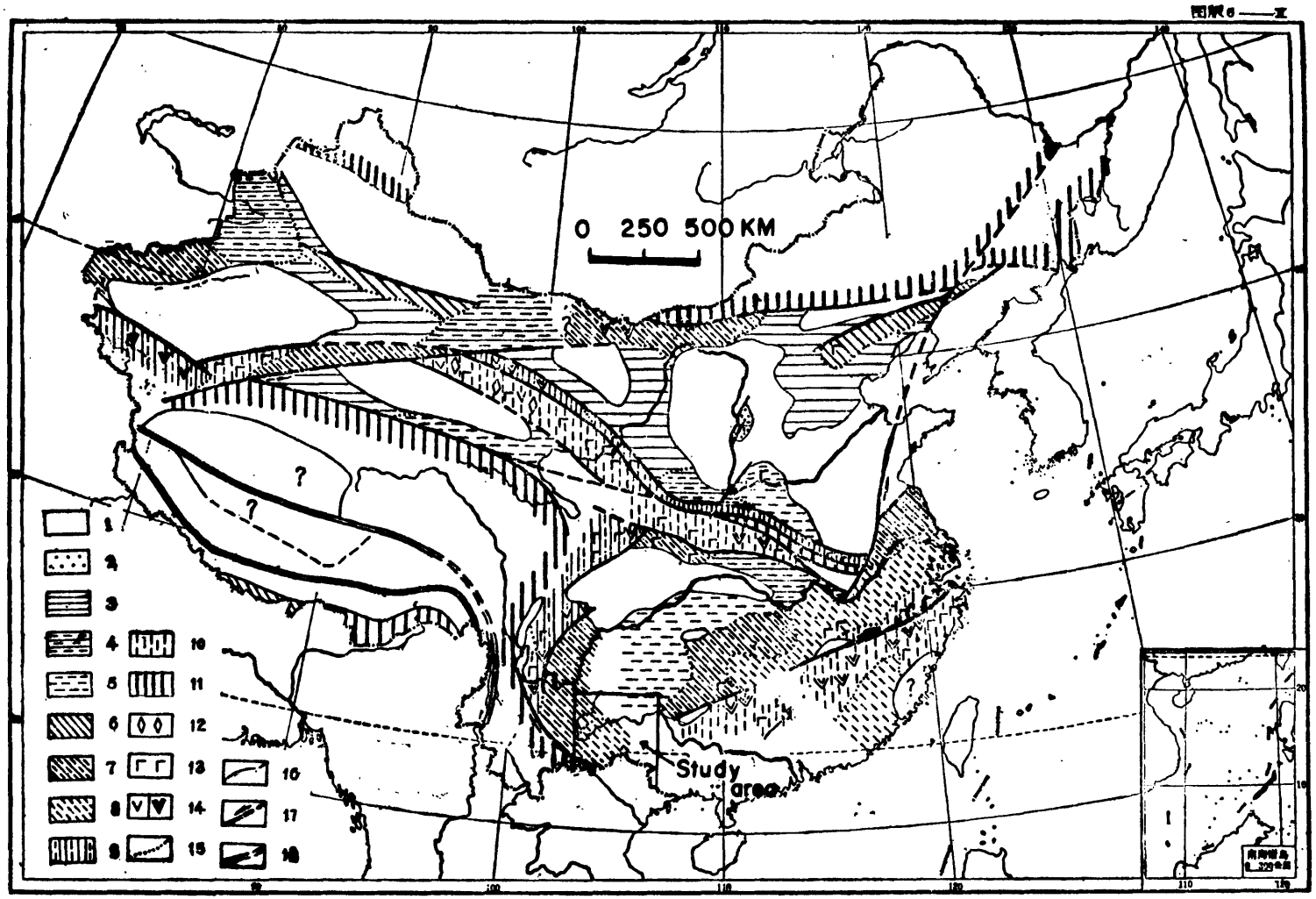


Figure 3.--Middle Proterozoic (1,800-1,000 m.y.) - Paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 6-II).

1. Area of denuded old landmass.
2. Principally continental deposits.

3-5. Marine stable types.

3. Chiefly carbonates.
4. Carbonates and clastics.
5. Mainly argillaceous deposits.

6-8. Marine transitional types.

6. Mainly carbonates.
7. Mainly calcareous and argillaceous deposits.
8. Clastic and argillaceous paraflysch deposits.

9-11. Marine mobile types.

9. Chiefly calcareous-argillaceous deposits.
10. Flysch deposits of clastic-argillaceous rocks.
11. Undifferentiated metamorphics.

12. Evaporites.
13. Intermediate to intermediate-basic volcanic rocks.
14. Left, basic volcanic rock; right, spilite.
15. Boundary of sedimentation types.
16. Boundary of areas of sedimentation as well as the marine-continental demarcation.
17. Boundary faults and later transcurrent faults.
18. Earth's crust suture zone.

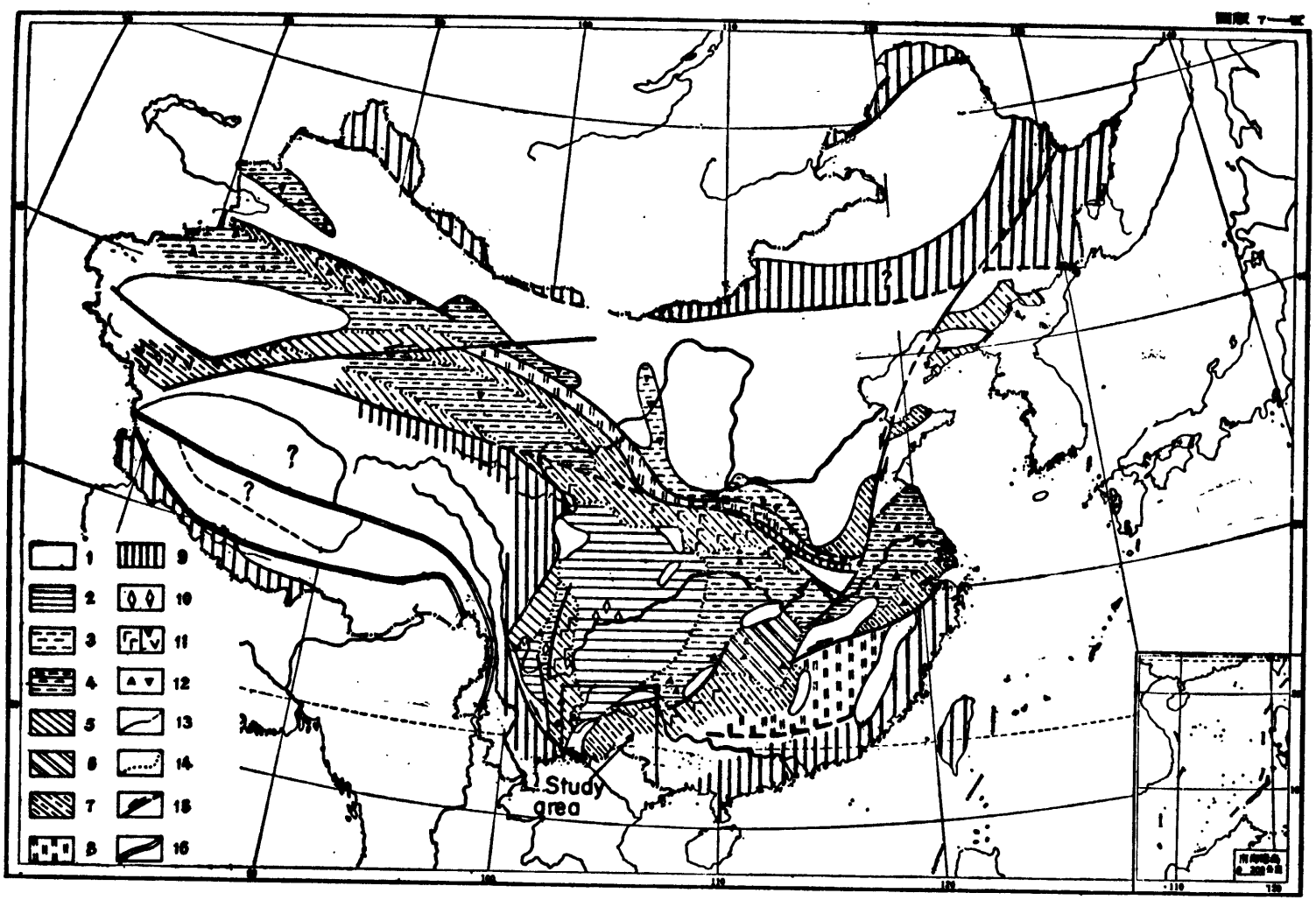


Figure 4.--Sinian paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 7-II).

1. Area of denuded old landmass.

2-4. Marine stable types.

2. Chiefly coastal and shallow-sea carbonates.
3. Chiefly coastal and shallow-sea argillaceous deposits.
4. Clastic deposits and carbonate deposits.

5-7. Marine transitional types.

5. Chiefly shallow-sea to semi-deep sea carbonate deposits.
6. Chiefly semi-deep sea arenaceous deposits.
7. Shallow-sea sandy argillaceous and calcareous-argillaceous deposits.

8-9. Marine mobile types.

8. Volcanic materials-bearing deposits.
9. Undifferentiated metamorphics.

10. Evaporites.
11. Left, intermediate-basic volcanic rock; right, spilite.
12. Tillite, left, Lower Series; right, Upper Series
13. Boundary of sea and land, as well as areas of deposition.
14. Boundary of sedimentation types.
15. Boundary fault and late transcurrent fault.
16. Earth's crust suture zone.

Middle Proterozoic

The Middle Proterozoic rocks are represented by the Kunyang System in southeastern and eastern Yunnan and western Guizhou, and by the Banxi Group in south-central Guizhou and western Guangxi.

In southeastern Yunnan, the Kunyang System consists of phyllite, slate, quartzite, schist, and red sandstone, which are intercalated with limestone lenses. It is well exposed in the valley of Yuanjiang. Thickness ranges from 2,000 to 10,000 m.

In eastern Yunnan and western Guizhou, the Kunyang System is made up of slate, phyllite, and marble. These rocks commonly contain a small amount of quartzite, sandstone, shale, mudstone, and locally cherty limestone, as well as limestone breccia. Within these rocks, there are well developed slaty cleavages, small-scale chevron folds, and quartz-filled fractures. Iron and copper sulfide mineral deposits, as well as banded iron ore, occur locally. Thickness ranges from 3,000 to 10,000 m.

In south-central Guizhou, the Banxi Group consists of neritic marine detrital metamorphosed rocks and submarine spilite-porphyry. Thickness is up to 20,000 m (Chinese Academy of Geological Sciences, 1973, p. 135).

In western Guangxi, the Banxi Group consists of gray shale, phyllite, and micaceous sandstone. It is about 410 m thick.

Upper Proterozoic

The Sinian System represents the Upper Proterozoic stratigraphic unit throughout the study region. This system represents the Upper Precambrian exposures of tillite, sandstone, shale, and limestone along the Yangzi (Chang Jiang) Gorge in western Hubei province. The radiometric age ranges from 800 ± 50 m.y. to 615 ± 20 m.y. (Chinese Academy of Geological Sciences, 1979, p. 41). It is, however, subdivided into the lower and upper stratigraphic units for discussion (table 1).

Lower Sinian

The Lower Sinian is represented by the Chengjiang Series in southeastern and eastern Yunnan, the Nantou Formation in western Guizhou, the Shijikou Series in south-central Guizhou, and the Changan, Fulu, and Nantou Formations in western Guangxi (table 1).

In southeastern and eastern Yunnan, the Chengjiang Series is made up of a lower sandstone sequence and upper glacial deposits. The sandstone is purplish-red or brownish- and reddish-green, medium- to coarse-grained, feldspathic, in part micaceous and calcareous, and thick-bedded; and, locally, basal conglomerate or quartzite and conglomeratic sandstone are present.

The upper glacial deposits generally consist of red conglomerate, overlain by red, micaceous shale (Institute of Geology, Academia Sinica, 1956, p. 440). In eastern Yunnan, the Chengjiang is well exposed in the vicinity of Chengjiang. Thickness ranges from 250 m to 2,500 m.

In western Guizhou, the Nantou Formation consists of lower detrital deposits of shale, sandstone, and conglomerate, and upper glacial deposits of tillite, shale, and clay. The Lower Sinian sequence is probably incomplete. Thickness is estimated to be about 200 m.

In south-central Guizhou, the Shizikou Series represents the upper part of the Lower Sinian sequence, which is probably equivalent to part of the Nantou Formation. This series consists of grayish-green, slaty shale and yellow, coarse-grained sandstone in the lower part, and dark-purple, sandy shale and micaceous sandstone in the upper part. Exposed thickness ranges from 100 to 500 m.

In western Guangxi, the Lower Sinian is probably represented by shallow marine detrital deposits of the Changan shale, sandstone, and conglomerate in the lower part; the Fulu sandstone, shale, and marl in the middle part; and the Nantou glacial tillite and outwash detrital rocks in the upper part. Thickness is about 400 m.

Upper Sinian

The Upper Sinian is generally represented by the Doushantou Formation in the lower part and the Dengying Limestone in the upper part throughout the study region.

In southeastern and eastern Yunnan, the Upper Sinian is represented by the Dengying Limestone or Dengying Formation (Wang and Liu, 1980, p. 92-94). The Dengying consists chiefly of lower oolitic and cross-laminated dolomite; medial dark-gray bituminous limestone and siliceous limestone with abundant Vendotaenia and Actinophycus; and upper bird's eye dolomite. Thickness ranges from 600 m to 900 m in eastern Yunnan.

In western Guizhou, the Doushantou Formation and Dengying Limestone represent the Upper Sinian sedimentary sequences. The Doushantou is made up of sandstone, variegated shale, and phosphorite-bearing carbonate rocks, and overlain by phosphorite-bearing dolomitic limestone and dolomite, which contain chert concretions and disseminated pyrite. Thickness of both formations is probably in excess of 450 m.

In south-central Guizhou, the Upper Sinian is represented by the Dengying Limestone (Institute of Geology, Academia Sinica, 1956, p. 467). The Dengying of this area is made up of lower light-gray and light-blue, thick-bedded, siliceous, dolomitic limestone; medial purplish-red and grayish-green, thin-bedded sandstone and shale; and upper light-gray, siliceous, blocky, thin- and thick-bedded dolomitic limestone, which contains chert layers and mercury ore deposits. The Dengying is well exposed in the areas of Xifeng, Kaiyang, and Fuquan. Thickness ranges from 100 m to 600 m.

In western Guangxi, the Doushantou Formation represents the Upper Sinian sequence and consists of shale, limestone, dolomitic limestone, phosphorite beds, chert, and stone-coal beds (Chinese Academy of Geological Sciences, 1973, p. 93).

General Paleogeography and Deposition of the Proterozoic Rocks

During the Early Proterozoic and Late Proterozoic, the Sino-Korean para-platform was formed between the Changcheng and the Huto (Hutuo) periods, 1,700 $^{+}$ 50 m.y. (Chungtiaoian, Huang and others, 1980, table 4) (table 2; figs. 5 and 6). These platforms formed a large-scale, east-west stable continental block in China, which divided the Chinese continent into two principal north and south domains. These domains have been active tectonically and sedimentally since the Proterozoic.

The Yangzi (Yangtze) (Chang Jiang) platform to the north of the study region was formed during early Middle Proterozoic time and became stable in the latest episode of the Yangzian (Yangtzeian) orogeny at the latest stage of Kunyang deposition (tables 1 and 2; fig. 3). The Kunyang sedimentary sequences to the west of the study region were deposited generally in shoreline environments, whereas the Banxi strata to the southeast of the study region were deposited in an open-marine environment, in accompaniment with submarine volcanic flows. These strata were locally intruded by basic and ultrabasic plutonic rocks during the Yangzian deformation.

During Late Proterozoic, the Lower Sinian sedimentary sequences were deposited in continental-fluvial, glacial, and marine-shoreline environments, whereas the Upper Sinian (Dengying) sedimentary rocks were generally deposited in open-marine environments owing to an increase in the subsidence rate to the east (figs. 4, 7 and 8).

Table 2. Subdivision of orogenic cycles and important events of the tectonic development of China (after Chinese Academy of Geological Sciences, Beijing, China, 1977; table 3, p. 14)

	Geological Chronology	Isotopic Age (m.y.)	Subdivision of Orogenic Cycles and Important Events of Tectonic Development of China			Orogenic Cycles of Europe
Cenozoic	Quaternary	15	Himalayan		Formation and development of M-P & T-H	Alpine
	Tertiary	67	Yenshanian			Cimmerian
Mesozoic	Cretaceous	137				
	Jurassic	190	Indosinian	Destruction and disintegration of parts of P-A; intensive activity of M-P & T-H ***		
	Triassic	230	Variscan	Consolidation of Central Asiatic-Mongolian . . . geosynclines; cementation of Siberian Platform with Sino-Korean & Tarim platforms; formation of P-A **		Variscan
Paleozoic	Permian	280				
	Carboniferous	350				
	Devonian	405	Caledonian	Formation of South China Platform	Formation and development of P-A	Caledonian
	Silurian	440				
	Ordovician	550				
	Cambrian	570	Hsingkaiian	Disintegration of Chinese Proto-platform; formation of Kunlun, Tsinling, Peishan, Tienshan (central & southern parts) & other geosynclines		
Late Proterozoic (Sinian Subera)	Eocambrian	700	Yangtzeian	Formation of Yangtze & Tarim Platforms; combination of these platforms with Sino-Korean Paraplatform to form the Chinese Proto-Platform		Assyntian
	Sinian s.s.					
	Chingpaikou	1000	?			Dalslandian
	Chihsien	1400				
	Changcheng	1700*	Chungtiaoian	Formation of Sino-Korean Paraplatform		Svecofennian
Early Proterozoic	Huto	2000	Wutaiian			Karelian
	Wutai	2500	Fupingian			Belomorian
Archaean	Fuping					

* According to the latest report by the Institute of Geochemistry, Academia Sinica, the lower limit of the Sinian Subera is fixed at 1.950±50 m.y. B.P. (June 17, 1976).

** P - A, Pal-Asiatic Tectonic Domain.

*** M - P, Marginal Pacific Tectonic Domain, & T - H, Tethys - Himalayan Tectonic Domain.

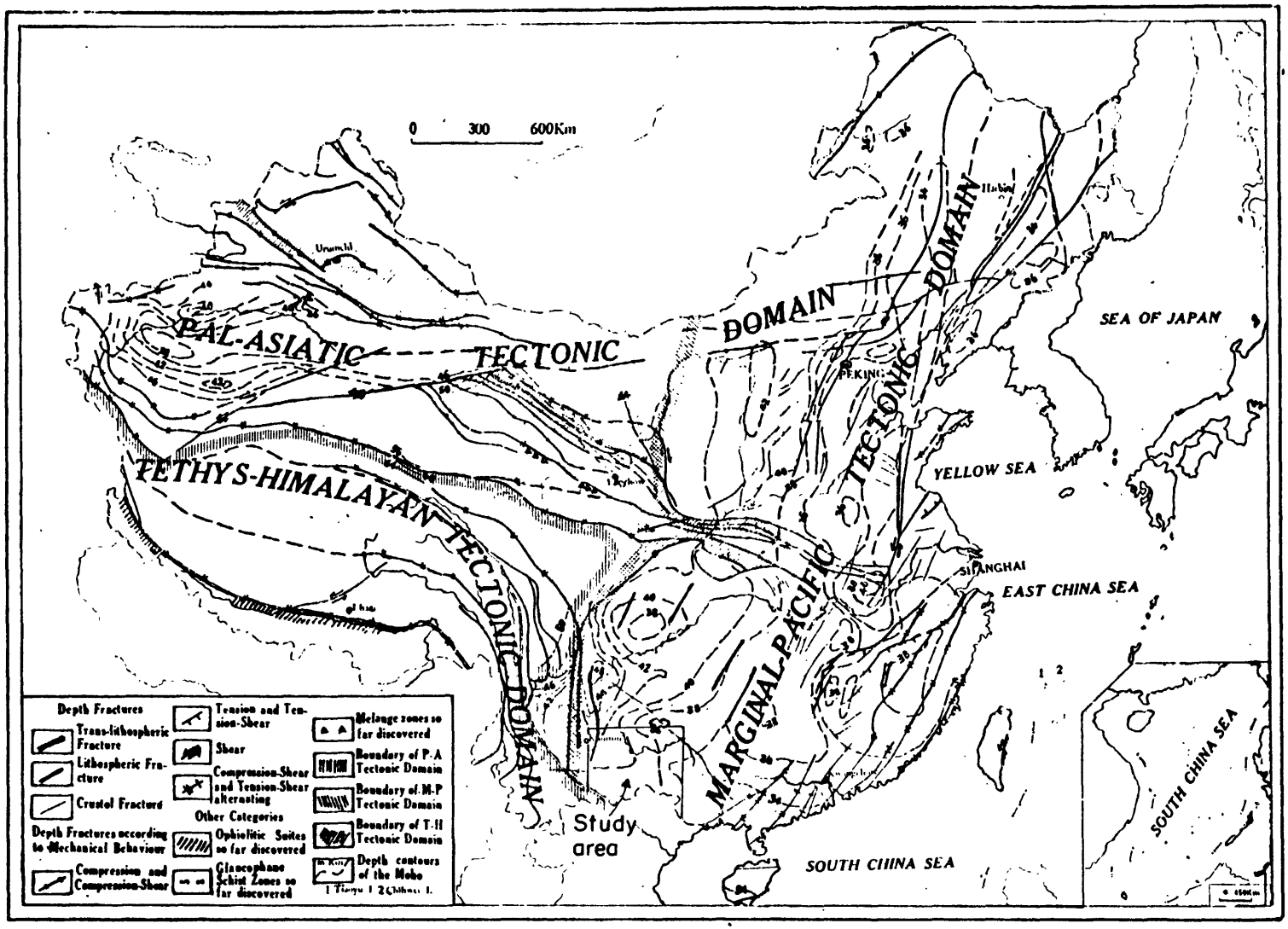


Figure 5,--Generalized map showing depth fractures and tectonic domains of China (adopted from Chinese Academy of Geological Sciences, Beijing, China, 1977, fig. 2, p. 8).

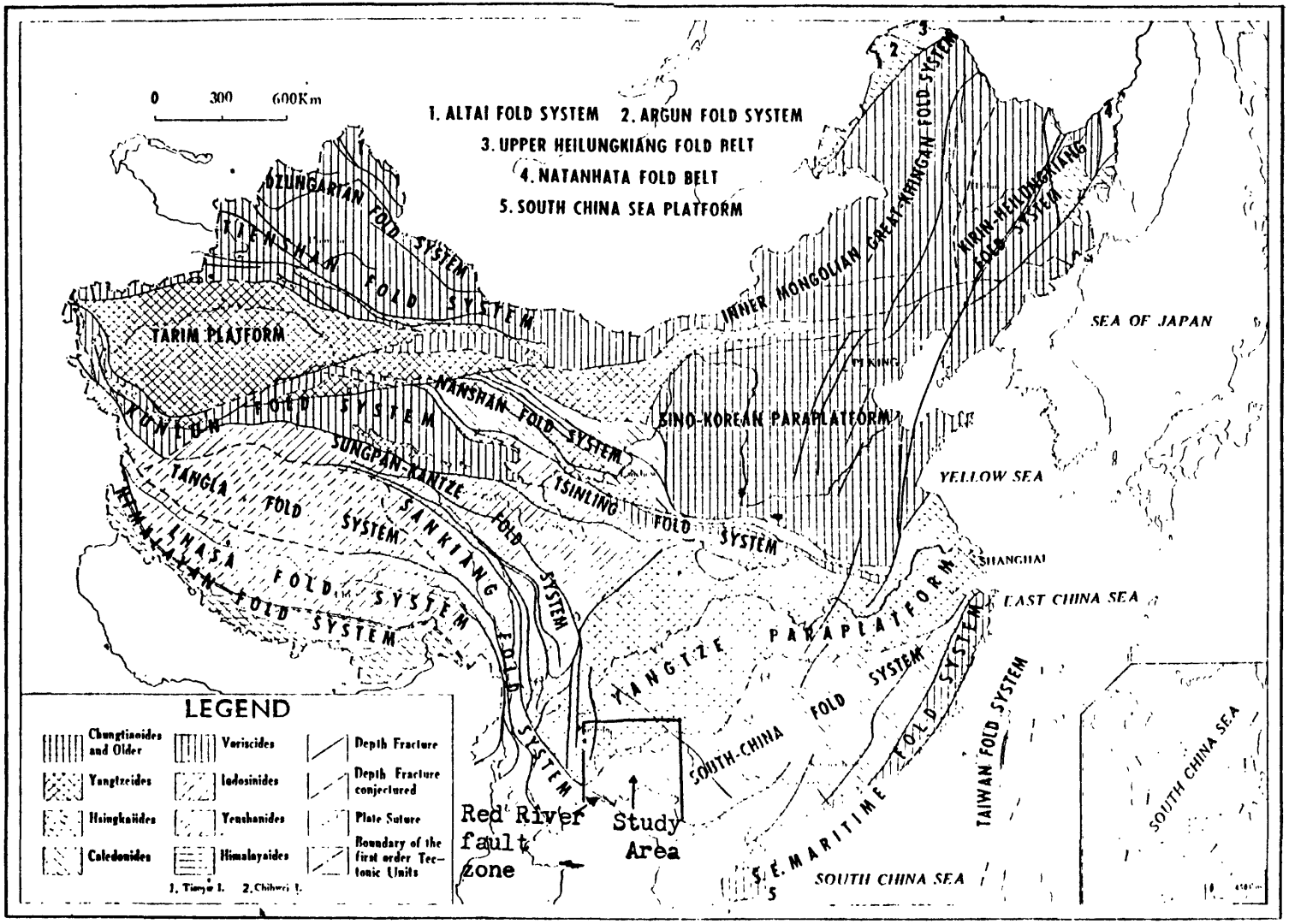


Figure 6.--Generalized tectonic map of China (after Chinese Academy of Geological Sciences, Beijing, China, 1977, fig. 1, p. 3).

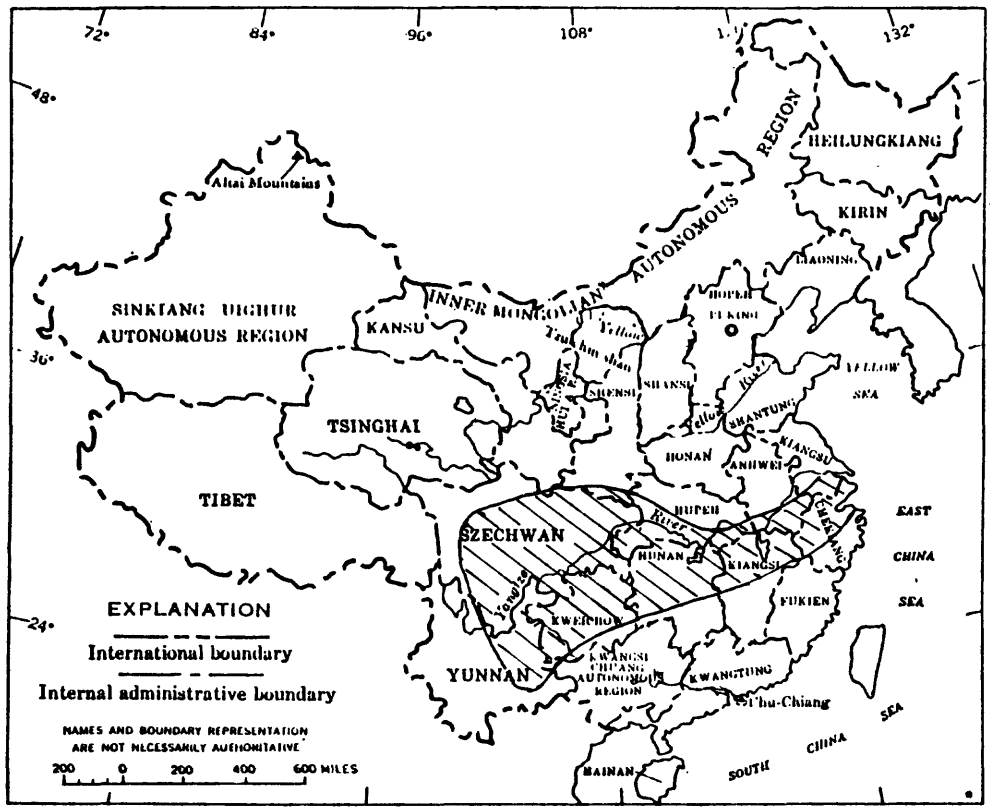
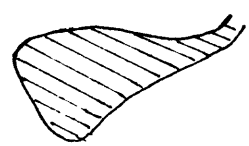


Figure 7. Index map of China showing areal coverage of Figure 8 (provincial names are in Wade-Giles spelling)

Area coverage of Fig. 8



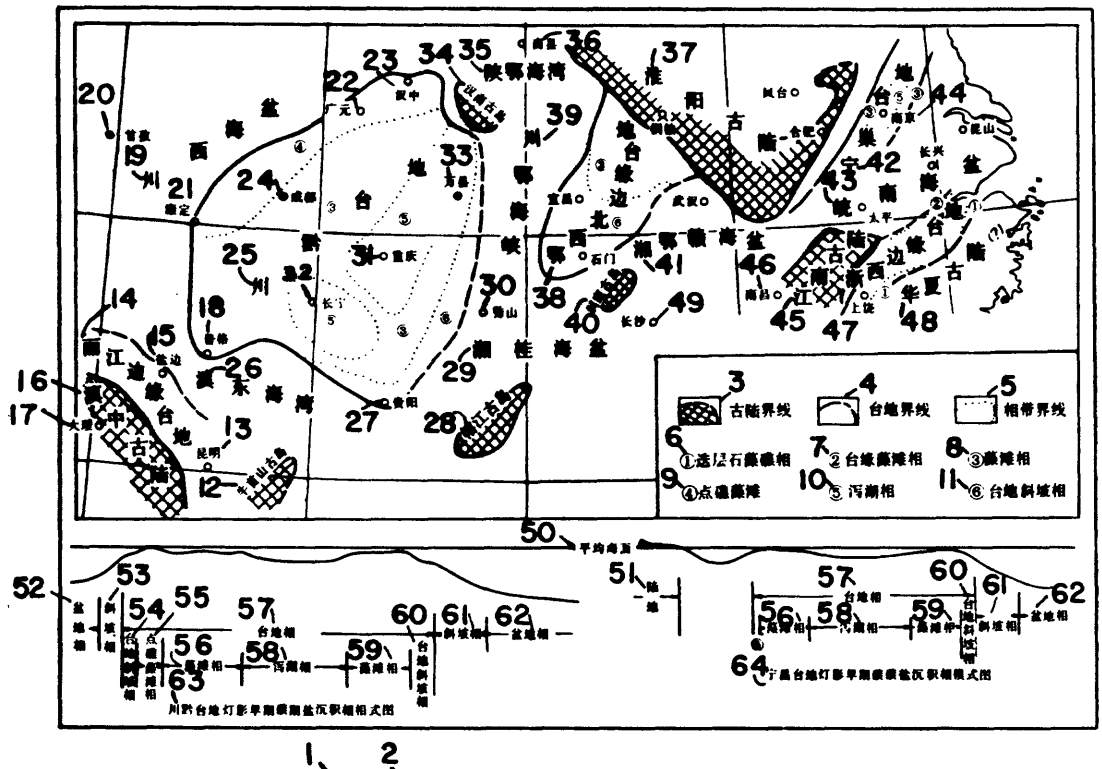


图 3 中国南部灯影早期碳酸盐沉积相及古地理图

1. Figure 8.

2. Early Dengying carbonate facies and paleogeography of South China (after Tang and others, 1981, fig. 3, p. 16).

3. Boundary of old landmass.
4. Boundary of platform.
5. Boundary of facies zone.
6. Stomatolite-algal reef facies.
7. Algal bank facies of platform margin.
8. Algal bank facies.
9. Patches of algal banks.
10. Lagoon facies.
11. Platform slope facies.
12. Niushoushan ancient island.
13. Kunming.
14. Lijiang marginal platform.

15. Yanbian. 16. Dianzhong old landmass. 17. Dali.

18. Puge. 19. Chuanxi sea basin. 20. Ganzi.

21. Kangding. 22. Guangyuan. 23. Hanzhong.

24. Chengdu. 25. Chuanqian platform. 26. Diandong bay.

27. Guiyang. 28. Rongjiang ancient island.

29. Xianggui sea basin 30. Xiushan. 31. Chongging.

32. Changning. 33. Wanxian.

34. Hannan ancient island.

35. Shane bay. 36. Shangxian.

37. Huaiyang old landmass.

38. Exibei marginal platform.

39. Chuane strait. 40. Dongting ancient island.

41. Siangegan sea basin 42. Ningchao platform. 43. Wannan sea basin.

44. Nanjing. 45. Jiangnan old landmass. 46. Nanchang.

47. Zhexi marginal platform.

48. Cathysian old landmass (?) 49. Changsha.

50. Average sea level. 51. Land. 52. Basin facies.

53. Slope facies 54. Platform slope facies.

55. Patch reef-algal bank facies.

56. Algal bank facies. 57. Platform facies. 58. Lagoon facies.

59. Algal bank facies. 60. Platform slope facies. 61. Slope facies.

62. Basin facies

63. Depositional model of Early Dengying carbonates of the Chuandian platform.

64. Depositional model of Early Dengying carbonates of the Ninchao platform.

Paleozoic

The Paleozoic stratigraphy of the Dian-Qian-Gui foldbelt consists chiefly of marine sedimentary sequences. The Cambrian and the Devonian to Permian strata are generally extensively distributed throughout the region. The Ordovician and Silurian strata, however, are locally absent because of the the presence of emergent landmasses during the deposition. In accord with available reports, the Upper Ordovician and Silurian strata are missing in southeastern Yunnan; the Middle Ordovician to most of Middle Silurian beds are missing in eastern Yunnan; the Lower Ordovician to Lower Silurian strata are absent in western Guizhou; and the Upper Ordovician to Lower Silurian beds are missing in south-central Guizhou. In western Guangxi, both Ordovician and Silurian Systems are absent (Institute of Geology, Academia Sinica, 1956, v. 1, p. 417-467; and 1958, v. 2, p. 96-98) (Chinese Academy of Geological Sciences, 1973, p. 93-94, p. 136-137, p. 140-141; and 1979, p. 6-30) (Wang and Liu, 1980). Discussion on individual stratigraphic systems is given below in ascending order (table 1 and fig. 2).

Cambrian

Generally the Cambrian System is widely distributed in the study region (fig. 2). This system belongs to the Yangzi (Chang Jiang) sedimentary type, which was deposited chiefly in continental shelf environments (fig. 9) (Wang and Liu, 1980; p. 110-112) (Chinese Academy of Geological Sciences, 1979, p. 6-7). Detailed study on Lower and Middle Cambrian has been done in eastern Yunnan. Detailed information on Cambrian stratigraphy in southeastern Yunnan, western Guizhou, south-central Guizhou, and western Guangxi are not available. Of these areas, southeastern Yunnan has the thickest Cambrian sedimentary sequences of more than 6,000 m (Chinese Academy of Geological Sciences, 1973, p. 140).

Lower Cambrian

The stratotype section of the Lower Cambrian is located in eastern Yunnan and consists of, in ascending order, the Meishucun Formation, the Qiongjhasi Formation, the Canglangpu Formation, and the Longwangmiao Formation (Chinese Academy of Geological Sciences, 1973, p. 4; and 1979, p. 7). Generally, information on the Lower Cambrian is fragmental or lacking for other areas, but in south-central Guizhou, the Lower Cambrian consists of about 600 m of shale and limestone (table 1).

Meishucun Formation.

The type section of this formation is located at Meishucun, Jinling, Yunnan, and characterized by a small shelly fauna without trilobites (Chinese Academy of Geologic Sciences, 1979, p. 7). It contains the lower Anabarites-Circotheca faunal assemblage and upper Allatheca-Yunnantheca faunal assemblage.

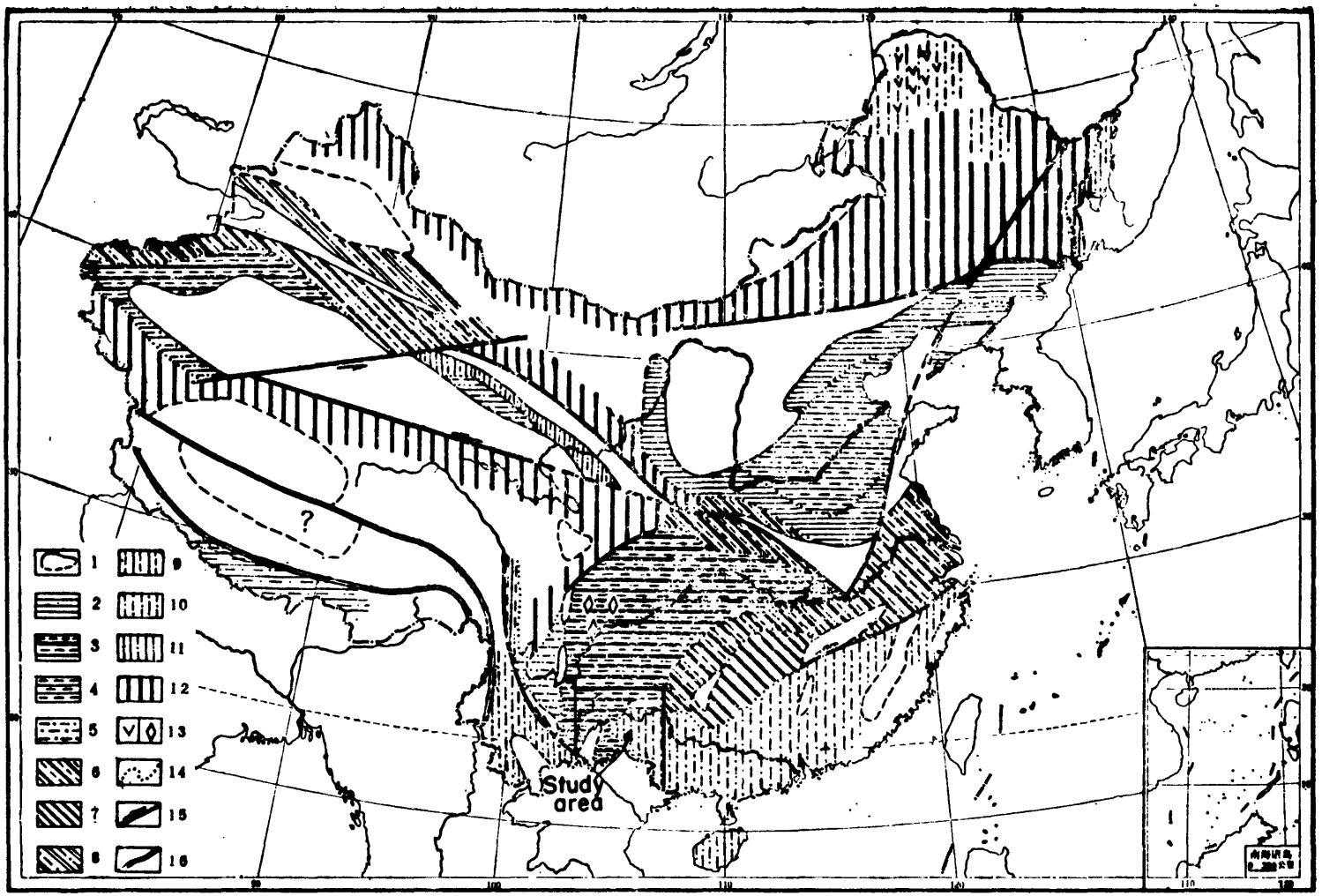


Figure 9.--Early Cambrian paleogeography and types of sedimentation of China. (after Wang and Liu, 1980, plate 8-III).

1. Area of denuded old landmass.

2-5. Marine stable types.

2. Coastal and shallow-sea calcareous-argillaceous deposits with upper overlapping.
3. Shallow-sea carbonaceous and calcareous-argillaceous deposits.
4. Coastal and shallow-sea early carbonate and late calcareous-argillaceous deposits.
5. Chiefly coastal and shallow-sea detrital argillaceous deposits.

6-8. Marine transitional types.

6. Shallow-sea to semi-deep sea carbonaceous and argillaceous deposits.
7. Chiefly semi-deep sea carbonaceous-arenaceous deposits.
8. Shallow-sea to semi-deep sea arenaceous-argillaceous deposits.

9-12. Marine mobile types.

9. Calcareous-argillaceous paraflysch deposits.
10. Clastic argillaceous paraflysch and flysch deposits.
11. Chiefly clastic argillaceous deposits, locally intercalated with limestone.
12. Undifferentiated.

13. Left, volcanic rock; right, evaporites.
14. Boundary of sedimentation types.
15. Late fault and direction of horizontal movement.
16. Earth's crust suture zone.

It is called the phosphorite-bearing formation. At Zhongyicun, Kunyang; Dongshan, Chengjiang; Caopu, Anning in east-central Yunnan, this sedimentary sequence consists of a lower brecciated quartzite, dense sandstone, and thin-bedded quartzose sandstone; and upper oolitic phosphorite-carbonate layers, 6.5 m thick, yielding Hyolithes sp. and overlain by yellowish-green and black shale. Generally, the thickness of this formation ranges from 10 to 25 m (Institute of Geology, Academia Sinica, 1956, p. 438-439).

Qiongzhusi Formation

This formation represents a shale and marl sedimentary sequence exposed at Qiongzhusi, Kunming, Yunnan. It consists of lower dark-gray and pinkish-gray sandstone and sandy shale, and upper yellowish-brown, blackish-gray, and calcareous shale, which yields Redlichia intermediata Lu, R. walcotti Mans., Pseudoptychoparia yunnanensis (Mansuy),and Bradoria sp. Thickness at Qiongzhusi ranges from 50 to 380 m.

Canglangpu Formation. The type section of this formation is located at Canglangpu, Malong, Yunnan, and consists of a lower unit of yellowish-brown, cross-bedded quartzose sandstone intercalated with gray, nonfossiliferous shale and an upper unit of fossiliferous, yellowish-gray, micaceous, sandy shale, greenish-gray clayey sandstone, and thin-bedded limestone (which contains a lower fossil zone yielding Palaeolenus lantenoisi Mansuy, P. douvillei Mansuy, P. deprati Mansuy, P. tingi Lu, Redlichia Chinensis Walcott, and R. mai Lu and an upper fossil zone yielding Paragraulos yunnanensis Lu, Ptychoparia szechuanensis Sun, Redlichia mai Lu, and R. Chinensis Walcott. Thickness is estimated at about 130 to more than 200 m.

Longwangmiao Formation.

This formation represents an excellent exposure beneath the Longmen temple of Xishan (West Hills), southwest of Kunming, Yunnan. Generally the Longwangmiao is extensively distributed throughout the region. It is made up of interlayers of light-gray and dark-gray, thin-bedded, blocky, and impure limestone, silty and calcareous shale, and micaceous, quartzose, and in part calcareous sandstone. Limestone is dominant in the upper part of this unit. The fauna of the upper middle part of this unit consists chiefly of Archaeocyathus sp., and those of the lower middle part consist of Miemacia transversa Lu, M. elongata Lu, and Redlichia Chinensis Walcott. The thickness of this unit is about 120 to 150 m in Eastern Yunnan.

The Lower Cambrian in south-central Guizhou is represented, in ascending order, by the Niutitang Shale, shale and sandstone, Mingxinshi Formation, shale and limestone, and the Jindingshan Formation, limestone and shale. Lower Cambrian fine detrital rocks and carbonate rocks are present throughout the remaining area.

Middle Cambrian

Most of the Middle Cambrian of eastern Yunnan is represented by the Douposi Formation and Shuanglongtan Formation (Wang and Liu, 1980, p. 111). The Douposi Formation consists of interbeds of dolomitic limestone, shale, and basal fine-grained sandstone. Thickness is about 70 m. The Shuanglongtan Formation is made up chiefly of limestone and dolomitic limestone, which are interbedded with shale and contain abundant trilobites and small-scale reef carbonates. Thickness is about 135 to 400 m. The Middle Cambrian carbonate-rock sequences are generally present throughout the region.

Upper Cambrian

In the south-central Guizhou, the Lushan Limestone represents an undifferentiated Middle-Upper Cambrian sedimentary sequence. The Lushan consists of gray to dark-gray dolomitic limestone, which is locally interbedded with shale and contains trilobites. This unit is well exposed in the areas of Lushan, Guiding, Duyun, and Kaiyang. Thickness ranges from 250 to 500 m.

Upper Cambrian carbonate rocks and fine detrital rocks are present in southeast Yunnan, western Guizhou, and western Guangxi, and are absent in eastern Yunnan.

General paleogeography and deposition of the Cambrian System

During Early Cambrian time, several marine transgressions and regressions occurred in China. During that time, one seaway came from the north and another came from the the south (Chinese Academy of Geological Sciences, 1979, p. 9) (fig. 9). In southwest China, locally, the clastic character of Early Cambrian sedimentary rocks is a distinctive feature of initial Paleozoic deposition in the continental shelf environment and indicates the proximity of land areas from which the sediments were derived. The study region is located in a portion of this southern seaway, which was never very deep, as indicated by the lithologic characteristics of the Cambrian strata. Later, the Cambrian sea gradually encroached eastward toward the old land area, then to the east of the study area, and formed widespread lagoonal and shelf marine depositional environments. Subsequently, due to the effects of tectonic movement between Early and Middle Cambrian time in North China and western Yunnan and the Sichuan provinces, the Middle and Upper Cambrian strata of the Upper Yangzi (Chang Jiang) drainage area were deposited in a semi-closed environment under arid-warm climate conditions (Chinese Academy of Geological Sciences, 1979, p. 9).

Ordovician

The Ordovician System is generally absent throughout much of the study region. This system is completely missing in western Guizhou and western Guangxi. Lower and Middle Ordovician strata, however, are exposed in southeastern Yunnan and south-central Guizhou. In eastern Yunnan, only Lower Ordovician detrital rocks are present (Table 1).

Lower Ordovician

The Lower Ordovician strata are exposed in southeastern and eastern Yunnan and south-central Guizhou, and consist of grayish-green, calcareous, silty shale, thin-bedded marl, and sandstone in the lower part; gray, grayish-red to dark-red, siliceous, dolomitic, fossiliferous, and thin-bedded limestone in the middle part; and grayish-green, yellowish-brown, and calcareous shale and sandstone as well as argillaceous and silty limestone in the upper part. Thickness ranges from 50 to 480 m.

Middle Ordovician

In southeastern Yunnan, the Middle Ordovician strata are made up of sandstone and shale, intercalated with impure gray, clayey limestone. In south-central Guizhou, the Middle Ordovician strata consists chiefly of light-gray, grayish-green, and grayish-red to dark purple, impure, thin- to thick-bedded, and crystalline limestone, which contains Vaginoceras var. multiplectoseptatum Yu, V. wahlenberg, Foord, Ophileta sp., and Pagodispira sp. Thickness ranges from 150 to 220 m.

General paleogeography and deposition of the Ordovician System

In Early Ordovician time, the distribution of sea and land was similar to that of the Late Cambrian. The Ordovician system of the study region belongs to the Yangzi paraplatform sedimentary type (Chinese Academy of Geological Sciences, 1979, p. 10) (fig. 10) and is characterized by a thin sedimentary sequence, which was deposited in the stable to active marine environment and shows thickness variations of carbonate and detrital rock interlayers in which the carbonate facies becomes thicker toward the east (fig. 10).

Silurian

The Silurian is generally absent throughout most of the region (fig. 2). This system is completely missing in southeastern Yunnan and western Guangxi. Middle and Upper Silurian strata are, however, known in eastern Yunnan, western Guizhou, and south-central Guizhou (Table 1).

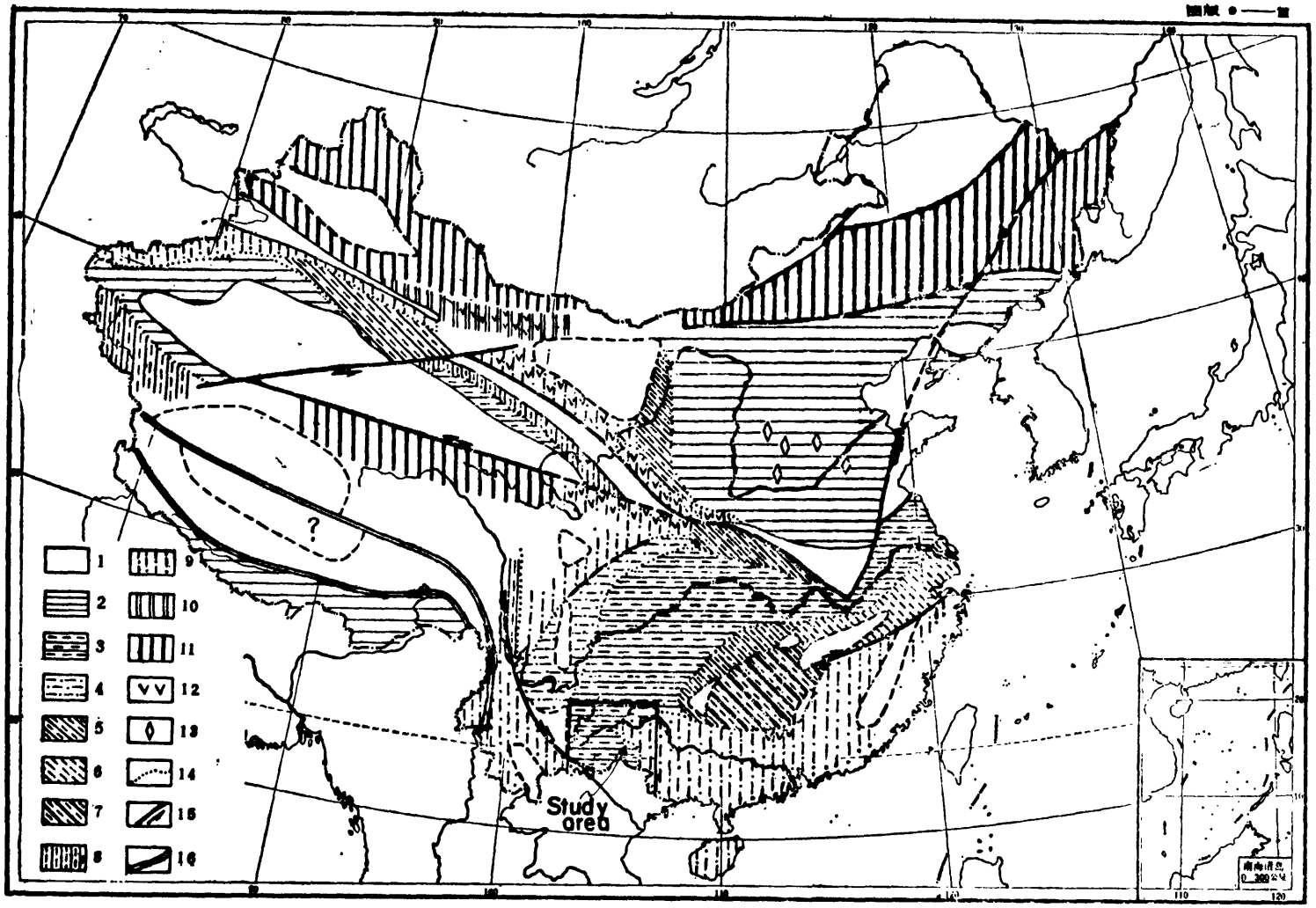


Figure 10.--Early Ordovician paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 9-III).

1. Area of denuded old landmass.

2-4. Marine stable types.

2. Shallow-sea carbonate deposits.
3. Shallow-sea carbonate and calcareous-argillaceous deposits.
4. Coastal and shallow-sea clastic argillaceous deposits.

5-7. Marine transitional types.

5. Shallow-sea to semi-deep sea calcareous-argillaceous deposits.
6. Chiefly argillaceous deposits and locally paraflysch deposits.
7. Shallow-sea to semi-deep sea carbonaceous and argillaceous paraflysch deposits.

8-11. Marine mobile types.

8. Chiefly calcareous-argillaceous paraflysch deposits.
9. Clastic argillaceous paraflysch and flysch deposits.
10. Siliceous- and argillaceous-rich deposits.
11. Undifferentiated.
12. Volcanic rock.
13. Evaporites.
14. Boundary of sedimentation types.
15. Late fault and direction of horizontal movement.
16. Earth's crust suture zone.

Middle Silurian

The Middle Silurian is represented by most of the Guandi Formation in the vicinity of Qujing of eastern Yunnan (Wang and Liu, 1980, p. 145-146). It consists of shale, intercalated with some siltstone, marl, and a bed of limestone, at the top which contains Favosites forbesi. Thickness is about 120 m. In western and south-central Guizhou, the Middle Silurian is represented by the Wengding Group. In western Guizhou, this group consists of sandstone, shale, and limestone of unknown thickness. In south-central Guizhou, this group at the Dongmajiatun, Guiding (east of Guiyang, which is outside of study), is made up of grayish-yellow, grayish-green, gray, and purple, calcareous, and silty shale with grayish-black shale interlayers in the lower part; green, impure limestone and shale, intercalated with red sandstone in the middle part; this unit grades upwards into interbedded red, green, and gray, soft sandstone and shale in the upper part. Thickness ranges from 200 to more than 700 m (Institute of Geology, Academia Sinica, 1956, p. 464-465).

Upper Silurian

The Upper Silurian strata are well exposed in eastern Yunnan, south-central Guizhou, and western Guizhou.

In eastern Yunnan, the Upper Silurian consists of the uppermost part of the Guandi Formation, which is made up of 120 m or shale and limestone, and the Miaogaoshan Formation, which consists of 700 m of interbeds of limestone and shale; this unit grades upwards into 350 m of thin-bedded limestone, marl, and black-shale of the Yulongsi Formation.

In south-central and western Guizhou, the Upper Silurian is represented also by the Wengding Group. This group consists of sandstone, shale, and limestone in Guizhou, and of about 450 (?) m of shale and sandstone in south-central Guizhou.

General paleogeography and deposition of Silurian System

During transgression of the Silurian Sea, Guangxi Province and most of the Guizhou and Yunnan Provinces emerged as landmass because of large-scale uplift throughout South China. A narrow seaway formed from the south in eastern and southeastern Yunnan, which connected the Yangzi (Chang Jiang) Silurian sea on the northeast and the western Yunnan Silurian sea on the southwest (Wang and Liu, 1979, p. 15) (fig. 11). In the study region, the sedimentary facies of the Silurian System are designated as "Yangzi (Chang Jiang) paraplatform" type because of their thin sedimentary sequences, a lithology characteristic of marine bay environments, and features of the faunal assemblage (Chinese Academy of Geological Sciences, 1979, p. 14-15).

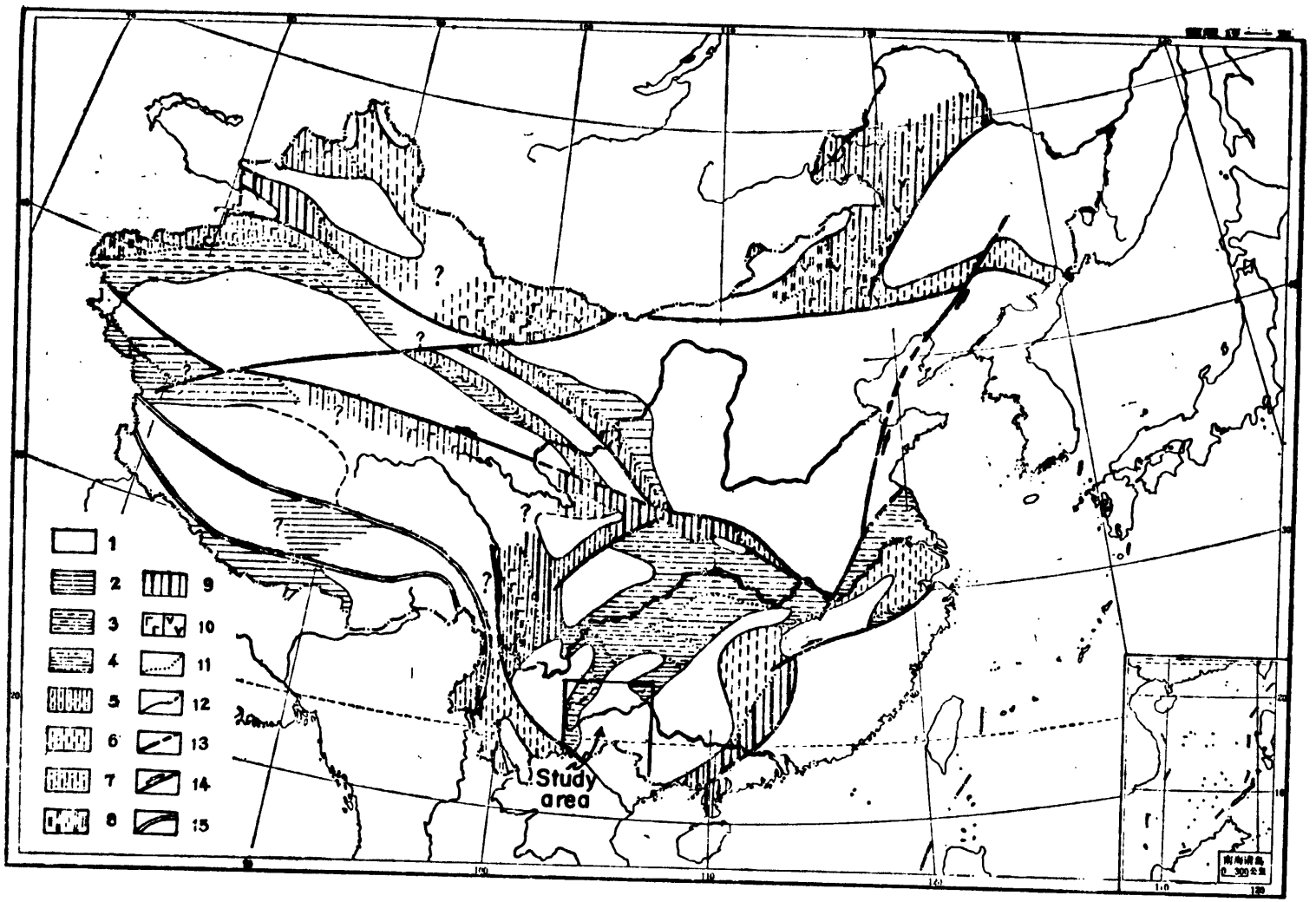


Figure 11.--Early and Middle Silurian paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 10-III).

1. Area of denuded old landmass.

2-4. Marine stable types.

2. Chiefly shallow-sea carbonate deposits.
3. Chiefly shallow-sea calcareous and argillaceous deposits.
4. Chiefly coastal shallow-sea clastic argillaceous deposits.

5-9. Marine mobile types.

5. Calcareous-argillaceous paraflysch deposits.
6. Argillaceous paraflysch deposits.
7. Arenaceous-argillaceous flysch and paraflysch deposits.
8. Siliceous- and calcareous argillaceous-rich deposits
9. Carbonaceous- and argillaceous-rich paraflysch deposits.

10. Left, intermediate basic volcanic rock; right, intermediate acidic volcanic rock.
11. Boundary sedimentation types.
12. Boundary of the areas of sedimentation as well as marine/continental demarcation.
13. Boundary fault.
14. Late transcurrent fault.
15. Earth's crust suture zone.

Devonian

The Devonian System is generally extensively distributed throughout the study region. This system is confined chiefly to South China, which includes the "Yangzi (Chang Jiang) paraplatform" and the South China fold-system (fig. 6), and is characterized by neritic and littoral sediments of platform type (Chinese Academy of Geological Sciences, 1979, p. 19-20). It is subdivided, in ascending order, into a Lower, Middle, and Upper Series (table 1). Detailed stratigraphy and fauna contents are shown in the appendix.

Lower Devonian

The Lower Devonian strata of this region generally consist of shale, marl, and sandstone. Local names are designated to represent stratigraphic units. On the basis of regional distribution, a descriptive statement of the Lower Devonian strata is given below.

In southwestern Yunnan, the Lower Devonian is represented by the Pojiao Shale. This shale is made up of fossiliferous brown, reddish-yellow, and gray shale, intercalated with greenish-gray, clayey shale and gray silty shale. The basal portion of the Pojiao Shale is not exposed but the exposed part is more than 100 m thick. The age of the Pojiao Shale, as a whole, has not yet been established (Institute of Geology, Academia Sinica, 1956, p. 98).

The Lower Devonian of eastern Yunnan is represented by clastic rocks of the Cuifengshan Group in the vicinity of Huaning (Chinese Academy of Geological Sciences, 1973, p. 140). This Group is probably equivalent to the Chanyi Series, which was designated as Lower Devonian in age (Institute of Geology, Academia Sinica, 1956, v. 2, p. 98).

In western and south-central Guizhou, the Lower Devonian consists of sandstone and conglomerate, and locally, in south-central Guizhou, shale intercalated with thin-bedded limestone in the areas of Dansai, Sandu, and Dushan. The thickness in south-central Guizhou ranges from about 5 m to more than 30 m (Institute of Geology, Academia Sinica, 1956, p. 464).

In western Guangxi, the Lower Devonian is represented by two formations, in ascending order: the Lianhuashan Formation and the Sipai Shale. The Lianhuashan Formation consists of purple, fine-grained quartzose sandstone, yellowish-brown sandstone, and purple shale. The thickness is about 100 m.

The Lianhuashan grades upward into the Sipai Shale, which is the upper unit of the Lower Devonian. This unit comprises gray, yellowish-brown, red shale, which is interbedded with dark-gray, clayey, fossiliferous limestone. The thickness is estimated to be more than 200 m (Institute of Geology, Academia Sinica, 1956, p. 509).

Middle Devonian

The Middle Devonian strata are generally widely distributed in western Guangxi, south-central Guizhou, eastern Yunnan, and western Guizhou. Generally, they are sporadically exposed in southeastern Yunnan.

The Middle Devonian of western Guangxi is subdivided, in ascending order, into the Majiaao Limestone, the Lazhutai Formation, the Wuzhishan Formation, the Tongchejiang Formation, the Chehe Formation, the Liangshuiao Formation and the Kengma Formation (Institute of Geology, Academia Sinica, 1956, p. 508-509).

The Majiaao Limestone is blackish-gray, impure, thin- to thick-bedded, and in part clayey, and weathers dark purple. The clayey variety is generally intercalated with black, thin-bedded shale. The thickness of this unit is about 250 m.

The Lazhutai Formation consists of light-gray or brownish-gray, dense, laminated chert layers in the upper part locally intercalated with black, carbonaceous shale and lenticular clayey limestone; and black, carbonaceous or grayish-black shale in the lower part. The thickness is estimated to be 87 m.

The Wuzhishan Formation comprises chiefly light-gray and greenish-gray, very thin-bedded or lenticular limestone intercalated with very thin chert layers. This unit is 55 m thick.

The Tongchejiang Formation is made up of black shale intercalated with sandy and carbonaceous shale. This shale grades upward into black, laminated limestone, and downward into light-gray chert layers. This unit is 230 m thick.

The Chehe Formation consists of gray, thick-bedded quartzose, brownish-gray sandstone in the upper part, and brown and gray shale intercalated with limonite-bearing sandstone, and in part, with quartzose sandstone, black shale, and dark-gray, clayey, thin-bedded crinoidal limestone in the lower part. The thickness ranges from 100 to 150 m.

The Donggangling Limestone (table 1) consists of the Liangshuiao Formation and the Kengma Formation (Institute of Geology, Academia Sinica, 1956, p. 508). The Liangshuiao Formation is made up of dark-gray, dense, thin-bedded limestone intercalated with chert nodules and shale, and is generally equivalent to the lower part of the Kengma Formation. This unit is 400 m thick. The Kengma Formation consists chiefly of yellow, light-purple shale, which is intercalated with carbonaceous, sandy shale. The thickness of the Kingma ranges from 100 to 150 m.

In south-central Guizhou, the Dushan Series embraces the entire Middle Devonian sedimentary sequence. This series is subdivided, in ascending order, into: the Bangsai Sandstone, the Jipao Limestone, the Songjiaqiao Sandstone, and the Jiwosai Limestone (Institute of Geology, Academia Sinica, 1956, p. 463-464).

The Bangsai Sandstone is made up chiefly of light-red and brownish- or grayish-yellow, light-gray, fine- to medium-grained, clayey, dense, and thick-bedded quartzose sandstone and quartzite with basal coarse-grained sandstone. Locally, the upper sandstone is intercalated with silty, carbonaceous shale and contains abundant euhedral pyrite. The thickness ranges from 10 to about 350 m.

The Jipao Limestone is chiefly dark-gray, clayey, dolomitic, and cherty limestone with basal dolomite. The thickness ranges from 40 to 200 m.

The Songjiaqiao Sandstone is coarse-grained and calcareous, and intercalated with thin-bedded silty shale. It has a great variation in thickness and ranges from zero to about 150 m.

The Jiwosai Limestone is grayish-black, fine-grained, siliceous, clayey in part, dolomitic, and crystalline limestone. It is brittle and much jointed and contains chert bands and coral fossils in the middle of the upper part. Locally, it is intercalated with a small amount of black, carbonaceous, and variegated shale. The thickness ranges from 100 to about 200 m.

In eastern Yunnan, the Middle Devonian is represented, in ascending order, by the Longhuashan Formation, Poxi Formation, and Qujing Formation. The Longhuashan Formation consists chiefly of brownish-yellow, brownish-purple, and gray sandstone and shale, which are intercalated with dark-gray, thin-bedded and nodular fossiliferous limestone. It is about 60 to 200 m thick. The Poxi Formation is comprised chiefly of dark-gray, in part clayey and cherty, thin-bedded limestone, which contains scattered breccia and abundant brachiopods. It is about 80 to 270 m thick. The Qujing Formation consists chiefly of gray, impure, blocky, clayey, dolomitic and cherty limestone, which is locally interbedded with shale, and is fossiliferous. Thickness ranges from 150 to 550 m.

Detailed information about the Middle Devonian of western Guizhou is generally lacking, but it is similar in lithology to the Middle Devonian strata of eastern Yunnan and consists chiefly of marl, impure limestone, dolomite, and shale.

In southeastern Yunnan, the Middle Devonian in the lower part consists of interlayers of gray and grayish-brown, clayey, thin-bedded limestone and shale; in the middle part, of dark-gray and dark-blue, thick-bedded limestone; and in the upper part, of light-gray, blocky, siliceous, and crystalline limestone. The thickness is about 400 m.

Upper Devonian

The Upper Devonian strata are generally widely exposed in eastern and southeastern Yunnan, south-central Ginzhou, and western Guangxi (Chinese Academy of Geological Sciences, 1973; p. 93, 137, and 140).

The Upper Devonian of eastern and southeastern Yunnan and western Guizhou is tentatively represented by the Yidade Formation (Chinese Academy of

Geological Sciences, 1973, p. 137 and 140). This formation in eastern Yunnan consists of light-gray, blocky, siliceous, crystalline limestone in the upper part; dark-gray and dark-blue, thick-bedded limestone in the middle part; and gray, grayish-brown, clayey, thin-bedded limestone, locally interbedded with shale in the lower part. Thickness ranges from 30 to about 350 m.

In south-central Guizhou, the Upper Devonian sedimentary sequences are included in the Maosai Series. This series is subdivided, in ascending order, into the Wangchengpo Formation and the Yaosuo Limestone (Institute of Geology, Academia Sinica, 1956, p. 462-463).

The Wangchengpo Formation is comprised of dark-gray to blackish-gray limestone, which is intercalated with variegated clayey shale and which contains thick-bedded dolomitic, blocky limestone in the upper and middle parts. The thickness of this formation ranges from 100 to 250 m (Institute of Geology, Academia Sinica, 1956, 462-463).

The Yaosuo Limestone is gray, siliceous, thin-bedded limestone intercalated with gray, brown, thin-bedded shale. Fossils are generally scare. Thickness of this unit ranges from about 140 to 340 m.

In western Guangxi, Upper Devonian strata are assigned within two stratigraphic units in ascending order to: the Huiluo Formation and the Shiti Limestone (Institute of Geology, Academia Sinica, 1956, p. 508).

The Huiluo Formation consists of gray limestone and grayish-black, impure limestone in the upper part; yellow to gray, siliceous shale in the middle part; and yellow, sandy, siliceous, and banded shale in the lower part. The thickness of this unit is about 200 (?) m.

The Shiti Limestone is light-gray or gray, thick-bedded limestone, and gray, grayish-green, light-gray, thin-bedded, lenticular limestone, which locally is intercalated with black limestone containing Amphipora sp. and Athyris sp. The thickness ranges from 150 to 200 m in the vicinity of Shiti.

General paleogeography and deposition of the Devonian System

The Devonian sedimentary sequences of the study region are of the platform type and consist of the Nandan facies and Xiangzhou facies (Wang and Liu, 1979, p. 22-23) (Chinese Academy of Geological Sciences, 1979, p. 21-22) (fig. 12).

The Xiangzhou facies consists of bioclastic limestone, dolomite, and marl, intercalated with clastic detritus, and generally contains thick-bedded, basal sandstone and conglomerate characteriistic of the facies of linear shoreline and shelf deposits. The biota is mainly benthic. This facies is mainly confined in areas to the northeast and east of the study region.

The Nandan facies is made up chiefly of biogenetic limestone, dolomite, chert, black mudstone, and basal clastic detritus. This facies represents

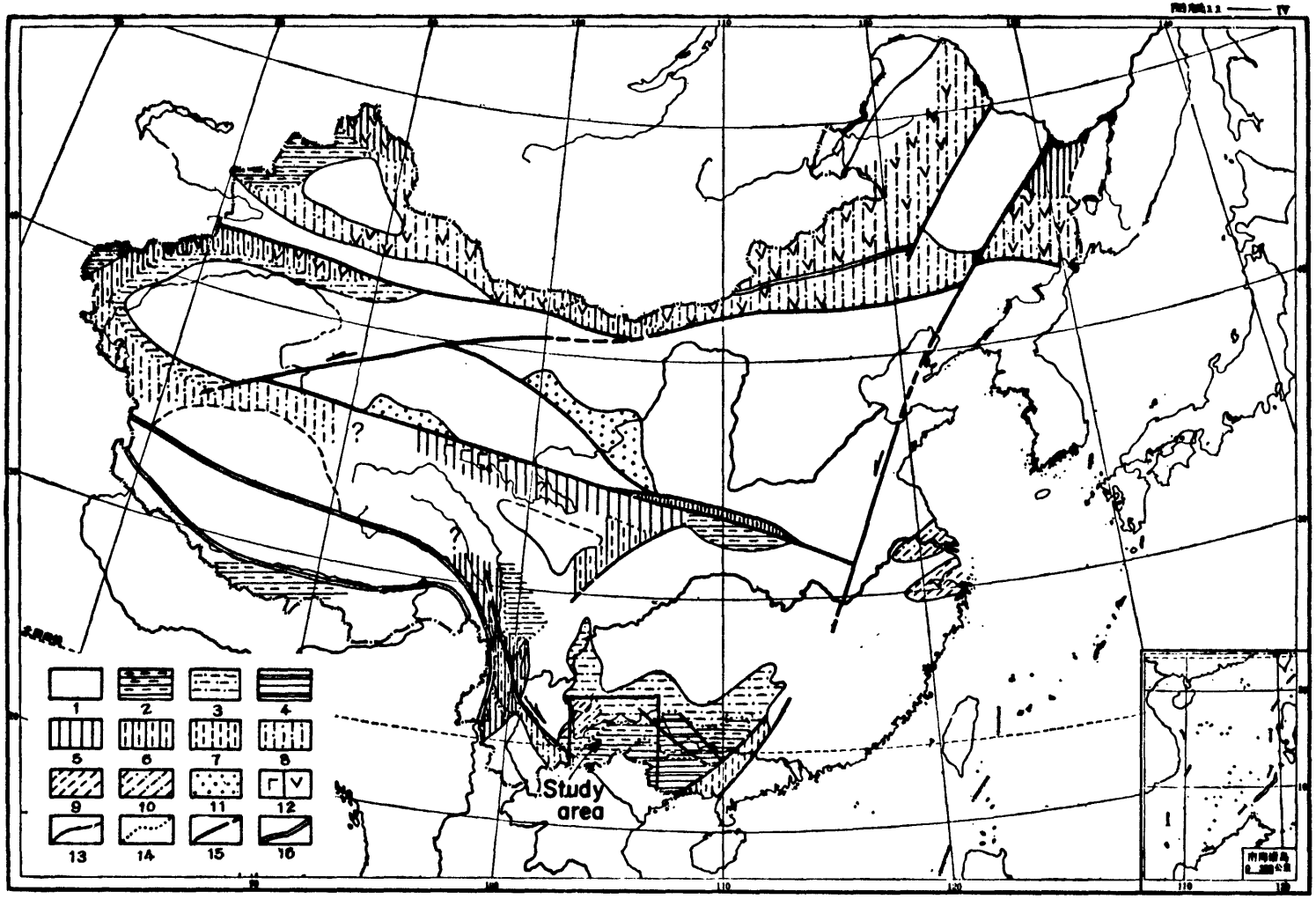


Figure 12.--Early Devonian paleogeography and types of sedimentation of China (after Wang and Lui, 1980, plate II-IV).

1. Area of denuded old landmass.

2-4. Marine stable types.

2. Chiefly shallow-sea calcareous-argillaceous deposits.
3. Shallow-sea clastic and argillaceous deposits.
4. Argillaceous and siliceous deposits.

5-8. Marine mobile types.

5 Chiefly carbonate deposits.
6. Chiefly calcareous-argillaceous deposits.
7. Chiefly argillaceous flysch and paraflysch deposits.
8. Clastic argillaceous paraflysch deposits.

9-11. Types of continental facies.

9. Continental argillaceous deposits.
10. Fluvial-lacustrine clastic argillaceous deposits.
11. Fluvial coarse-clastic deposits.

12. Basic and intermediate acidic volcanic rocks.
13. Boundary of denuded areas.
14. Boundary of sedimentation types.
15. Late transcurrent fault or boundary fault.
16. Earth's crust suture zone.

open marine carbonate deposits, of which the distribution was controlled by growth faults during deposition (Wang and Liu, 1979, p. 22). The biota is characterized by the occurrence of ammonoids, tentaculites, and pelagic trilobites (Chinese Academy of Geological Sciences, 1979, p. 21). This facies occurs chiefly in western Guangxi and south-central Guizhou.

Mixed facies of the Nandan and Xiangzhou types occur in south-eastern and eastern Yunnan, as well as in western Guizhou.

Carboniferous

The Carboniferous System of the study region is extensively distributed (fig. 2). The sedimentary sequences consist of carbonate rocks, shale, mudstone, and coal. These rocks are defined as the platform type and were deposited in littoral-marine to neritic-marine environments (Chinese Academy of Geological Sciences, 1979, p. 23-25). This system is subdivided, in ascending order, into Lower and Upper stratigraphic units (table 1) in accord with paleontologic evolution, lithologic characteristics, and paleogeographic development (Yang, 1980, p. 167-175). Detailed stratigraphy and fauna contents are listed in the appendix.

Lower Carboniferous

The Lower Carboniferous of this region is represented by the Fengning Series and consists of littoral-marine shelf to neritic-open marine sedimentary sequences.

In southeastern Yunnan, the Lower Carboniferous is represented by the Dunei Formation in the lower part and the Weixian Formation in the upper part (Institute of Geological Academia Sinica, 1958, p. 97-98).

The Dunei Formation is dark-blue, relatively thin-bedded limestone and is exposed in the northern part of Shipingxian and along the sides of Yuanjiang. This formation contains Pseudoralinia, Zophiertis, and Cyathophyllum, etc. Thickness data are not available.

The Weixian Formation consists chiefly of dark-gray, dense, thick-bedded, dolomitic limestone, which is intercalated locally with sandstone and mudstone in the lower part, chert bands and purplish-green shale in the middle part, and limestone-breccia in the upper part. In the areas of Mengzi and Jinping, the thick-bedded limestone of the upper part is dense and brittle and contains fossil corals, crinoids, blastoids, and fusulinids. This limestone grades downward into gray, thin-bedded limestone,or interbedded shale and sandstone. The thin-bedded limestone commonly contains coarse-grained sand and abundant fossil corals, crinoids, and brachiopods. The shale is black and is interlayered with carbonaceous shale, thin-bedded marl, and coal. The thickness of this unit is estimated to be more than 500 m.

The Lower Carboniferous stratigraphy of eastern Yunnan is generally similar to that of southeastern Yunnan. In eastern Yunnan, the Lower Carboniferous sedimentary sequence is subdivided, in ascending order, into the Gelaohe Formation, the Shangsijiusi Formation, and the basal portion of the Upper Limestone (Institute of Geological Academia Sinica, 1956, p. 426-427).

The Gelaohe Formation is chiefly pale-gray or grayish-black, planar-laminated, sandy dolomite and dolomite, which contain small amounts of pure limestone. Locally, this formation has a distinctive lithologic progression. Generally, the dolomite of this formation contains more quartz sand and clay

in the basal part; is intercalated with bands of chert and bluish-green, thin-bedded shale in the middle part; and limestone near the top, which is yellowish-gray and marly, as it is in the vicinity of Kunming. In the north of Zhanyi, this formation consists chiefly of blocky dolomite and attains a maximum thickness of 400 m. The thickness of this unit increases to the northeast and generally ranges from less than 20 to about 400 m.

The Shangsi-Jiusi Formation consists of a coal-bearing facies and basin margin facies. The coal-bearing facies is made up of black, carbonaceous, light-gray quartzose sandstone, bauxite-beds, and several beds of anthracite, and attains a thickness of more than 50 m. Toward the west, the coal-bearing facies changes into limestone breccia of the basin margin facies in the areas of Yuxi, Anning, and Luquan, and attains a thickness of less than 35 m.

The basal part of the "Upper Limestone" conformably overlies the Shangsi-Jiusi Formation in several places in eastern Yunnan. Locally, this unit consists of a 1- to 8-m thickness of limestone containing basal chert concretions. The thickness is unknown.

The Lower Carboniferous (Fengninian Series) in south-central Guizhou is subdivided, in ascending order, into the Gelahoe Formation, the Tangbagou Formation, the Jiusi Formation, the Shangsi Formation, and the Laoganzhai Limestone. It is well exposed in the area of Dushan.

The Gelaohe Formation is made up of light-gray to gray, very fine-grained, thick-bedded, dolomitic limestone and dolomite in the lower part, and dark-gray to black, thin- to thick-bedded, very fine-grained limestone, which is intercalated with black shale, in the upper part. The thickness of this formation is about 280 m.

The Tangbagou Formation consists generally of quartzose sandstone or quartzite and is intercalated with grayish-black and impure limestone, sandstone, shale, carbonaceous shale, and thin coal beds. The thickness varies greatly locally, but in the vicinity of Dushan, it is about 190 m.

The Jiusi Formation consists of marine and continental deposits of bluish-gray, impure, thin-bedded limestone intercalated commonly with black, coal-bearing shale in the lower part in the area between Jiusi and Liuzhai, Datang, southeast of Guiyang. Southwesterly from Datang, the Jiusi changes into quartzose sandstones intercalated with 60 meters of thin-bedded clay and coral-bearing shale, then grades upwards into 50 meters of gray, thin-bedded and impure limestone interbedded with shale, then up into 100 meters of quartzose sandstone and small amounts of gray shale in the area between Tangbagou and Heishiguan, Dushan. Northwesterly from Dushan, the Jiusi is made up chiefly of light-gray quartzose sandstone commonly intercalated with grayish-yellow, black shale and fire clay with coal beds in the black shale of the upper part of this sequence in the area of Mazonling, about 10 km east of Guiyang. In the vicinity of Guizhu, the Jiusi consists chiefly of 5 to 10 meters of black carbonaceous, lenticular shale and anthracite beds, as well as a basal ferruginous sandstone at Yunwushan. The black and carbonaceous shale sequence is overlain by yellow, green, purple, and brittle shale; bauxite beds of 3 to 8 m thick occur in the middle part. Thickness of Jiusi ranges from 10 to 240 m.

The Shangsi Formation consists of dark-blue, pure, brittle, thin-bedded limestone in the lower part and light-gray, thick-bedded limestone in the upper part. Blocky and banded chert masses are common in the limestone, and the lowest thin-bedded part commonly contains carbonaceous shale, coal, and locally thin-bedded quartzose sandstone. In the area of Shangsi, south of Dushan, the thickness of the unit is about 200 m, but it reaches 450 m in the area between Jiusi and Liuzhai, Datang.

The Laoganzhai Limestone consists of dense, pure, fossiliferous dolomitic limestone and dolomite in the vicinity of Dushan. The thickness ranges from 15 to about 400 m.

The Lower Carboniferous of western Guizhou is represented by the Fengninian Series, which includes the Fengning Limestone and the Weining Limestone (table 1). The Fengning Limestone consists of shale and coal and is from 100 to 350 m thick. The Weining Limestone consists of chert, marl, and shale and is from 280 to 800 m thick.

The Lower Carboniferous of the western Guangxi consists of the Laoxu Shale in the lower part and the Xinzhoujie Limestone in the upper part (Institute of Geology, Academia Sinica, 1956, v. 1, p. 508).

The Laoxu shale is black and carbonaceous and is intercalated with black or dark-gray, thin-bedded limestone. It is exposed in the area between Hechi and Nandan. The thickness of this unit is about 200 m.

The Xinzhoujie Limestone is light-gray and thick-bedded. Most of the formation was metamorphosed into marble in contact with intrusive rocks. Cassiterite is common in the marble. Stratigera gigantus Grabau occurs in this unit. The limestone is well exposed in the vicinity of Xinzhoujie, Nandan. The thickness is 20 m.

Upper Carboniferous

The Upper Carboniferous of this region is represented by the Hutian Series and consists chiefly of neritic, marine carbonate rocks (Chinese Academy of Geological Sciences, 1979, p. 23-26).

In southeastern Yunnan, the Upper Carboniferous is represented entirely by the Maping Group (table 1), which is made up of light-red to light-gray, brittle, thin-bedded limestone in the upper part, and yellowish-gray, gray or black, impure limestone interbedded with blocky limestone and some coal in the lower part.

The Upper Carboniferous stratigraphy of eastern Yunnan is generally similar to that of southeastern Yunnan, and it has been studied in detail during the past. In this region, the Upper Carboniferous is represented by the Weining Group in the lower part and the Maping Group in the upper part.

The Weining Group consists chiefly of medium-gray or grayish-black, well laminated, sandy, dolomitic limestone, dolomite and rather pure limestone. Most of these carbonate rocks are bioclastic with abundant corals and brachiopods. In the lower part of the group, brecciated marlstone is exposed locally, or in the northwestern suburb of Kunming. In the middle part, bauxite is intercalated with marly limestone, and quartzose sandstone crops out locally along the eastern margin of the ancient central-Yunnan swell. The thickness of this unit ranges from 30 m in the west and south of this region to more than 300 m in the northeast and east of this region.

The Maping Group is composed of basin marginal and neritic sedimentary facies. The basin marginal facies consists of sandy shale, which is often intercalated with poor quality coal beds and bauxite layers. The neritic facies is made up of light-gray and grayish-black, clayey, impure limestone, black shale, thin coal, and bauxitic clay. This unit is sporadically distributed throughout eastern Yunnan and contains fossil protozoans, hydrozoan corals, crinoids, blastoids, brachiopods, and pelecypods. Thickness ranges from 10 to 100 m.

The Upper Carboniferous in south-central Guizhou is represented by the Laoganzhai Limestone in the lower part and the Maping Limestone in the upper part (Yang and others, 1979) (Yang Shipu and others, 1980).

The Laoganzhai Limestone is light-gray and locally light-pink, pure to dolomitic, and thick bedded. It is well distributed in the areas of Dushan and Longli and thins out toward the north. The thickness of this unit varies from 15 to about 400(?) m.

The Maping Limestone is light-gray to gray, pure, and thick-bedded. It is sporadically exposed in the vicinity of Dushan and contains Pseudoschwagerina princeps Enrenberg. The thickness of this unit varies from zero to about 30 m.

The Upper Carboniferous in western Guizhou is similar to that of eastern Yunnan, except that it is much thicker in western Guizhou. It is also represented locally by the Weining Group in the lower part and the Maping Group in the upper part.

The Weining Group consists of light-gray to dark-gray, cherty, thin- to thick-bedded limestone and dolomitic limestone, both of which contain abundant fossil corals, fusulinids, crinoids, brachiopods, and cephalopods. It is well distributed in the area of Hezhang, Shuicheng, and Puan. The thickness ranges from 280 to 500 m.

The Maping Group consists of dark-gray and yellowish-gray, calcareous shale, and blackish-gray, clayey limestone, locally containing beds of sandstone in the lower part; blackish-gray, clayey limestone, which is intercalated with light-gray, crystalline, and pure limestone, and gray to blackish-gray, calcareous shale in the middle part; and light-gray and gray, cherty, dolomitic, and thin- to thick-bedded limestone in the upper part. It is widely exposed in the areas of Hezhang, Shuicheng, Puan, Panxian, Zhijin, Zhenfeng, and Cean. This unit contains abundant fossil fusulinids, brachiopods, crinoids, and cephalopods. It ranges in thickness from 40 to 600 m.

The Upper Carboniferous in western Guangxi consists of the Huanglong Limestone in the lower part and the Maping Limestone in the upper part (Yang and others, 1979, chart 1).

The Huanglong Limestone is dark-gray, cherty, blocky and thin- to thick-bedded limestone and is locally intercalated with beds of cherty nodules. The thickness is 150 m in the areas of Hechi and Nandan.

The Maping Limestone consists of black, cherty, thin-bedded limestone in the lower part; and light-gray and gray, crystalline, fusulinid-bearing limestone in the upper part. It is well exposed in the areas of Hechi, Nandan, Tiane, Fengshan, Lingle, Tianyang, Tiandong, Debao, Longming, Fusui, and Chongzuo. This unit is from 250 to 300 m thick.

General paleogeography and deposition of the Carboniferous System

The Carboniferous System has been deposited extensively in western and south-central Guizhou, and at present this system is subdivided into the Lower and Upper Carboniferous series on the basis of sedimentation cycles, diastrophism, and faunal assemblages (Yang and others, 1979; Xing and others, 1979, p. 23-26) (fig. 13).

The paleogeography and deposition of the Carboniferous System in the study area were solely controlled by the after effects of the late stage of the Caledonian orogenic movements during Late Silurian and Early Devonian time, but the early stage of the Variscan movements had only slight affects throughout the study area (Huang and others, 1980, p. 24-25). Commencing with Caledonian movements, the South China fold system was formed on the south side of the Yangzi (Chang Jiang) paraplatform (fig. 6). Scattered lowlands developed in eastern Yunnan and western and south-central Guizhou. Similarly, uplands were scattered in southeastern Yunnan and northwestern Guangxi. During the Carboniferous Period, the seas were generally larger than those of the Devonian. The transgression of the sea during deposition of the Fengninian Series came from south of the study region. This sea passed through the seaways in the old Vietnam landmass on the south, and encrouched on the Chuan-Dian landmass on the west, the upper Yangzi (Chang Jiang) and Jiangnan landmass to the north, and the Yunkai landmass to the east (figs. 14, 15, and 16). During regression in the middle part of the Fengninian sequence, coal was formed in coastal delta, lagoon, bay, and coastal plain environments (Han and Yang, 1980, p. 160-163).

The Weixian Formation and Laoxu Shale were probably deposited in bay and lagoon environments and are characterized by prominent argillaceous rocks. The Shangsi-Jiusi Formation of eastern Yunnan was formed in a coastal delta environment indicated by well developed sandy detrital rocks. The Fengning Limestone sequence of western Guizhou was formed chiefly in a coastal-plain environment characterized by fine-grained detrital rocks. The coal beds of the Tangbagou, Jiusi, and Shangsi Formations were deposited in coastal-delta and coastal-plain environments, as indicated by the prominent arenaceous and detrital rocks in association with bauxitic layers.

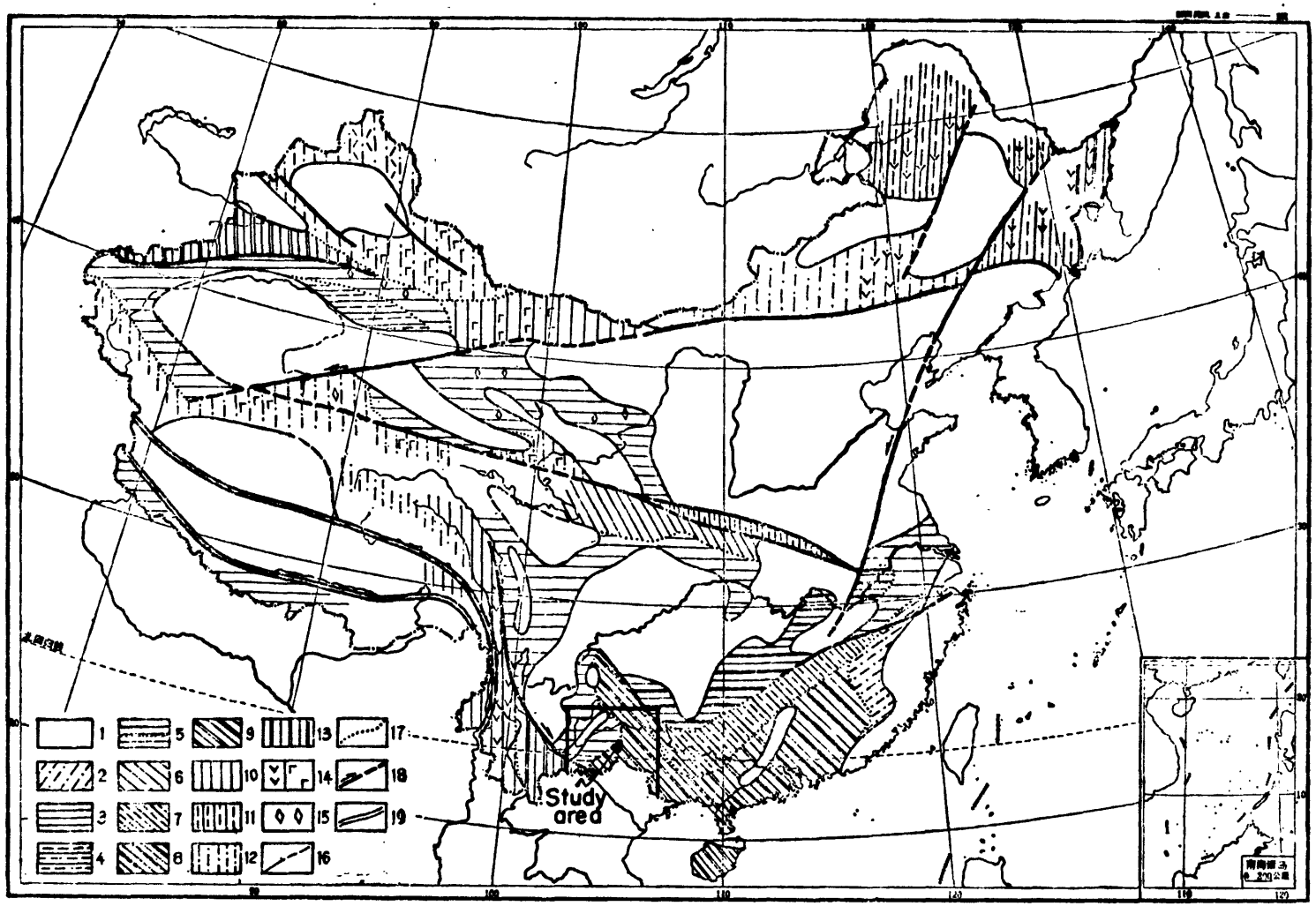


Figure 13.--Early Carboniferous paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 12-III).

1. Area of denuded old landmass.
2. Continental clastic argillaceous deposits.

3-5. Marine stable types.

3. Chiefly shallow-sea carbonate deposits.
4. Shallow-sea carbonate and argillaceous deposits.
5. Shallow-sea calcareous-argillaceous deposits.

6-9. Marine transitional types.

6. Chiefly carbonate deposits.
7. Carbonate and arenaceous-argillaceous deposits.
8. Early calcareous-argillaceous and late coal-bearing deposits.
9. Littoral marine argillaceous and siliceous deposits.

10-13. Marine mobile types.

10. Chiefly carbonate deposits.
11. Calcareous-argillaceous paraflysch deposits.
12. Clastic argillaceous flysch deposits.
13. Semi-deep sea siliceous carbonate and argillaceous, siliceous deposits.

14. Volcanic rocks.
15. Evaporites.
16. Boundary of areas of sedimentation as well as marine/continental demarcation.
17. Boundary of sedimentation types.
18. Boundary fault and late transcurrent fault.
19. Earth's crust suture zone.

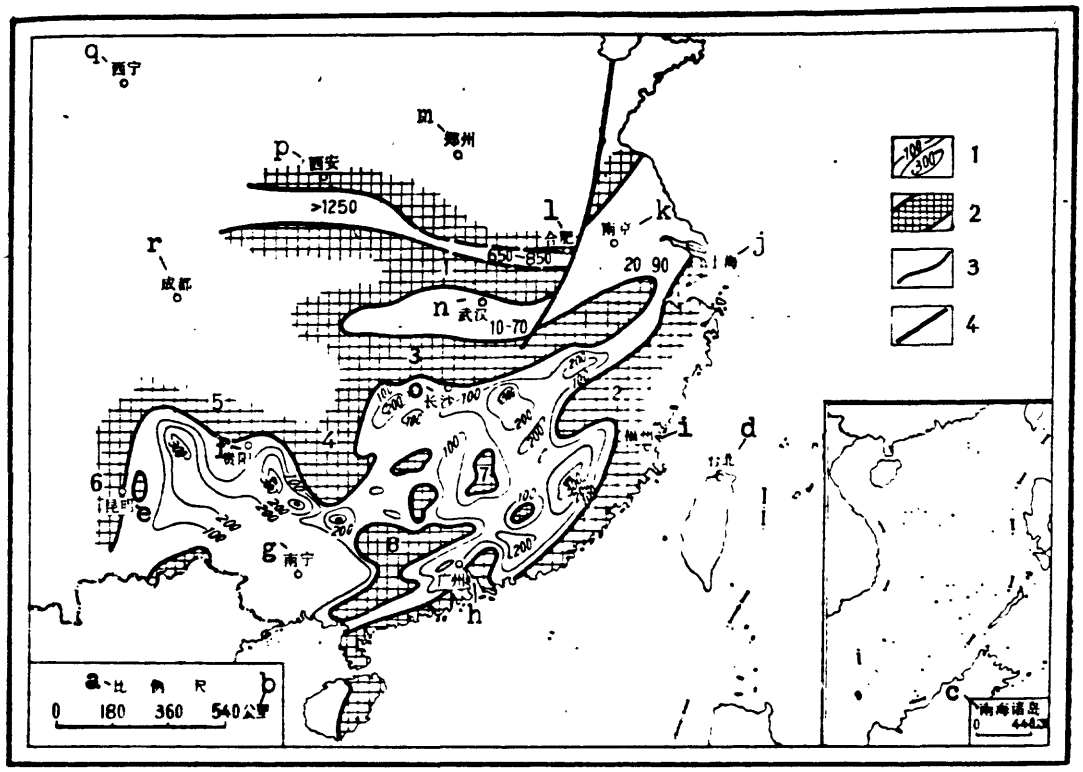


Figure 14. Isopachs of coal-series of the Lower Carboniferous Weixian coal accumulation stage, South China (after Department of Coal Teaching and Researches, Wuhan Geologic College, fig. III - 36, p. 35)

1. Isopachs of coal-series. 2. Area of uplift. 3. Boundary of uplift. 4. Faulting after coal accumulation.

Names of uplift: 1 - Dabieshan uplift. 2 - Cathysian uplift.
3 - Jiangnan uplift. 4 - Xuefeng uplift.
5 - Qianbei uplift. 6 - Chuan-Dian uplift.
7 - Zhuguang uplift. 8 - Yunkai uplift.

a. Scale. b. Kilometers. c. Islands of South China Sea.
d. Taibei. e. Kunming. f. Guiyang. g. Nanning. h. Guangzhou.
i. Fuzhou. j. Shanghai. k. Nanjing. l. Hefei. m. Zhengzhou.
n. Wuhan. o. Changsha. p. Xian. q. Xining. r. Chengdu.

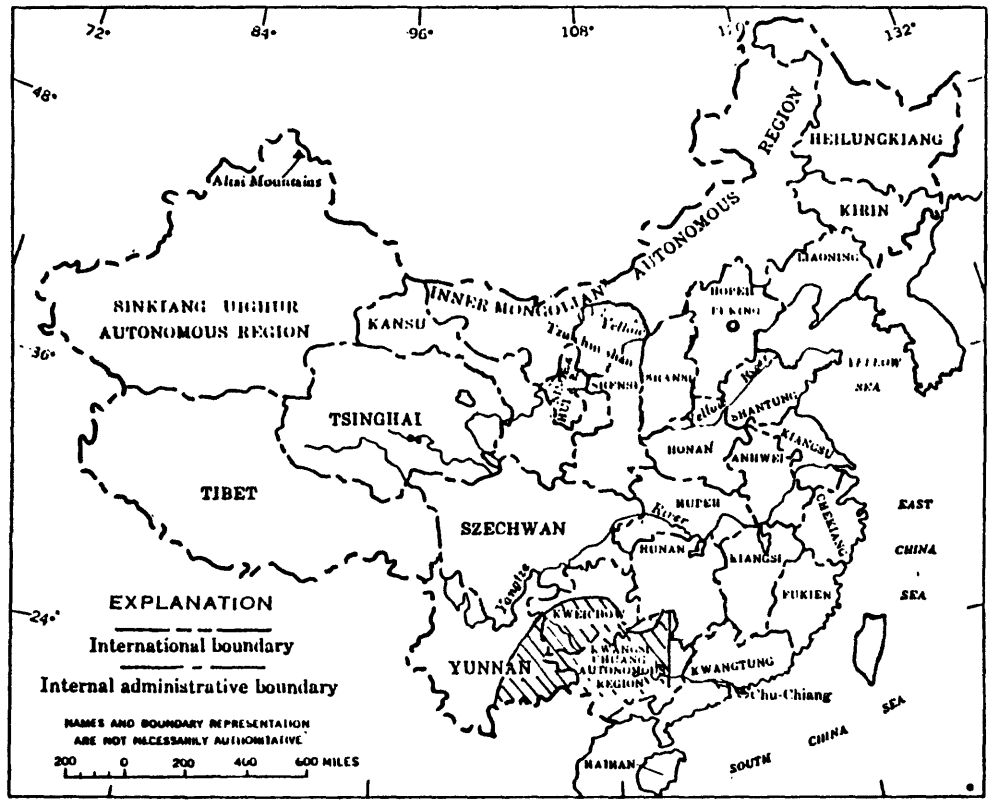


Figure 15. Index map of China showing the approximate location and coverage of Figure 16 (provincial names are in Wade-Gile spelling)

Area of approximate coverage

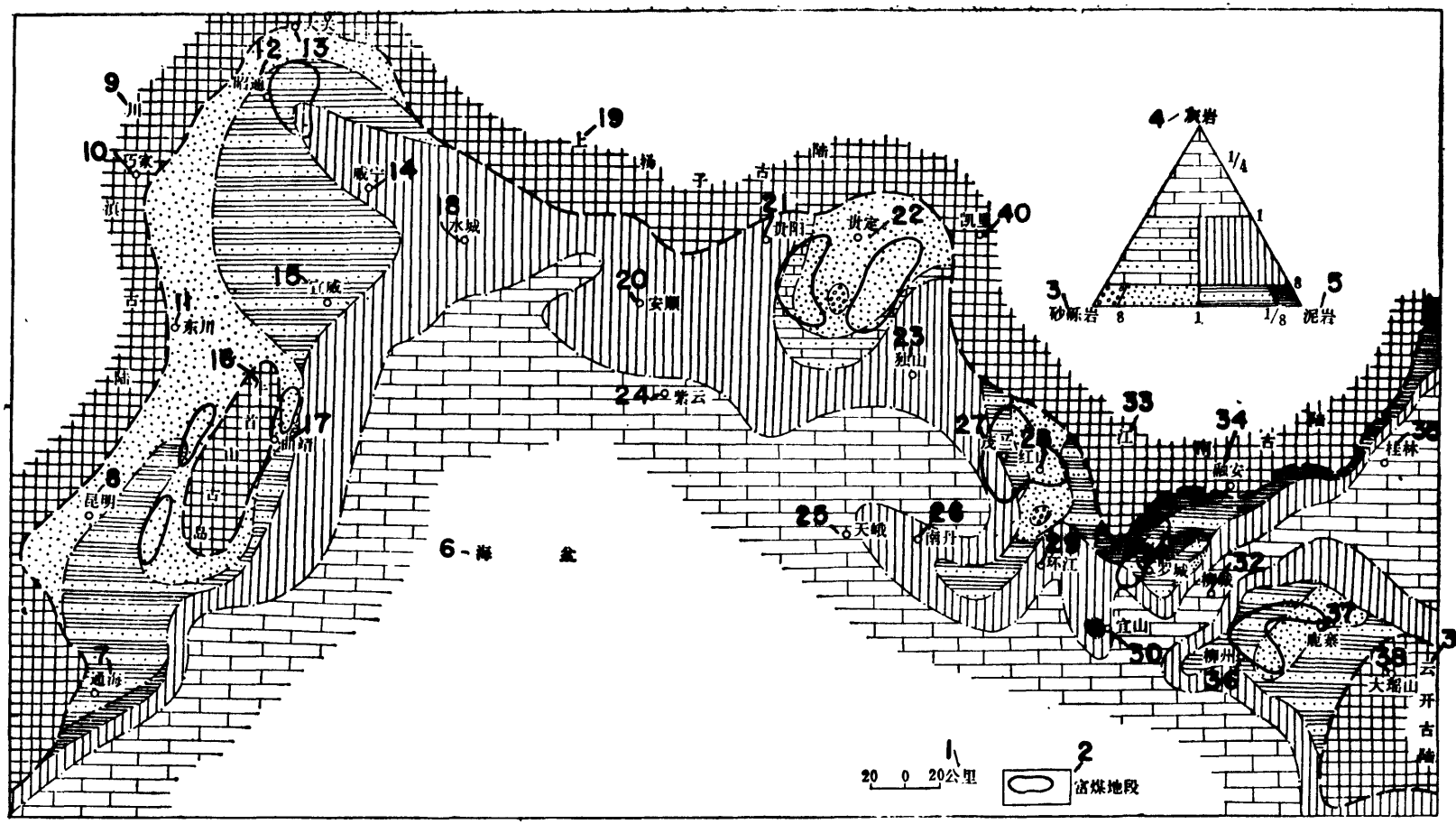


Figure 16.--Lower Carboniferous coal-bearing sedimentary rock ratios and characteristics in the western depositional region of South China (after Han and Yang, 1980, figs. 4-50, p. 161).

1. Kilometers
2. Area of rich-coal deposits.
3. Sandy conglomerate
4. Limestone
5. Mudstone.
6. Sea basin.
7. Tonghai.
8. Kunming.
9. Chuandian old landmass.
10. Qiaojia.
11. Dongchuan.
12. Zhaotong.
13. Daguan.
14. Weining.
15. Xuanwei.
16. Niushoushan ancient island.
17. Qujing.
18. Shuicheng.
19. Upper Yangzi old landmass.
20. Anshun.
21. Guiyang.
22. Guiding.
23. Dushan.
24. Ziyun.
25. Tiane.
26. Nandan.
27. Maolan.
28. Hongshan.
29. Huanjiang.
30. Yishan.
31. Luocheng.
32. Liucheng.
33. Jiangnan old landmass
34. Rongan.
35. Guilin.
36. Liuzhou.
37. Luzhai.
38. Dayaoshan.
39. Yunkai old landmass.
40. Kaili.

Permian

The Permian System of the study region is the type locality of the Permian marine sedimentary sequences in South China (fig. 2). The sedimentary sequences consist of Lower Permian marine cherty, blocky limestone with basal coal-bearing shoreline deposits, and Upper Permian marine and continental coal-bearing cherty limestone, shale, and basal sandstone. Generally the Permian in China is divided into two parts. The Yangxin Series represents the Lower Permian and the Laoping Series represents the Upper Permian (Institute of Geology, Academia Sinica, 1956) (table 1). Detailed stratigraphy and faunal contents are listed in the appendix.

Lower Permian

The Lower Permian of the study region is represented by the Yangxin Series and consists of littoral marine shelf to neritic open-marine sedimentary sequences.

In southeastern Yunnan, the Lower Permian Yangxin Series consists of alternating dark-gray and light-gray, thick-bedded limestone, with a basal conglomerate in the lower part, and dark-gray, pure, brittle and blocky limestone in the upper part. The thickness of the Yangxin is estimated to be about 100 m.

The Yangxin Series of this area is overlain by the Emeishan Basalt. This basalt is chiefly amygdaloidal, dark, and aphanitic. The vesicles are filled with zeolites. Generally this basalt has distinct flow layers and contains tuffaceous shale interbeds. The thickness ranges from 50 to 100 m. Formerly this unit was assigned to the upper part of the Yangxin Series, but at present it is assigned to the lower part of the Upper Permian Series (Wang and Lui, 1980, p. 208-209).

In eastern Yunnan, the Lower Permian consists of, in ascending order, the Qixia Limestone and the Maokou Limestone, which are overlain by the Emeishan Basalt. The Qixia Limestone of eastern Yunnan is mostly light-gray, bluish-gray to blackish-gray, crystalline, blocky or thick-bedded limestone and dolomitic limestone. Partially, this carbonate sequence contains chert concretions or bands. The thickness of the Qixia is estimated to range from 50 to 300 m.

The Maokou Limestone consists of light-gray to gray, pure to impure, dolomitic, blocky to thick-bedded limestone and commonly contains layers and concretions of black chert. Locally it contains limestone breccia and is intercalated with sandy shale and sandstone near the base. The thickness of the Maokou ranges from 150 to 400 m.

The Emeishan volcanics consists of basalt, andesite, tuff, and a small number of thin layers of rhyolite; locally the flows incorporate tuffaceous shale in the upper part, tuff and agglomerate in the middle part, and sandy

or copper-bearing shale in the lower part. The thickness of the unit ranges from several meters to as much a 1,000 m. The thickest flow sequences occur in the area between Chenggong and Jinning.

In south-central Guizhou, the Lower Permian Yangxin Series is represented by three stratigraphic units: Coal-bearing Formation, Qixia Limestone, and Maokou Limestone (table 1). The Coal-bearing Formation is made up of yellowish-white or brownish-yellow quartzite, quartzose sandstone, and yellowish-brown and black, sandy shale, containing several thin coal beds and locally impure limestone. The thickness of this unit ranges from zero to 50 m.

The Qixia Limestone consists mostly of dark-gray or dark-blue, thin- to thick-bedded, cherty limestone in which the lower part locally contains bituminous-rich, thin-bedded limestone with black calcareous, clayey shale or black chert layers. The thickness of the Qixia is 120 to 500 m, and the thickest sequence occurs in areas of Longli and Guiding.

The Maokou Limestone is light-gray, gray, pure, blocky and contains a small amount of chert concretions. After weathering, it generally forms "stone-forest" karst landforms. This unit ranges in thickness from 40 to 250 m; the thickest sequence occurs in the areas of Longli and Guiding.

The Emeishan basalt is missing throughout this region.

In western Guizhou, the Yangxin Series consists of similar stratigraphic units as in south-central Guizhou, but the total thickness of the series is much greater in western Guizhou than in south-central Guizhou. The Coal-bearing Formation comprises yellowish-gray quartzite, quartzose sandstone, and blackish-gray shale, which are intercalated with blackish-gray, thin-bedded or lenticular, clayey limestone and coal beds. It is well exposed in the areas of Shuicheng, Puan, Panxian, Qinglong, Langdai, Guanling, and Cexiang. The thickness of this unit ranges from 2 to 130 m.

The Qixia Limestone is made up of bluish-gray to dark-gray, cherty, thin-bedded limestone in the lower part and bluish-gray to grayish-black, cherty limestone in the upper part. It is about 450 m thick.

The Maokou Limestone is light-gray to dark-gray, dense, thick-bedded, fossiliferous, and blocky limestone. The thickness ranges from 200 to 600 m.

The Emeishan basaltic flow consists of dark-gray, aphanitic, amygdaloidal basalt; locally it contains gray rhyolite and a tuffaceous shale in the upper part. The thickness of this unit ranges from 50 to 400 m.

In western Guangxi, the Lower Permian is represented by the Qixia Limestone and the Maokou Limestone. They are well exposed in parts of Hechi, Jandan, Lingle, Donglan, and Tiandong. The Qixia Limestone is black, thin- to thick-bedded limestone, which contains chert concretions and lenticular layers. The thickness of the Qixia is about 150-200 m.

The Maokou Limestone consists of light-gray to gray, thick-bedded limestone, which contains chert concretions in the lower part and dark-gray, thick-bedded limestone in the upper part. The thickness of the Maokou is about 250-300 m.

Upper Permian

The Upper Permian of the study region is represented by the Laoping Series and consists chiefly of marine and coal-bearing continental sedimentary sequences.

In southeastern Yunnan, the Upper Permian is divided, in ascending order, into the Coal Series and the Laoping Series. The Coal Series consists of interbeds of gray, grayish-yellow shale, light-brown, compact sandstone, and coal beds. The thickness of the series is unknown. The Laoping Series consists of light-gray, crystalline limestone. The thickness is not available.

In eastern Yunnan, the Laoping Series occurs along the eastern border of the province and consists of continental, coal-bearing, sedimentary strata. Principal rock types are yellowish-green, brownish-green sandstone, shale, and sandy shale. Several mineable coal beds occur in the lower part of the sequence and generally average 3 m thick. Locally, conglomerate occurs near the base. The Laoping ranges in thickness from 50 to 250 m.

In south-central Guizhou, the Upper Permian Laoping Series consists of three formations, in ascending order: the Zhutang Formation, Changxing Limestone, and Dalong Formation. Well-exposed beds occur in the areas of Guiying, Longli, and Duyun.

The Zhutang consists chiefly of marine sedimentary facies, which is intercalated with detrital continental facies. In south-central Guizhou, the Zhutang Limestone is made up of dark-gray, thin-bedded, cherty limestone with concretions and lenses of chert. This limestone is commonly overlain by brownish-gray, gray, yellowish-gray shale and fire clay; it is underlain by coal-bearing carbonaceous shale, cherty beds, coal beds, and ferrugineous sandstone. The Zhutang beds are well exposed in the areas of Guiyang, Longli, Duyun, and Libo; the thickness is 560 m.

The Changxing Limestone is gray to dark-gray, thick-bedded, blocky, and, in part, crystalline limestone; it commonly contains cherty nodules and lenses of chalk, and is intercalated locally with thin-bedded calcareous shale. It is well exposed in the vicinity of Guiyang. Thickness of the Changxing ranges from 50 to 120 m.

The Dalong Formation consists of interlayers of yellowish-gray chert beds and clayey, sandy, calcareous shale or thin-bedded, cherty limestone. At the base of the Dalong, coal beds are present locally. The thickness of the Dalong ranges from zero to 35 m.

In western Guizhou, the Upper Permian is represented, in ascending order, by the Longtan Formation, Changxing Limestone, and Dalong Formation.

The Longtan Formation consists chiefly of brownish-yellow, greenish-gray, yellowish-gray, and black sandstone and shale (locally with a 10-meter thickness of basal quartzite), which are intercalated with a small amount of thin-bedded, clayey limestone. This formation contains numerous coal beds; the thickest coal bed is about 2 m. The shale is mostly siliceous or sandy, in part calcareous, and locally contains siderite concretions. The Longtan beds are well exposed in the areas of Bijie, Dading, Qianxi, Anshun, Zhening, Zhenfeng, Xingren, Xingyi, Panxian, Puan, Liangdai, and Shuicheng. The thickness of this formation ranges from 10 to 400 m.

The Changxing Limestone is chiefly of dark-gray and cherty limestone, which is intercalated with yellow and dark-green sandstone, shale, and sandy shale. The limestone is generally brittle and the shale is carbonaceous. Good exposures are in the areas of Zhenning, Guanling, Xingren, and Zhenfeng. The thickness of the Changxing ranges from 30 to 100 m.

The Dalong Formation consists mostly of yellowish-gray and, locally, green shale, which is intercalated with light-gray, thin-bedded limestone. It is well exposed in areas of Dushun and Zhenning. The thickness of the unit ranges from 2 to 10 m.

In western Guangxi, the Upper Permian is represented by the Heshan Formation and Dalong Formation (table 1). Exposures are scattered throughout the areas of Duan, Tiane, Donglan, Fengshan, Lingle, and Tiandong.

The Heshan Formation comprises chiefly dark-gray, black, cherty, thin-bedded limestone, which is generally intercalated with thin-bedded shale in the lower part; it contains red, iron-bearing sandstone at the base. The thickness of the Heshan ranges from 60 to 200 m.

The Dalong Formation is made up chiefly of purplish-black, calcareous shale, which yields Ullmannia aff. bronni and Trilobites. The thickness of the unit is about 15 m.

General paleogeography and deposition of the Permian System

The Permian platform sedimentary sequences were deposited in relatively restricted, broad, ocean-basin and shoreline environments during the Lower Permian sea transgression in South China, from the northeast, the northwest, and the southwest (figs. 17, 18, 19, 20, 21, 22, and 23). Most of the old landmasses were submerged and covered by shallow-sea water. In the study area, the Permian coal deposits were formed in delta and barrier beach environments (figs. 18 and 21). Especially along the eastern flank of the Chuan-Dian old landmass in eastern Yunnan and western Guizhou, the coal-bearing sedimentary series is in the marine and continental transitional zone, which bordered the land slope on the west and the offshore calcareous argillaceous shallow marine on the east. Generally, the coal-bearing transitional zone attains a thickness of 10 to 30 m, and locally up to several hundred meters. This zone is characterized by arenaceous and argillaceous rock types.

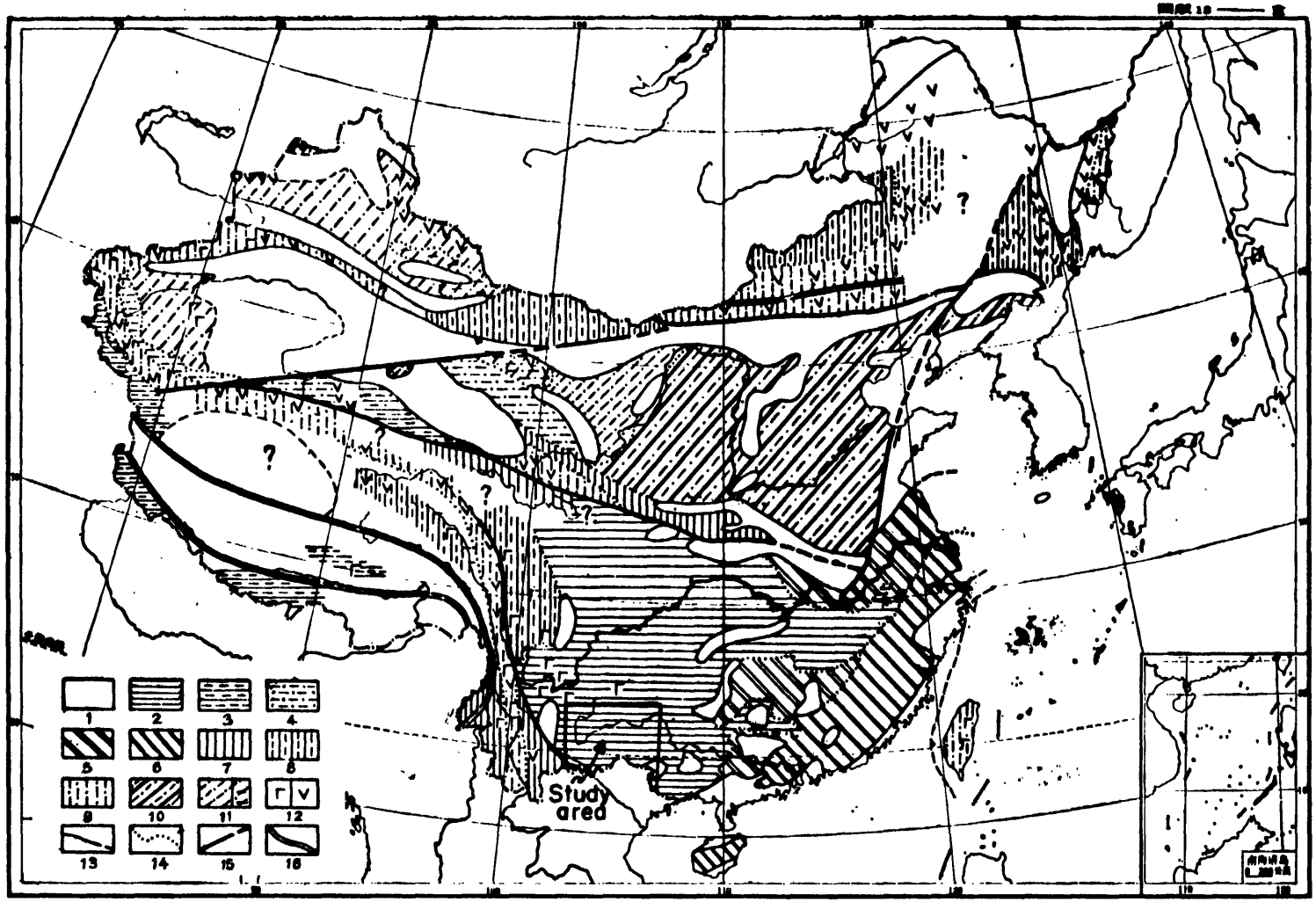


Figure 17.--Early Permian paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 13-III).

Figure 17.--Early Permian paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 13-III).

1. Area of denuded old landmass.

2-4. Marine stable types.

2. Chiefly shallow-sea carbonate deposits.
3. Shallow-sea carbonate and clastic deposits.
4. Chiefly littoral marine clastic deposits.

5-6. Marine transitional types.

5. Early carbonate and late siliceous deposits.
6. Early carbonate and late marine-continental alternating coal-bearing deposits.

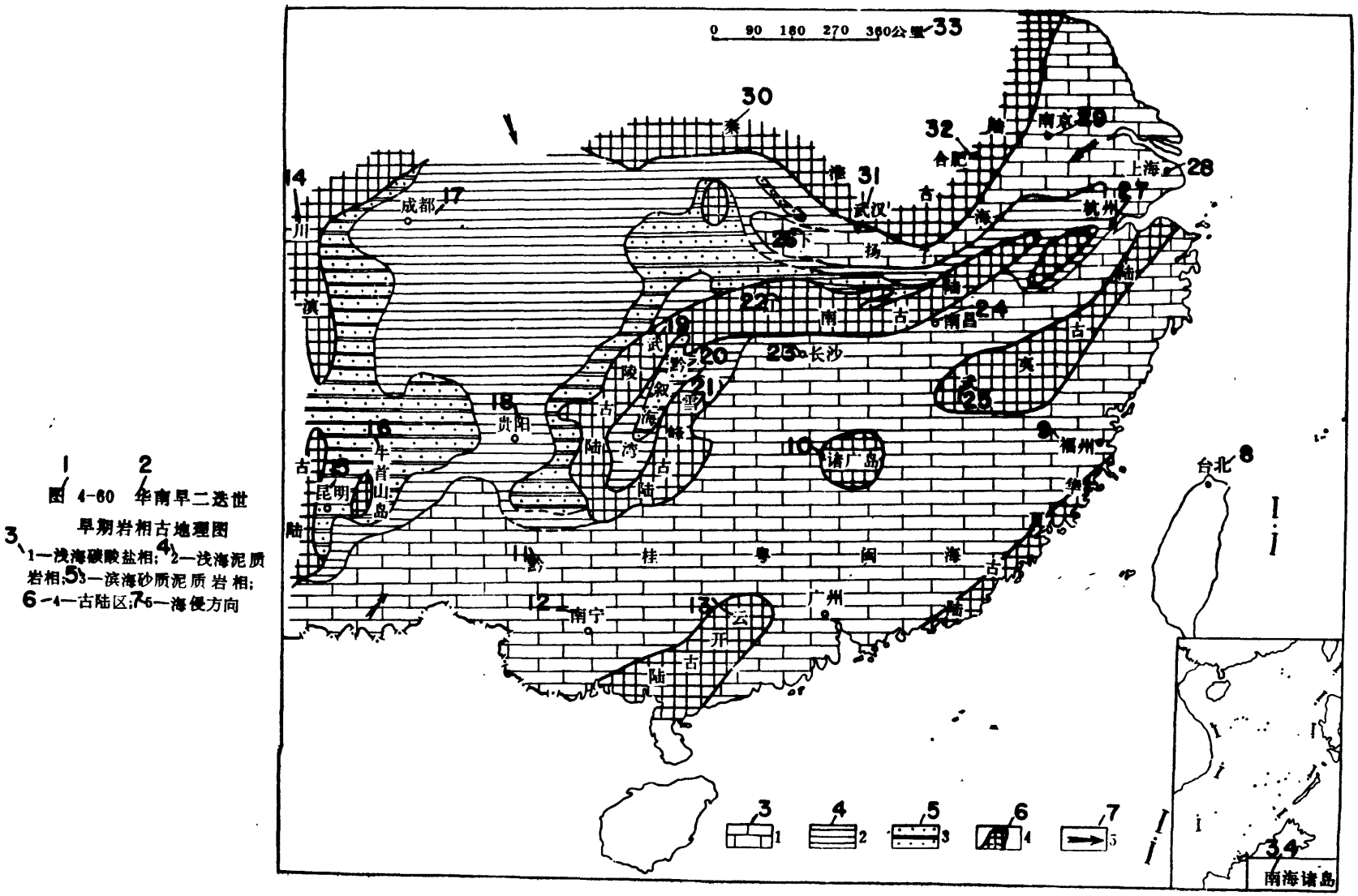
7-9. Marine mobile types.

7. Chiefly carbonate deposits.
8. Clastic and carbonate deposits.
9. Semi-deep sea to shallow-sea clastic deposits, locally containing siliceous beds.

10-11. Continental stable types.

10. Early coal-bearing deposits, and late fulvial-lacustrine clastic deposits.
11. Variegated fluvial-lacustrine clastic deposits containing marine interbeds.

12. Basic or intermediate acidic volcanic rocks.
13. Boundary of the areas of sedimentation as well as marine/continental demarcation.
14. Boundary of the types of sedimentation.
15. Boundary fault and late transcurrent fault.
16. Earth's crust suture zone.



1. Figure 18.
2. Early Lower Permian lithofacies and paleogeography of South China (after Han and Yang, 1980, fig. 4-60, p. 169).

3. Shallow-sea carbonate facies.
4. Shallow-sea argillaceous facies.
5. Coastal arenaceous and argillaceous facies.
6. Area of old landmass.
7. Direction of sea transgression.

8. Taibei
9. Fuzhou.
10. Zhuguang Island
11. Quianguiyuemin Sea.
12. Nanning
13. Yunkai old landmass.
14. Chuandian old landmass.
15. Kunming.
16. Niushoushan Island
17. Chungdu.
18. Guiyang
19. Wuling old landmass.
20. Qianxu bay
21. Xuefeng old landmass.
22. Jiangnan old landmass
23. Changsha.
24. Nanchang.
25. Wuyi old landmass.
26. Lower Yangzi Sea.
27. Hangzhou.
28. Shanghai.
29. Nanjing.
30. Qinhuai old landmass.
31. Wuhan.
32. Hefei
33. Kilometers.
34. Islands of South China Sea.

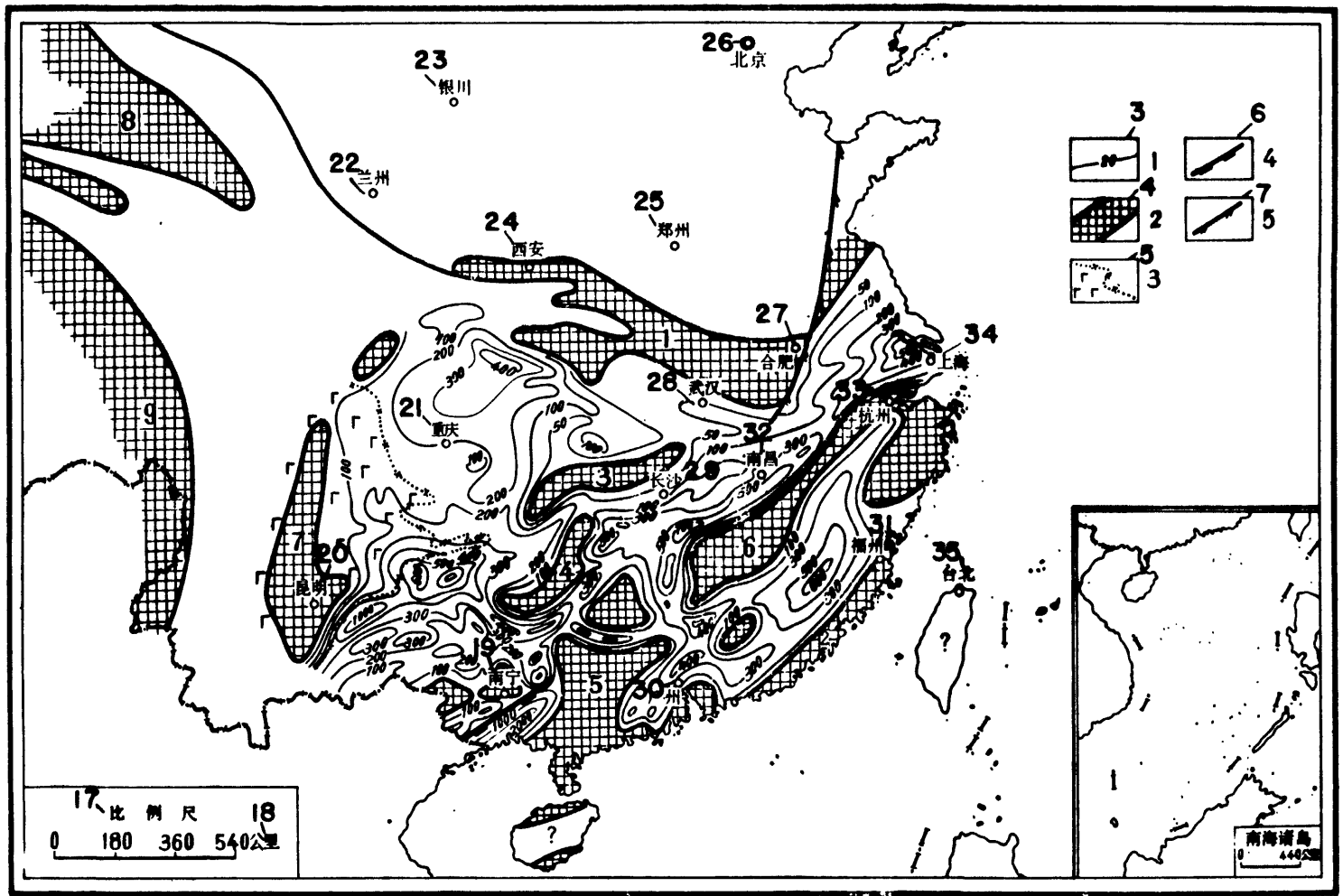


图 Ⅲ—62 华南晚二叠世早期含煤地层等厚线图

1—含煤地层等厚线；2—隆起区；3—晚二叠世早期玄武岩分布区；4—同沉积断裂；5—聚煤期后断裂

隆起区 1—秦岭-大别隆起（包括其分支大巴隆起）；2—华夏隆起；3—武陵-洞庭隆起；4—雪峰隆起；5—云开隆起；6—诸广-怀玉隆起；7—川滇隆起；8—柴达木隆起

1. Figure 19.
2. Isopachs of Early Upper Permian coal-bearing strata of South China (after Department of Coal Teaching and Researches, Wuhan Geologic College, 1980, fig. III-62, p. 69).

3. Isopach of coal-bearing strata.
4. Uplift area.
5. Area of Early Upper Permian basalt.
6. Syndepositional faulting.
7. Faulting after coal accumulation.
8. Areas of uplift.
9. Qinling-Dabieshan uplift (including the Dabieshan discrete units of uplift).
10. Cathysian uplift.
11. Wuling-Dongting uplift.
12. Xuefeng uplift.
13. Yunkai uplift.
14. Zhuguang-Huaiyu uplift.
15. Chuandian uplift.
16. Chaidamu uplift.
17. Scale
18. Kilometers.
19. Nanning.
20. Kunming.
21. Chongqing.
22. Lanzhou.
23. Yinchuan.
24. Xian.
25. Zhengzhou.
26. Beijing.
27. Hefei.
28. Wuhan.
29. Changsha.
30. Guangzhou.
31. Fuzhou.
32. Nanchang.
33. Hangzhou.
34. Shanghai.
35. Taibei.

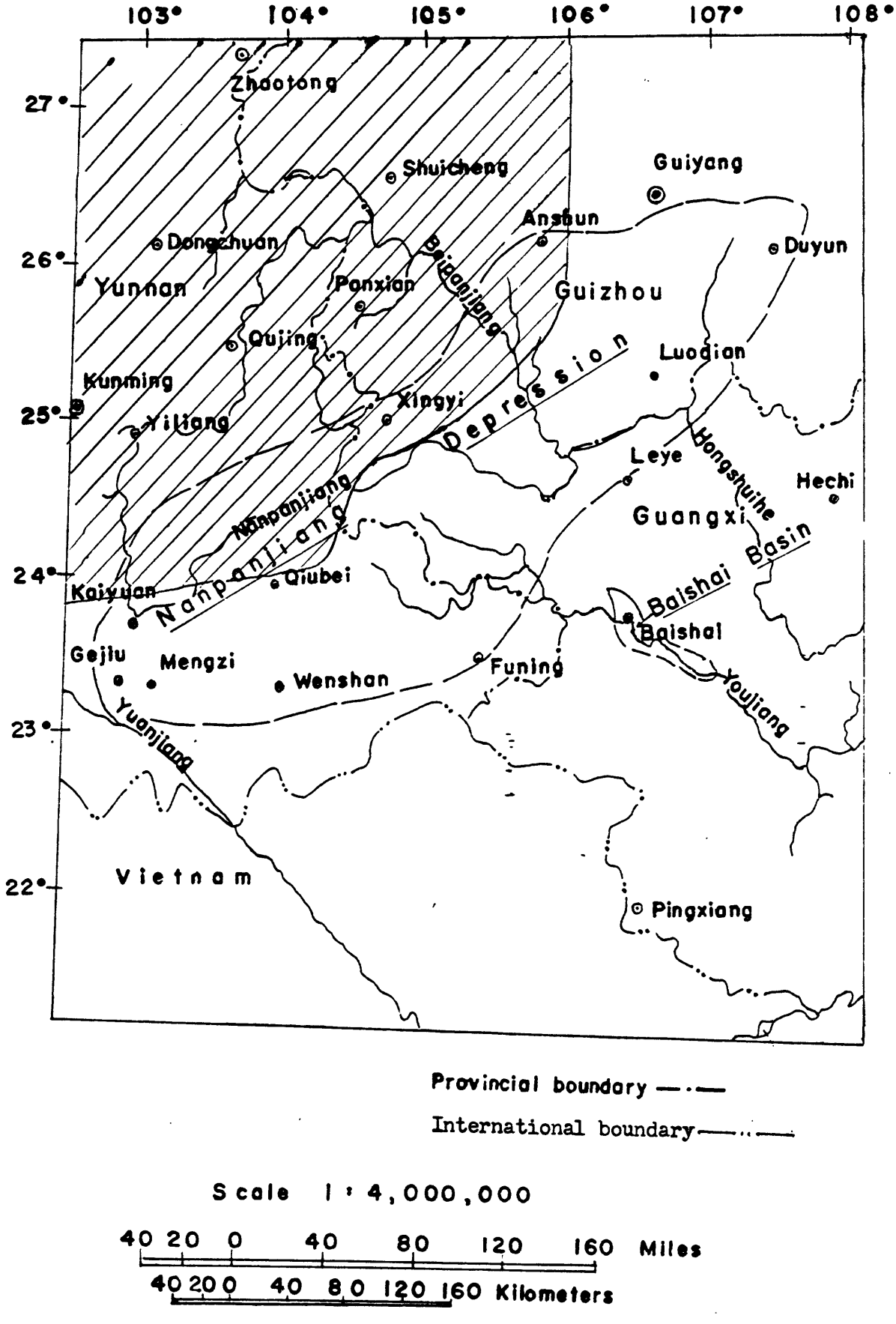


Figure 20.--Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location and coverage of Figure 21.

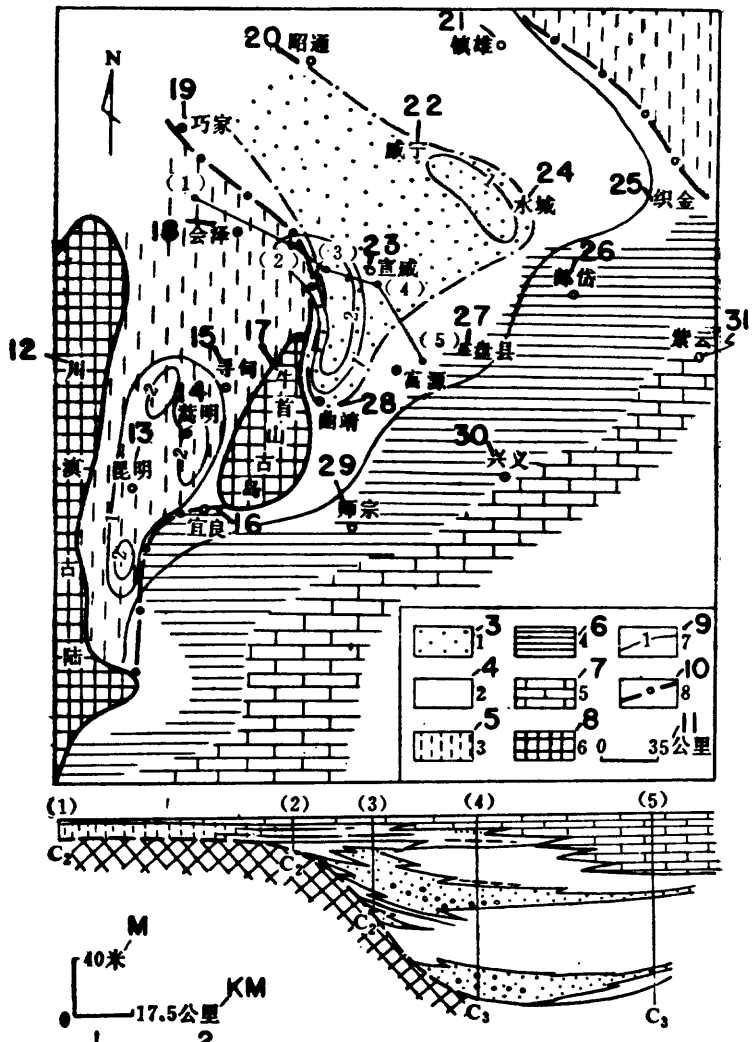


图 4-61 滇东、黔西早二迭世早期岩相古地理示意图

1—三角洲砂砾沉积范围；2—滨海砂、泥质沉积；3—滨海铝土质、泥质沉积；4—浅海泥质、碳酸盐沉积；5—浅海碳酸盐沉积；6—古陆；7—煤层等厚线；8—梁山段初期古陆界线

1. Figure 21.
2. Early Lower Permian lithofacies and paleogeography of eastern Yunnan and western Guizhou (after Han and Yang, 1980, fig. 4-61, p. 170).

3. Area of deltaic sand and gravel deposits.

4. Coastal arenaceous and argillaceous deposits.

5. Coastal aluminous and argillaceous deposits.

6. Shallow-sea argillaceous and carbonate deposits.

7. Shallow-sea carbonate deposits.

8. Old landmass.

9. Isopach of coal seam.

10. Boundary of old landmass at initial stage of Liangshan Member.

11. Kilometers.

12. Chuandian old landmass.

13. Kunming.

14. Haoming.

15. Xundian.

16. Yiliang.

17. Niushoushan ancient island.

18. Huize.

19. Qiaojia.

20. Zhaotong.

21. Zhenxiong.

22. Weining.

23. Xuanwei.

24. Shuicheng.

25. Zhijin.

26. Langdai.

27. Panxian.

28. Qujing.

29. Shizong.

30. Xingyi.

31. Ziyun.

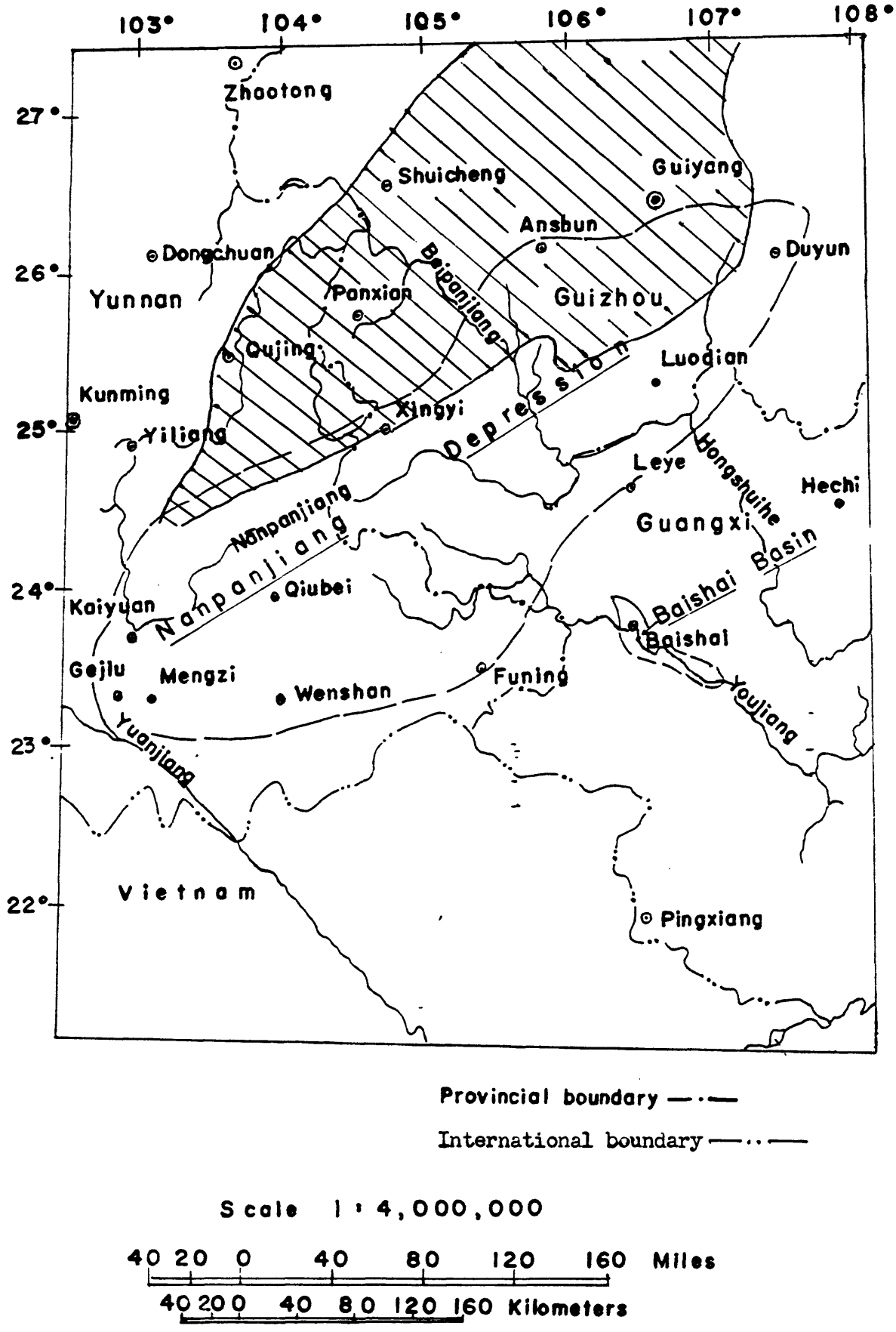


Figure 22.--Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location and coverage of Figure 23.

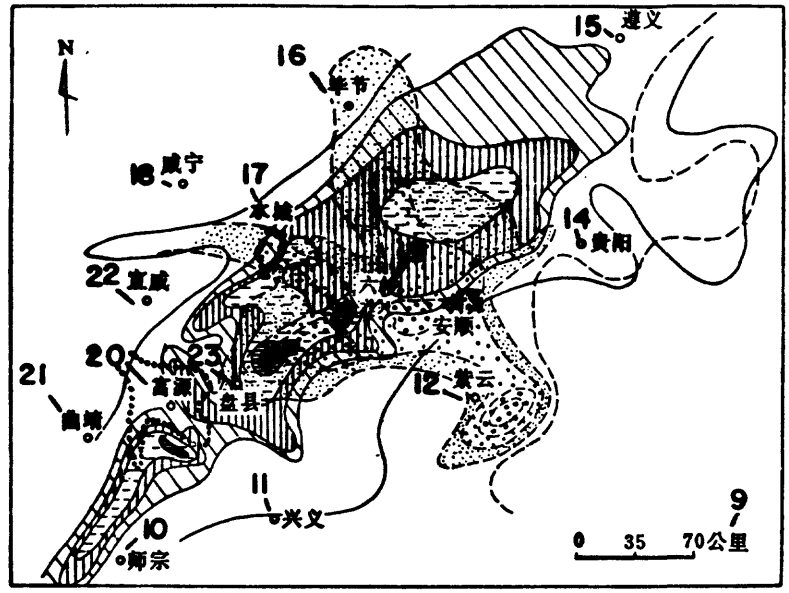


图 4-86 黔西晚二迭世龙潭组下段砂体及含煤性变化图

1～6—煤层总厚度级（厚→薄）；7—砂岩总厚>150米；8—砂岩总厚150～100米；9—砂岩总厚 100～50米；10—砂岩总厚<50米；11—底砾岩分布范围

1. Figure 23.

2. Isopachs of the Lower Member sandstone bodies of the Upper Permian Longtan Formation and the coal thickness variation (after Han and Yang, 1980, fig. 4-86, p. 195).

3. Scale of total coal-bed thickness (thick ------> thin).

4. Total thickness of sandstone >150 m.

5. Total thickness of sandstone 150～100 m.

6. Total thickness of sandstone 100～50 m.

7. Total thickness of sandstone <50 m.

8. Scope of basal conglomerate distribution.

9. Kilometers. 10. Shizong. 11. Xingyi. 12. Ziyun.

13. Anshun. 14. Guiyang. 15. Zunyi. 16. Huajie.

17. Shuicheng. 18. Weining. 19. Liuzhi. 20. Fuyuan.

21. Qujing. 22. Xuanwei. 23. Panxian.

In Permian time, the carbonate shelf sedimentation of the study area proceeded from the deep part of the ocean basin to its margin northwesterly in the following manner: lithographic limestone in the western Guangxi Province, generally grading into coal-bearing sandstone, siltstone, shale, and limestone in south-central Guizhou; and then grading into pelletoidal dolomite and limestone and more coal-bearing sandstone, siltstone, and shale of the shoreline environment in eastern Yunnan and western Guizhou Provinces.

Subsequently, in upper Permian time, the shoreline depositional environment was further expanded with the formation of Upper Permian bioherms under shallow-shelf environment in southwestern Guizhou (figs. 24 and 26), due to uplifting of the Chuan-Dian old landmass on the west, accompanied by basaltic flow eruption throughout Southwest China, and the general regression of the Permian sea. The shoreline depositional environment of the study area, however, continued to exist until the transgression of the Triassic sea.

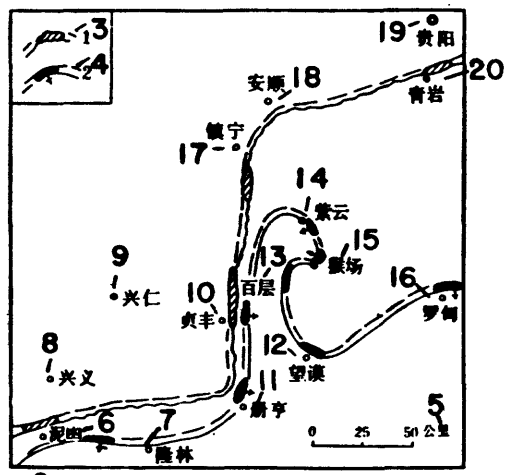


图 8 贵州上二叠统与中三叠统生物礁带分布图

3、1. 中三叠统生物岩礁带

4、2. 上二叠统生物岩礁带，箭头示礁前方向

1. Figure 25.
2. Distribution of Upper Permian and Middle Triassic bioherms of Guizhou (after He and others, 1981, fig. 8, p. 9).
3. Belt of Middle Triassic bioherms.
4. Belt of Upper Permian bioherms, arrow showing frontal direction of reef.
5. Scale and kilometers.
6. Nidang.
7. Longlin.
8. Xingyi.
9. Xingren.
10. Zhenfeng.
11. Ceheng.
12. Wangmo.
13. Baiceng.
14. Ziyun.
15. Houchang.
16. Luodian.
17. Zhenning.
18. Anshun.
19. Guiyang.
20. Qingyan.

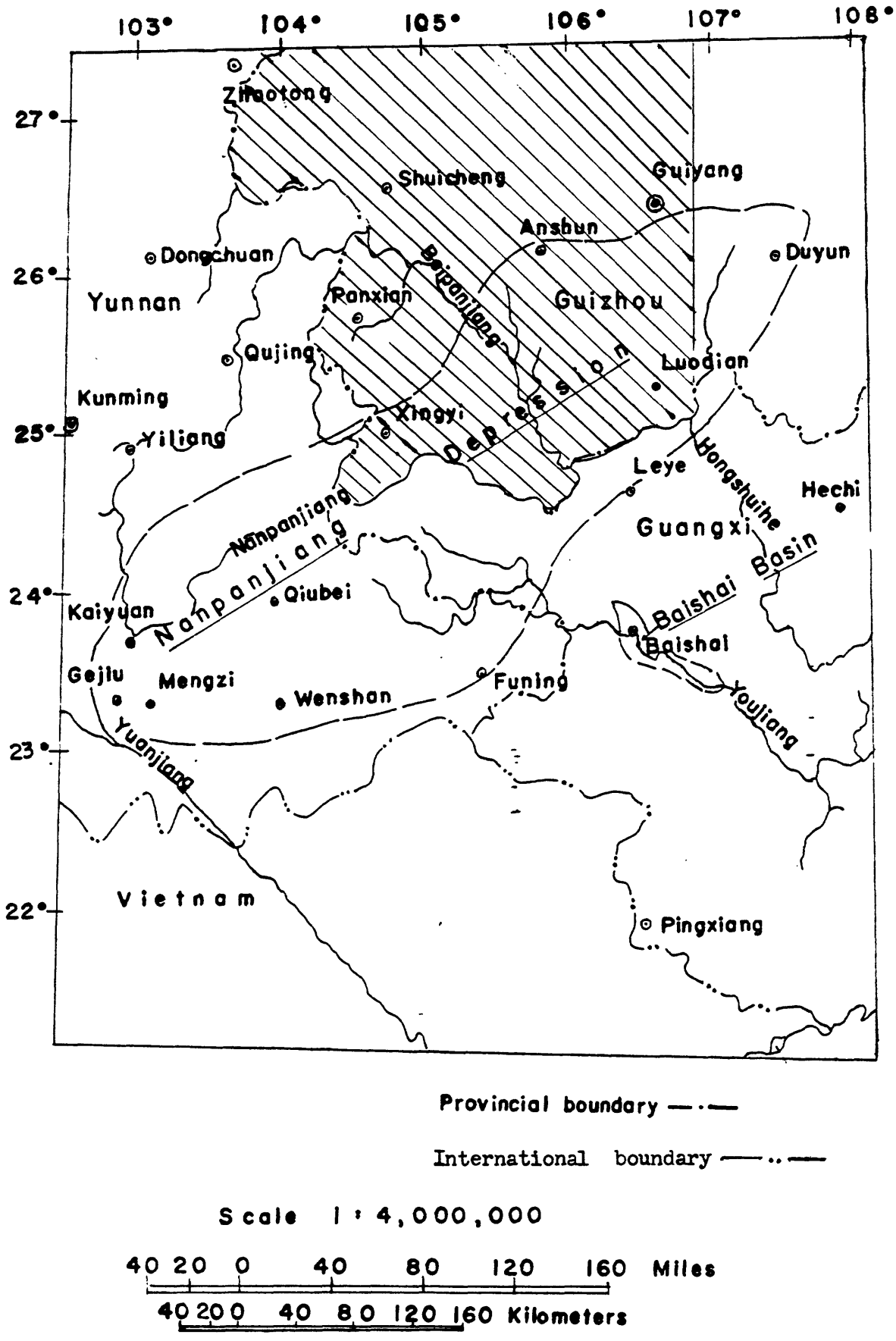


Figure 26.--Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location and coverage of Figure 27.

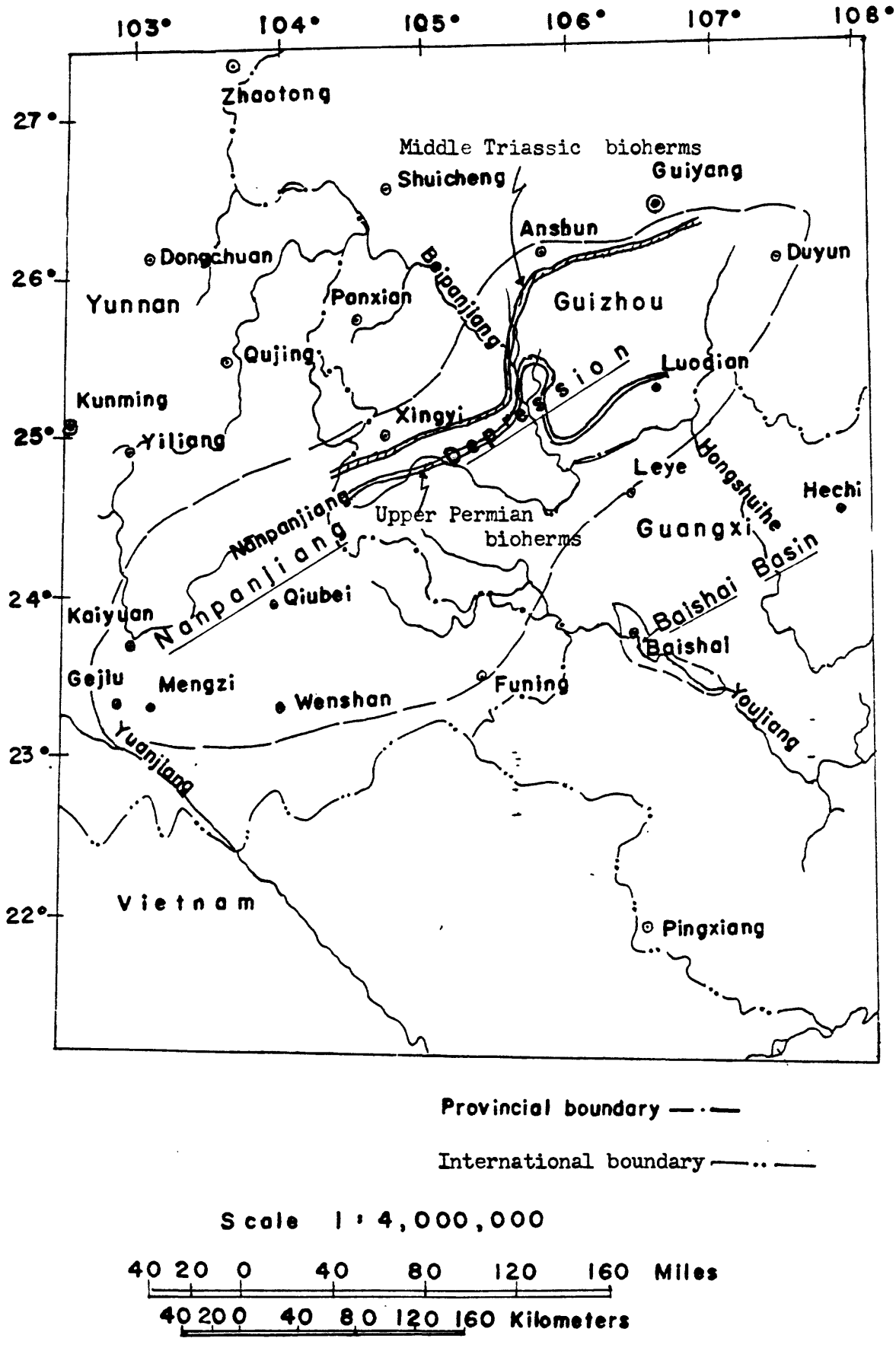


Figure 24. Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location and coverage of Figure 25.

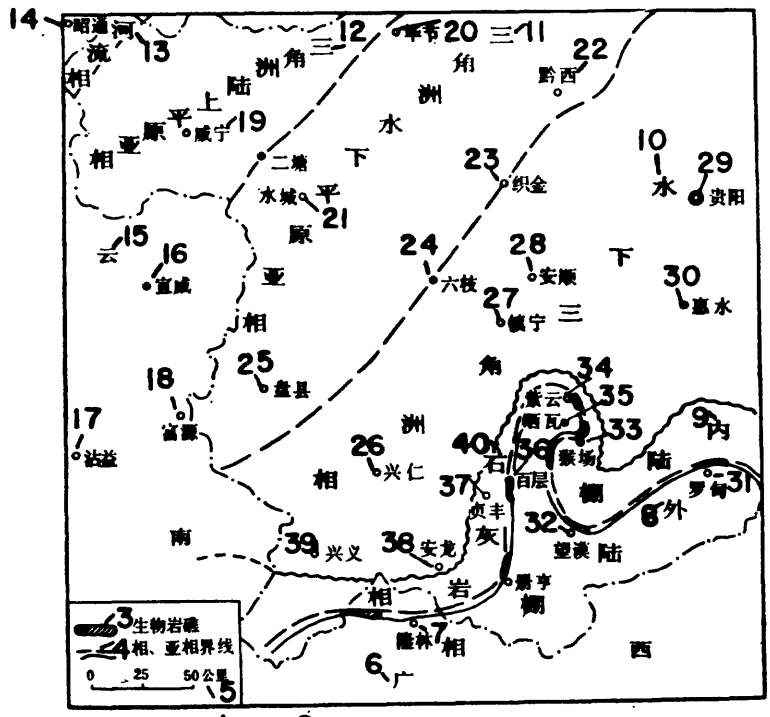


图1 贵州晚二叠世沉积相示意图

1. Figure 27.

2. Upper Permian depositional facies of Guizhou (After He and others, 1981, fig. 1, page 3).

3. Bioherms.
4. Facies and subfacies boundaries.
5. Scale and kilometers.
6. Guangxi.
7. Longlin.
8. Outer continental shelf facies.
9. Inner continental shelf facies.
10. Subaqueous delta facies.
11. Subaqueous deltaic plain subfacies.
12. Terrestrial deltaic plain subfacies.
13. Fluvial facies.
14. Zhaotong.
15. Yunnan.
16. Xuanwei.
17. Zhanyi.
18. Fuyuan.
19. Weining.
20. Huajie.
21. Shuicheng.
22. Qianxi.
23. Zhijin.
24. Liuzhi.
25. Panxian.
26. Xingren.
27. Zhenning.
28. Anshun.
29. Quiyang.
30. Huishui.
31. Luodian.
32. Wangmo.
33. Houchang.
34. Ziyun.
35. Shaiwa.
36. Baiceng.
37. Zhenfeng.
38. Anlong.
39. Xingyi.
40. Limestone facies.

Mesozoic

The Mesozoic stratigraphy of the study region consists of marine and continental sedimentary sequences of Triassic, Jurassic, and Cretaceous Systems. The Triassic system consists chiefly of marine sedimentary rocks. The Jurassic and Cretaceous Systems generally consist of continental deposits, which are scattered throughout the region (Institute of Geology, Academia Sinica, 1956, p. 417-467; 1958, p. 96-98) (Chinese Academy of Geologic Sciences, 1979, p. 31-45) (Wang and Liu, 1980, p. 229-232). Discussion of the stratigraphy of the individual Mesozoic Systems is given below in ascending order (table 1) (fig. 2). Detailed stratigraphy and fauna contents are listed in appendix.

Triassic

Generally, sedimentation between the Permian and Triassic systems in the study region was continuous, except locally along the margin of the old landmass. The depositional framework of the Triassic strata was generally similar to that of the Late Carboniferous and Permian. However, during the Early Middle Triassic Anisian stage, the ocean basins intensely subsided, accompanied by widely spread sea transgression. This transgression continued into the Late Middle Triassic Ladinian stage. Shortly before the Late Ladinian stage of the Middle Triassic, the sea gradually regressed because of uplifting of the adjacent landmass. As a result, the Upper-Triassic strata from Carnian to Rhaetian stages consist of transitional marine and continental and coal-bearing continental sedimentary sequences (Wang and Liu, 1980, p. 229-232) (Yang and others, 1981, p. 1-21). The Triassic system is subdivided, in ascending order, into the Lower, Middle, and Upper Series (table 1).

Lower Triassic

The Lower Triassic strata of the study region are widely distributed. A description of this series is based generally on its areal distribution in the study region.

In southeastern Yunnan, the Lower Triassic sedimentary sequence is represented by the Red Beds Series that consists of interbedded, purplish-red and gray shale and sandstone, which is, in part, intercalated with thin-bedded, clayey limestone. This series is well exposed in the area of Gejiu. It ranges in thickness from 100 to 200 m.

In eastern Yunnan, the Lower Triassic strata are assigned to the Yelang Series. This series in the lower part is made up of dark purplish-red, greenish-gray, orange-yellow sandstone and tuffaceous sandstone, shale, conglomerate, and basal conglomerate; in the middle part of thin-bedded sandstone and shale intercalated with thin-bedded limestone and marl; and in the upper part of thin- to thick-bedded limestone intercalated with calcareous shale, clayey shale, and sandstone. This unit is well exposed in the areas

of Louping, Shizong, Luxi, and Mile. The thickness of the Yelang ranges from 150 to more than 400 m.

In south-central Guizhou, the Lower Triassic sedimentary sequence is represented by the Yelang Series, which is subdivided into, in ascending order, the Shabaowan Shale and the Yulongshan Limestone.

The Shabaowan Shale is light-yellow, yellowish-gray, yellowish-green, and clayey shale intercalated with thin-bedded and lenticular, clayey limestone. Thickness of the Shabaowan ranges from 10 to 35 m.

The Yulongshan Limestone is gray or pinkish-gray, thin-bedded, blocky, crystalline limestone, locally containing dolomite and calcareous sandy shale. The thickness ranges from 160 to more than 500 m.

In western Guizhou, the Lower Triassic sedimentary sequences are also represented by the Yelang Series (Institute of Geology, Academia Sinica, 1956, v. 1, p. 445-446) (Wang and Liu, 1980, p. 229-232). The Yelang is divided, in ascending order, into the Feixianguan Formation and the Yongningzhen Formation.

The Feixianguan Formation consists chiefly of purplish-red sandstone and mudstone intercalated with marl and copper-bearing sandstone. The thickness ranges from 200 to about 800 m.

The Yongningzhen Formation comprises grayish-green, purple shale, marl, limestone, and dolomite. The thickness is about 900 m.

The Yelang Series is well exposed in the areas of Dading, Shuicheng, Zhenning, Guanling, Qinglong, Xingren, Zhenfeng, Anlong, Cexiang, and Xingyi. The thickness is estimated to range from 200 to 1,700 m.

In western Guangxi, the Lower Triassic is represented by the Luolou Formation (Yang and others, 1982, p. 10) (Institute of Geology, Academia Sinica, 1956, p. 506-507). This formation consists in the lower part of bluish-gray, black, light-gray, thin- to thick-bedded, clayey limestone and pure limestone intercalated with light-orange dolomite; and in the upper part of bluish-gray shale intercalated with thin-bedded sandstone. Four ammonites zones are recognized in the lower part of this formation; in ascending order they are: the Gyronitan zone, Flemingatan zone, Owenitan zone, and Columbitan zone. This unit is well exposed in the areas of Lingyun, Tianlin, Tiandong, Donglan, Fengshan, Tiane, and Lingle. The thickness of the Luolou is 200 m.

Middle Triassic

The Middle Triassic of the study region consists chiefly of neritic marine carbonate rocks. Generally the Middle Triassic unit is represented by, in ascending order, the Guanling Formation and the Falang Formation in southeastern and eastern Yunnan and western and south-central Guizhou. In south-central Guizhou, Yang and others (1982, p. 11) replaced the Guanling Formation with the Qingyan Formation, which is probably undifferentiated Falang and Guanling Formations.

In southeastern Yunnan, the Middle Triassic sedimentary sequence is tentatively subdivided, in ascending order, into the Guanling Formation and the Falang Formation (Institute of Geology, Academia Sinica, 1958, p. 96-97) (Wang and Liu, 1980, p. 229-232).

The Guanling Formation consists of gray to dark-gray, thick-bedded, micritic and dolomitic limestone, which contains abundant crinoides and algae. The thickness ranges from 800 to 1,000 m.

The Falang Formation of this area consists chiefly of the Wuge Shale, which is composed of interbeds of reddish-yellow, carbonaceous limestone, and thin-bedded, clayey limestone, locally interlayered with yellowish-green, dark-gray shale, sandy shale and brown sandstone; it contains an abundant fauna. The thickness is about 200 m.

In eastern Yunnan, the Middle Triassic is represented by the Hongxi Formation, which is equivalent to the Guanling Formation of southeastern Yunnan and western Guizhou, and the Gejiu Formation, which is equivalent to the Falong Formation of western Guizhou.

The Hongxi Formation consists of gray, thin-bedded or blocky limestone, dolomitic limestone and marl, and contains locally intercalated clayey, calcareous shale and limestone breccia. The thickness ranges from 20 to 170 m.

The Gejiu Formation is made up of gray, light-yellow, thin-bedded to thick-bedded, dolomitic limestone, limestone, and marl, and contains intercalated purple, green, light-yellow sandstone and shale in the lower part, and dark-gray and black, calcareous shale and clayey shale in the upper part. The thickness ranges from 50 to 200 m.

In south-central Guizhou, the Middle Triassic is well exposed in the area between the Qingyan and Pingyue and is assigned to the Qingyan Formation (Institute of Geology, Academia Sinica, 1956, p. 454-456) (Yang and others, 1982, p. 11). The Qingyan consists chiefly of clayey limestone intercalated with yellowish-green shale. The thickness is 610 m.

In western Guizhou, the Middle Triassic is represented by, in ascending order, the Guanling Formation and the Falong Formation (Institute of Geology, Academia Sinica, 1956, p. 444-445) (Wang and Liu, 1980, p. 229-230).

The Guanling Formation consists of light-gray, gray, dark-gray, thin- to thick-bedded, blocky, and impure limestone interbedded with dark-yellow,

dark-purple, and yellowish-green sandy shale, siliceous limestone, and dolomite. The shale varies greatly in thickness, and the limestone is clayey and contains numerous lenticular clayey bands. This formation is well exposed in the areas of Zhenning, Guanling, Qinglong, Xingren, and Zhenfeng. Maximum thickness given by the Institute of Geology, 1956, is 700 m. This contrasts with a thickness of more than 1,400 m cited by Wang and Liu (1980, p. 230).

The Falong Formation is comprised of light-gray to dark-gray, clayey, siliceous, thin-bedded, and blocky limestone intercalated with variegated sandy shale and shale. This sequence grades upwards into light-yellow and light-gray, fissile shale and yellowish-brown, dense sandstone, which contains clayey concretions in the uppermost part. This unit is well exposed in the areas of Zhenning, Guanling, Zhenfeng, Anlong, and Cexiang. The thickness ranges from 200 to 350 m (Institute of Geology, Academia Sinica, 1956, p. 444). This contrasts with an estimated thickness of this formation of more than 1,000 m by Wang and Liu (1980, p. 230).

In western Guangxi, the Middle Triassic is represented by the Pingerguan Series, which consists of grayish-green, yellowish-gray, and light-brownish-red shale, grayish-yellow and yellow sandstone, and dark-gray and blue, slatey shale intercalated with black, thin-bedded or concretional and impure limestone. The unit is well exposed in the vicinities of Donglan, Fengshan, Lingle, and Nandan. The thickness ranges from 510 to about 800 m.

Upper Triassic

The Upper Triassic sedimentary sequence in most of the study region consists of foredeep molasse red beds and marine and continental coal-bearing deposits. The continental facies is in the upper part of the sequence. Yang and others (1982, p. 3, table 1, and p. 6) subdivided the Upper Triassic, in ascending order, into two formations: the Pingdong Formation and the Fulongao Formation in southern Guizhou, southeastern Yunnan, and most of western Guangxi (table 1). Wang and Liu (1980, p. 229) had earlier subdivided the Upper Triassic, in ascending order, into three formations: the Banan Formation, the Huobachong Formation, and the Erqiao Formation in the vicinity of Zhenfeng of southwestern Guizhou (table 1). Yang and others (1982) tentatively correlated the Pingdong Formation with the Banan Formation and most of the Huobachong Formation, and the Fulongao Formation with the uppermost part of the Huobachong Formation and the Erqiao Formation.

In southeastern Yunnan, the Pingdong Formation consists of gray, clayey, thin- to thick-bedded limestone containing a basal, yellow, thin-bedded shale. In eastern Yunnan, however, this formation consists chiefly of shale and sandstone, which are locally intercalated with thin-bedded limestone. The thickness ranges from 250 to 300 m in southeastern Yunnan and 400 m in eastern Yunnan.

The Fulongao Formation in southeastern and eastern Yunnan consists of variegated shale intercalated with fine-grained, carbonaceous shale and lenticular coal beds. The thickness ranges from 300 to more than 700 m in southeastern Yunnan and 300 to 700 m in eastern Yunnan.

In south-central Guizhou, the Pingdong Formation consists of 40 to 700 m of fossiliferous, light-gray, pinkish-gray, and gray, thin-bedded, blocky, dolomitic limestone interbedded with greenish-gray, yellowish-gray, and gray, thin-bedded, micaceous, fossiliferous shale, and contains a basal limestone conglomerate. The Fulongao Formation consists of interbedded black, fossiliferous shale and sandstone. The thickness is estimated to be more than 300 m.

In western Guizhou, Wang and Liu (1980, p. 229) gave a brief statement of the Upper Triassic stratigraphy from an excellent profile at Zhenfeng of the Banan Formation, Huobachong Formation, and Erqiao Formation. The Banan Formation consists of interbedded grayish-yellow sandstone and shale intercalated with marl, carbonaceous shale, and a trace of coal. This formation is generally fossiliferous. The thickness is greater than 400 m.

The Huobachong Formation comprises interbedded gray sandstone and black shale intercalated with coal beds. The thickness is greater than 700 m.

The Erqiao Formation is made up of gray, quartzose, medium- and coarse-grained sandstone and conglomeratic sandstone in the lower part, and sandy mudstone intercalated with carbonaceous shale in the upper part. The thickness is greater than 300 m.

In western Guangxi, the Upper Triassic Pingdong and Fulongao Formations are combined into the Sile Series, which consists chiefly of molasse red beds and coal-bearing continental and marine sedimentary strata. Fossils are generally scarce. Coal beds 10 to 20 cm thick occur in the lower part of the Pingdong Formation. The thickness is estimated to be more than 1,000 m in the area of Lingle.

General paleogeogrpahy and deposition of the Triassic System

The Permian-Triassic sedimentary sequences were deposited in shoreline and shallow-shelf sea environments where emergent old landmasses in the study region and outside the region were the principal contributors of detrital sediments (fig. 28). Shoreline environments predominated during the sedimentation of Lower Triassic strata, and the microlithofacies of beach environments indicate the depositional nature in relationship to the water currents of a shallow-sea basin (fig. 29). Unfortunately, the geographic locations of these microlithofacies are not well established, although there are numerous well locations. As the transgression of the sea proceeded from late Lower Triassic time to Middle Triassic time, the study region was largely covered by the sea. The Triassic transgression culminated generally in Middle Triassic time and was accompanied by a growth of bioherms during the Ladinic stage (figs. 30 and 32). During late Ladinic time to Upper Triassic time, shoreline deposition again played a major role, as recorded by alternating marine and continental coal-bearing arenaceous-detrital sedimentary sequences (figs. 34 and 35).

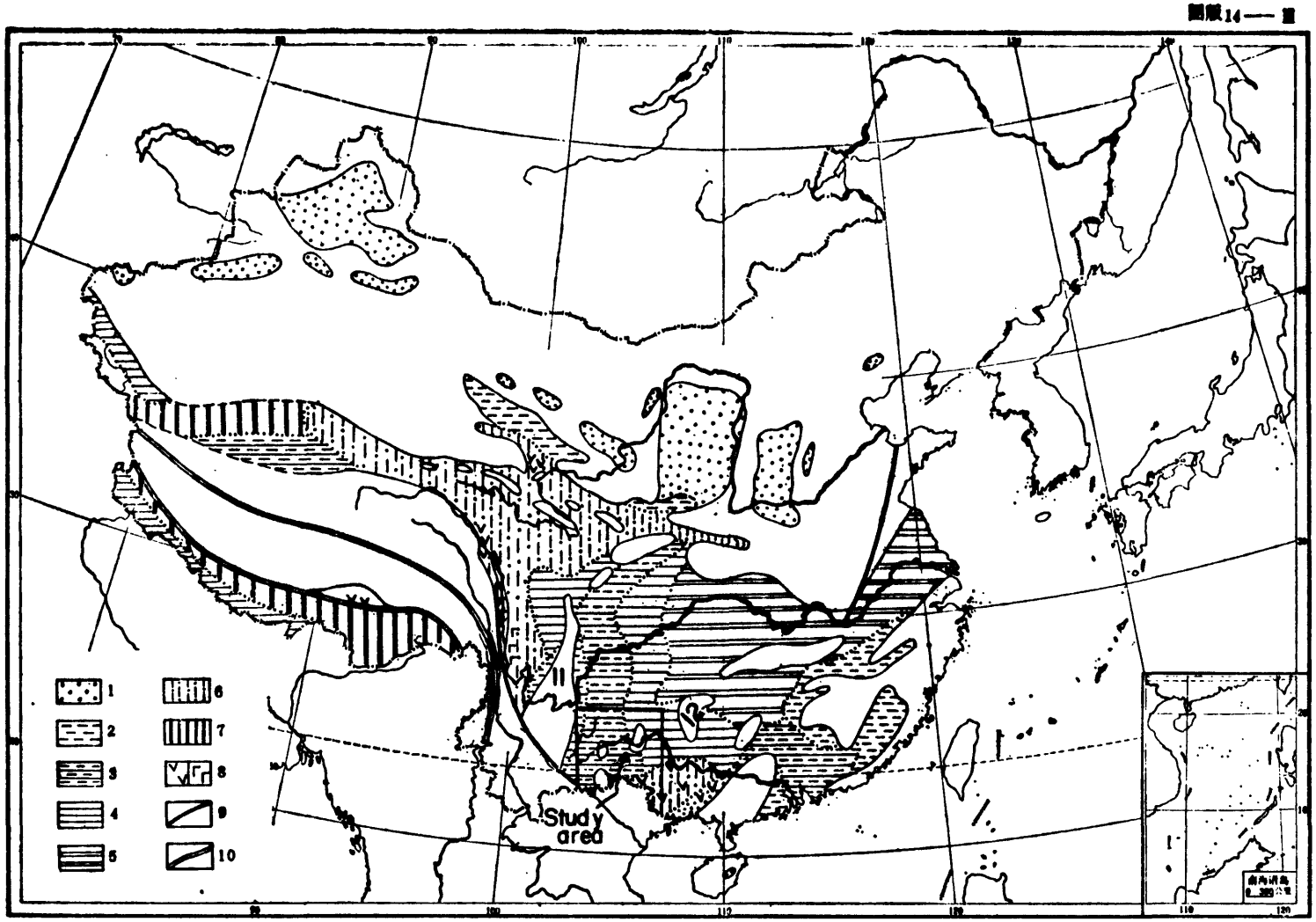


Figure 28.--Early Triassic paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 14-III).

1. Inland fluvial and lacustrine Red Beds.

2-5. Marine stable types.

2. Littoral clastic deposits.
3. Littoral and epicontinental sea clastic deposits, intercalated with carbonate.
4. Chiefly epicontinental sea carbonate.
5. Early carbonate overlain by late evaporite.

6. Marine mobile types.

7. Undifferentiated Triassic.

8. Intermediate acidic and intermediate basic volcanic rocks.

9. Late transcurrent fault.

10. Earth's crust suture zone.

11. Chuan-Dian old landmass.

12. Xuefeng uplift.

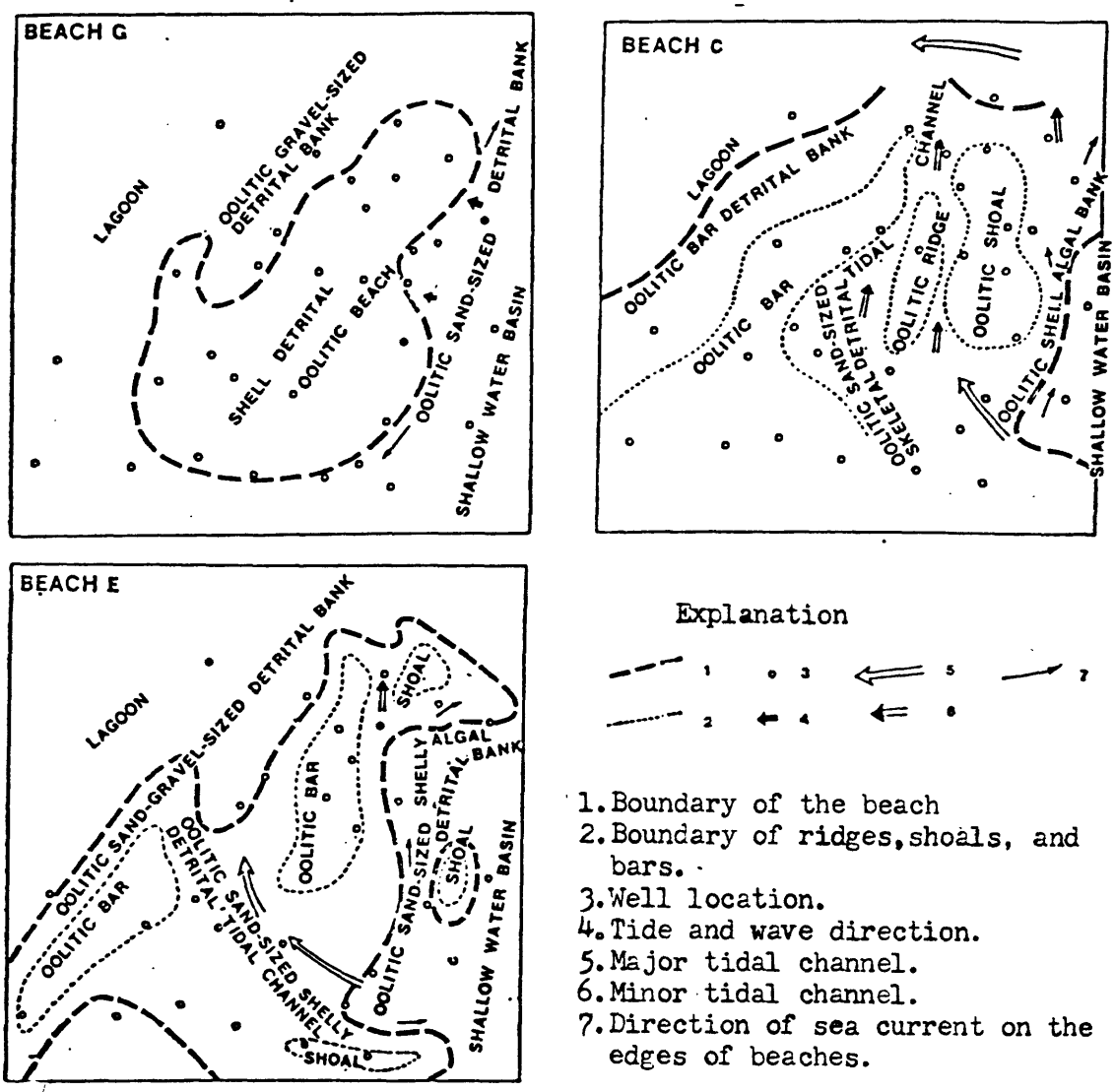


Figure 29. Microfacies units of the beaches G,E, and C during deposition of the Lower Triassic strata (after Cheng and others,1977, fig. 9, p.18).

Beach G, a shelly oölitic beach.
Beach E, a detrital and skeletal oölitic beach.
Beach C, a shelly oölitic beach.

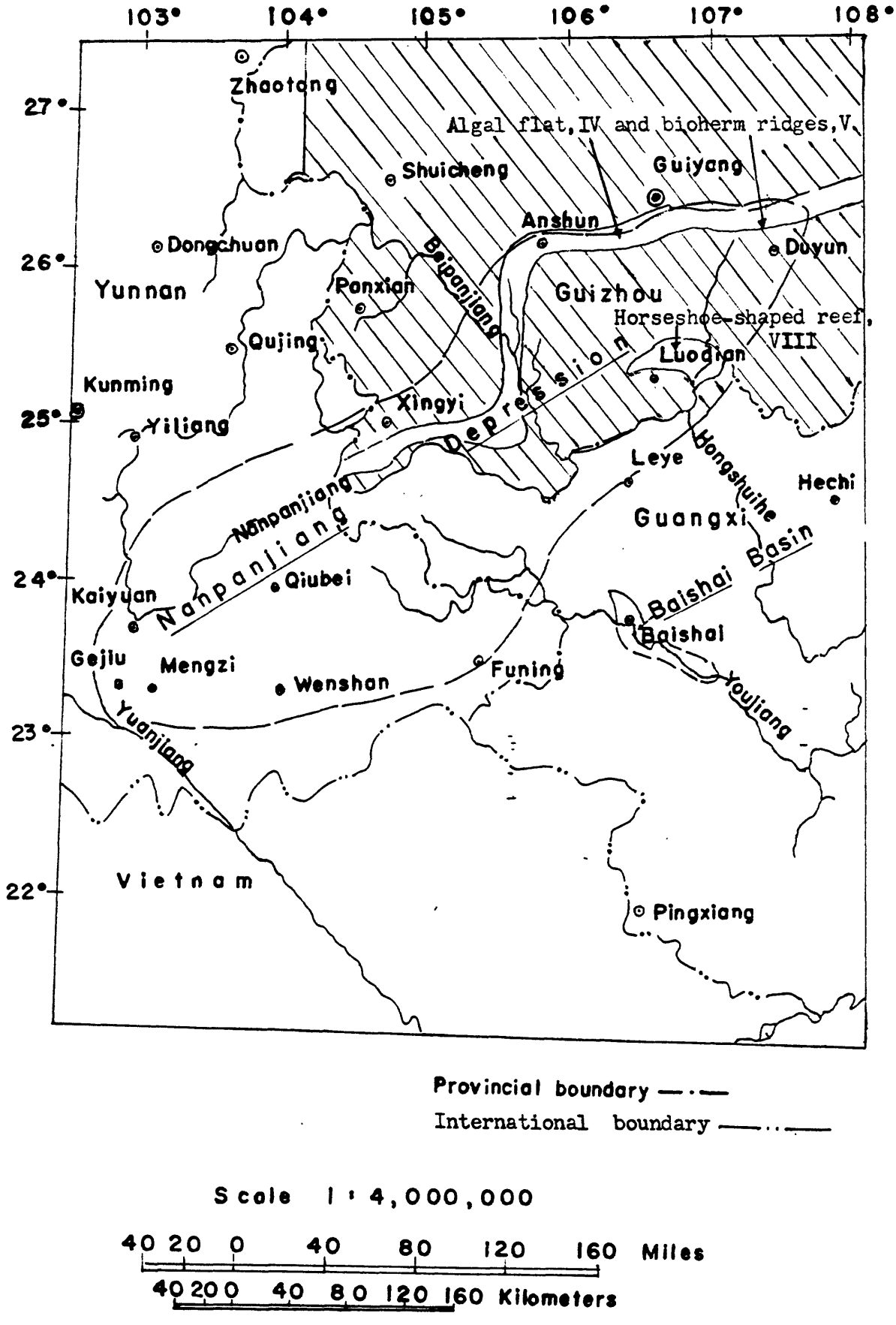


Figure 30.--Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location and coverage of Figure 31.

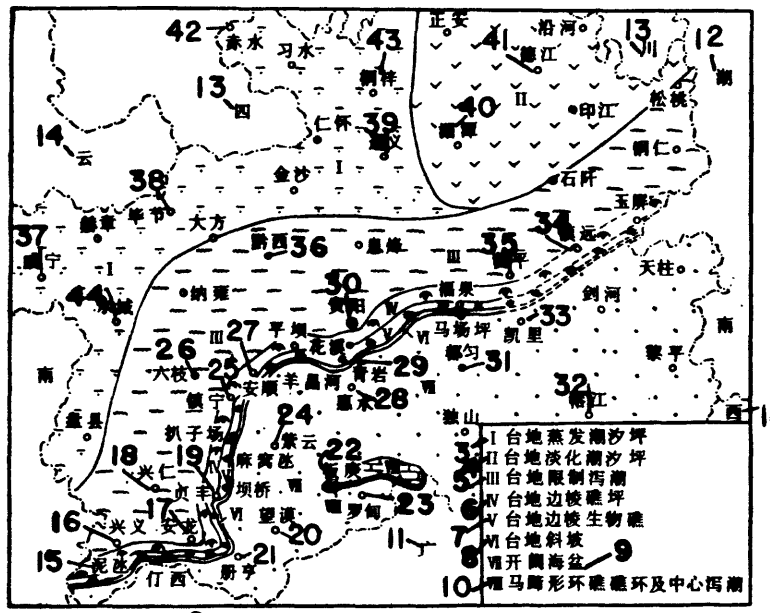


图1 贵州中三叠世拉丁尼克期沉积环境示意图

1. Figure 31.

2. Depositional environments of the Middle Triassic Ladinic stage of Guizhou (after Ho and others, 1980, fig. 1, p. 257).

3. Evaporite tidal flat of carbonate platform.
4. Desalinized tidal flat of carbonate platform.
5. Lagoons of restricted marine carbonate platform.
6. Algal flat of carbonate platform margin.
7. Bioherm ridges of carbonate platform edge.
8. Slope of carbonate platform, which consists of two regimes: platform slope zone is the high-energy regime and basin margin is the low-energy regime.
9. Open sea basin.
10. Horseshoe-shaped reef and central lagoon.
11. Guangxi. 12. Hunan. 13. Sichuan. 14. Yunnan.
15. Nidang. 16. Xingyi. 17. Anlong. 18. Xingren.
19. Zhenfeng. 20. Wangmo. 21. Ceheng. 22. Bangeng.
23. Luodian. 24. Ziyun. 25. Zhenning. 26. Liuzhi.
27. Anshun. 28. Huishui. 29. Qingyan. 30. Guiyang.
31. Duyun. 32. Rongjiang. 33. Kaili. 34. Zhenyuan.
35. Huangping. 36. Qianxi. 37. Weining.
38. Huajie. 39. Zunyi. 40. Meitan. 41. Dejiang.
42. Chishui. 43. Tongzi. 44. Suicheng.

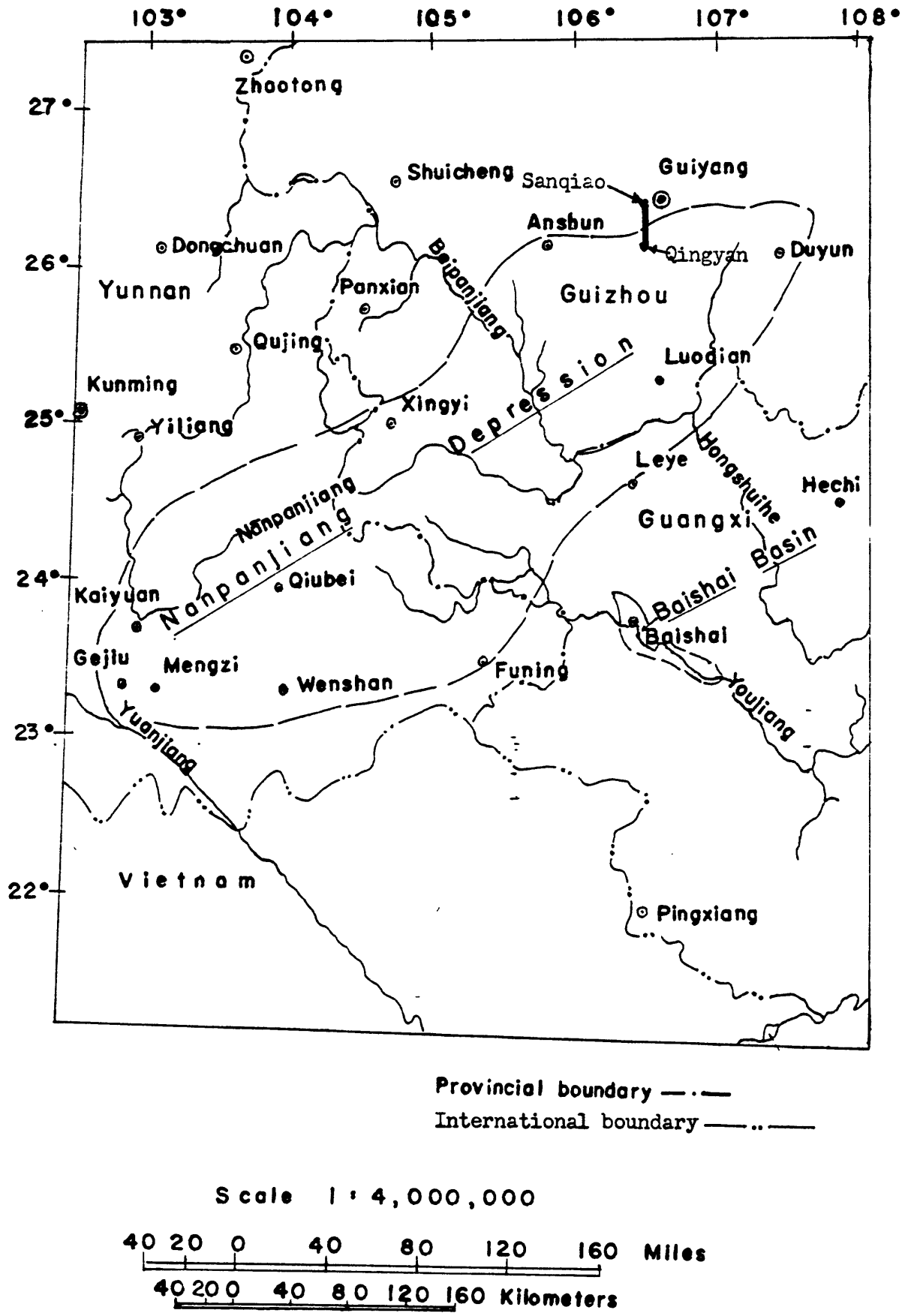


Figure 32.--Index map of the Dian-Qian-Gui foldbelt, Southwest China, showing the location of Figure 33.

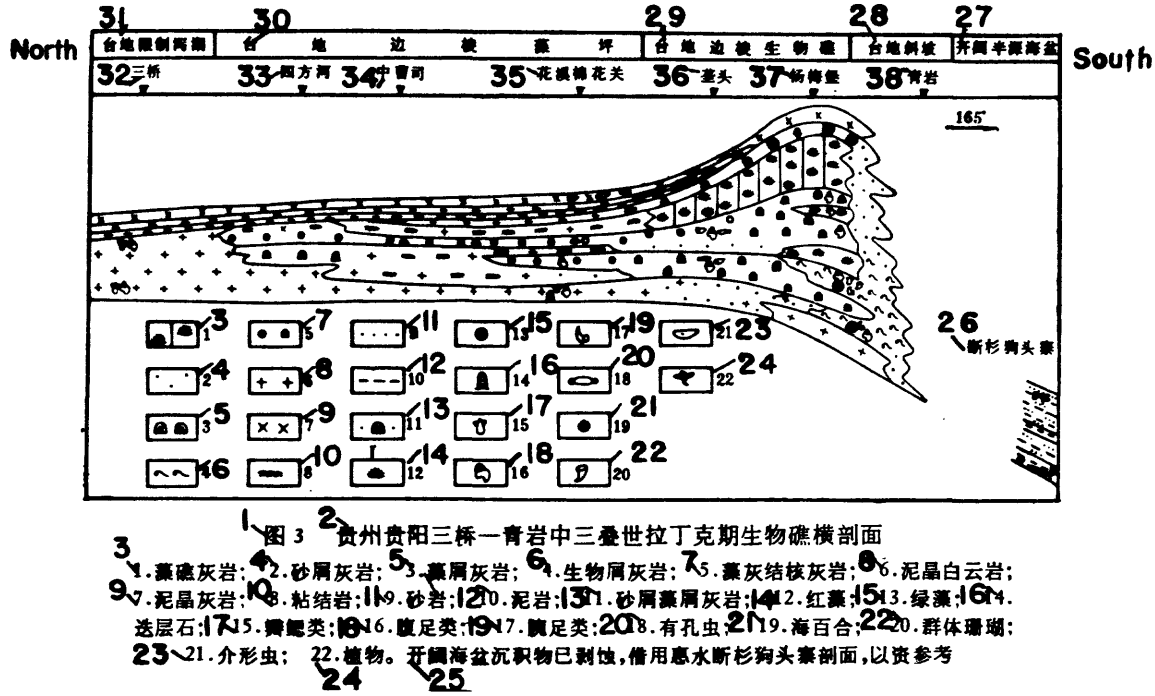


图 3 贵州贵阳三桥—青岩中三叠世拉丁克期生物礁横剖面

1.藻礁灰岩; 2.砂屑灰岩; 3.藻屑灰岩; 4.生物屑灰岩; 5.藻灰结核灰岩; 6.泥晶白云岩; 7.泥晶灰岩; 8.粘结岩; 9.砂岩; 10.泥岩; 11.砂屑藻屑灰岩; 12.红藻; 13.绿藻; 14.迭层石; 15.腹足类; 16.腹足类; 17.腹足类; 18.有孔虫; 19.海百合; 20.群体珊瑚; 21.介形虫; 22.植物。开阔海盆沉积物已剥蚀,借用惠水断杉狗头寨剖面,以资参考

1. Figure 33.
2. Bioherm profile of the Middle Triassic Ladinic stage in the area from Sanqiao, Guiyang, to Qingyan, Guizhou Province (after Ho and others, 1980, fig. 3, p. 259).
3. Algal reef limestone.
4. Sandy limestone.
5. Limestone of algal fragments.
6. Limestone of organism detritus
7. Algal nodular limestone.
8. Dolomite of clay detritus.
9. Limestone of clay detritus.
10. Claystone.
11. Sandstone.
12. Mudstone
13. Sandy and algal detrital limestone.
14. Red algae.
15. Green algae.
16. Stromatolites.
17. Lamellibranchiata.
18. Gastropods.
19. Brachiopods.
20. Foraminifera.
21. Crinoidea.
22. Compound corals.
23. Ostracods.
24. Plant.
25. Because of the erosion of ocean-basin deposits, this profile was made with reference to exposures at the Duanshagoutouzhai section, Huishui.
26. Duanshagoutouzhai.
27. Ocean basin.
28. Platform slope.
29. Bioherm of platform edge.
30. Algal mats of platform margin.
31. Lagoons of restricted platform.
32. Sanqiao.
33. Sifanghe.
34. Zhongcaosi.
35. Huaximianhuaguan.
36. Longtou.
37. Yangmeibao.
38. Qingyan.

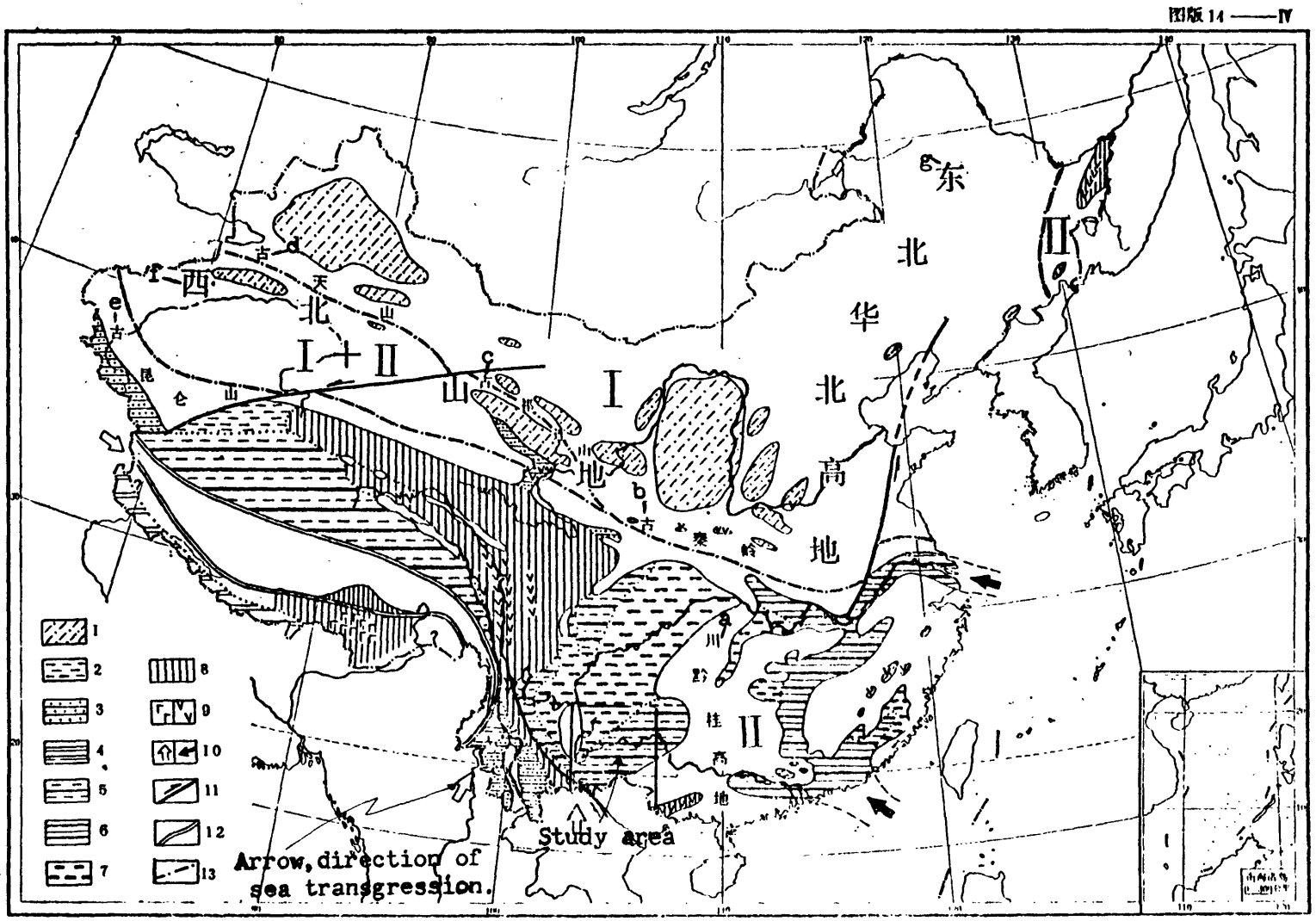


Figure 34.--Late Triassic paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 14-IV).

1. Inland fluvial and lacustrine detrital deposits (coal-bearing upper part).

2-7. Marine stable types.

2. Alternating marine and continental clastic deposits.
3. Littoral and epicontinental sea clastic deposits.
4. Shallow-sea carbonate and clastic deposits.
5. Lower carbonate and upper alternating marine and continental coal-bearing deposits.
6. Alternating marine and continental coal-bearing clastic deposits.
7. Alternating marine and continental coal-bearing clastic deposits with late overlapping.

8. Marine mobile types.
9. Intermediate basic and intermediate acidic volcanic rocks.
10. Transgression directions of palaeotethys and circum-Pacific sea.
11. Late transcurrent fault and direction of horizontal movement.
12. Earth's crust suture zone.
13. Plant demarcation line.

I. Plant area of Danaeopsis-Bernoullia.
II. Plant area of Dictyophyllum-Clathropteris.
I + II. Mixed plant area.

a. Chuan-Qian-Gui highlands.
b. Ancient Qinling.
c. Ancient Qilianshan.
d. Ancient Tianshan.
e. Ancient Kunlunshan.
f. Northwest mountainous region.
g. Northeast and North China highlands.

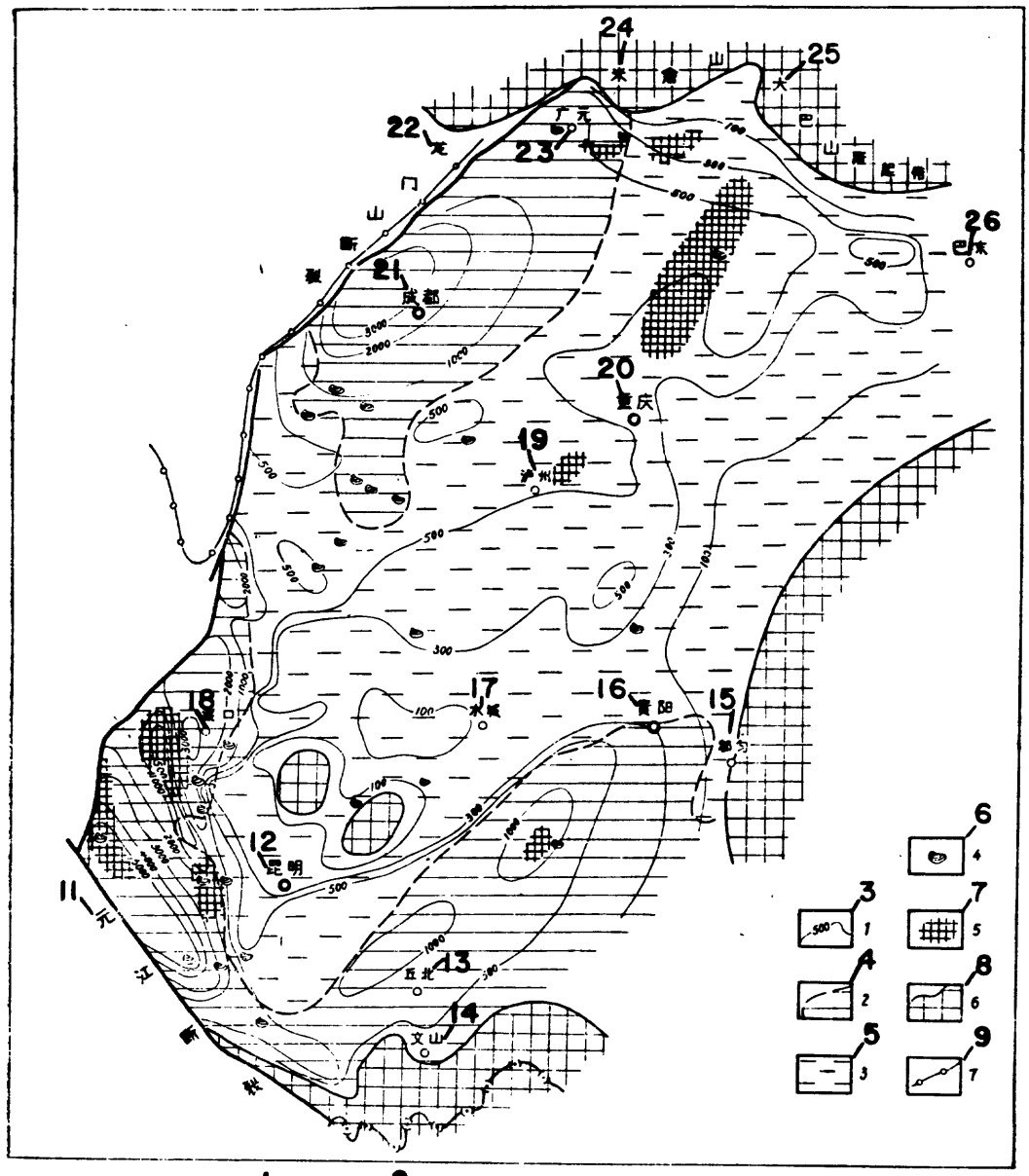


图 Ⅲ—77 扬子区晚三叠世含煤沉积分布图

1—晚三叠世地层等厚线；2—晚三叠世早、中、晚期沉积发育较全的地区；3—只发育晚三叠世中、晚期沉积的地区（相当须家河组的层位）；4—晚三叠世中、晚期沉积中产半咸水瓣鳃动物化石的地点；5—聚煤相对较富的地区；6—剥蚀区；7—晚三叠世晚期剥蚀区界限（早期与西部特提斯海相通，晚期封闭）

（据成都地质矿产研究所资料，略有修改、补充）

1. Figure 35.
2. Distribution of Upper Triassic coal-bearing deposits of the Yangzi region (after Department of Coal Teaching and Researches, Wuhan Geologic College, III-77, p. 91).

3. Isopach of Upper Triassic strata (in meters).

4. Area of relatively complete development of the Upper Triassic early, middle, and late stages of deposition.

5. Area of the only developed Upper Triassic middle and late stages of deposition (equivalent to the Xujiahe Formation).

6. Locality of semi-saline mollusk fauna in the Upper Triassic middle and late stages of deposition.

7. Area of relatively rich coal accumulation.

8. Area of denudation.

9. Boundary of denudation area of the Upper Triassic late stage.

10. Slightly modified and supplemented after the data of the Chengdu Institute of Geology and Mineral Resources.

11. Yuanjiang Fault.
12. Kunming.
13. Qiubei.
14. Wenshan.
15. Duyun.
16. Guiyang.
17. Shiucheng.
18. Dukou.
19. Luzhou.
20. Chongqing.
21. Chengdu.
22. Longmenshan fault
23. Guangyuan.
24. Micanshan.
25. Dabieshan uplift zone.
26. Badong.

Jurassic

The Jurassic System of the study region is represented chiefly by Lower Jurassic continental sedimentary sequences, which were deposited in inland basins. Exposures are generally sparse and are located only in western Guizhou, south-central Guizhou and eastern Yunnan (Institute of Geology, Academia Sinica, 1956 and 1958).

In western Guizhou, the Jurassic is represented by the Xiangxi Series of Early Jurassic age. This series consists of green, yellowish-green, yellowish-brown, thick-bedded, feldspathic or quartzose, coarse-grained sandstone and sandy shale; it contains one to two coal beds, which are associated with the plant fossils Pecopteris and Cladophlebis. It is well exposed in the areas of Zhenfeng, Shuicheng, Anlong, and Langdai. The thickness ranges from 40 to 600 m.

In south-central Guizhou, the Lower Jurassic consists of light-gray, micaceous, blocky, coarse-grained sandstone and interbeds of yellow shale. It is well exposed in the areas of west Guiyang and Guizhou. The thickness ranges from 300 to 400 m (?) (Institute of Geology, Academia Sinica, 1956, p. 453).

In eastern Yunnan, the Jurassic System is divided, in ascending order, into the Lufeng and the Shimen Series (Institute of Geology, Academia Sinica, 1956, p. 419). The Lufeng Series is about 1,030 m thick and consists of mudstone, shale, siltstone, sandstone, and conglomerate. The Shimen Series consists chiefly of dark-purplish-brown sandstone with shale interbeds and a basal conglomerate. It ranges from 100 to 300 m thick.

General paleogeography and deposition of the Jurassic System

During the Jurassic period, this region was a landmass with scattered inland basins. These basins were filled with continental red detritus in Early Jurassic time. From Early Jurassic to Late Jurassic time, although the stratigraphic records are lacking throughout the study region, the rate of erosion in the highlands of the study region was greater than the rate of deposition, and a considerable amount of detrital materials was transported westward outside of the study region and deposited as red beds sequences in central Yunnan basin (fig. 36).

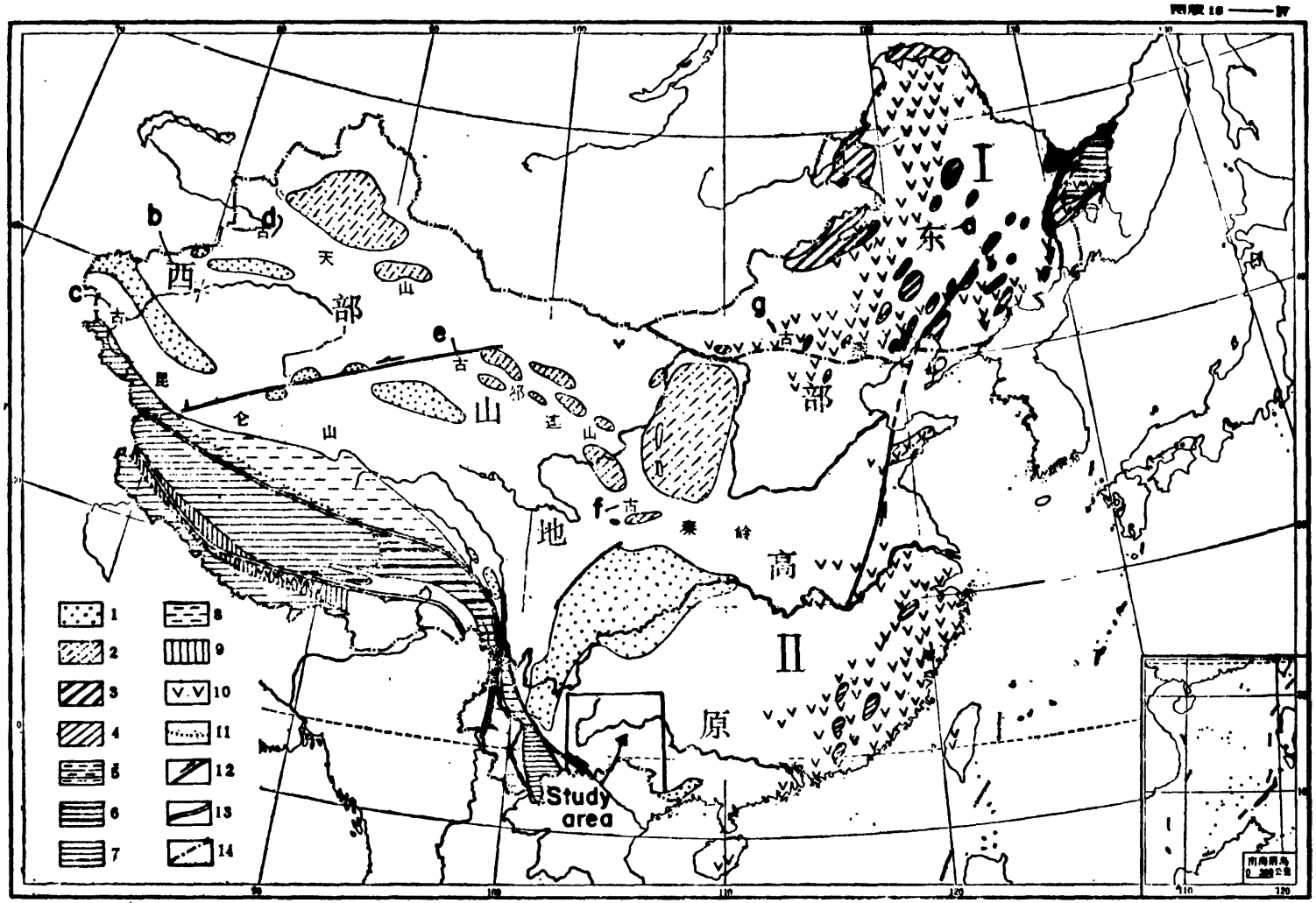


Figure 36.--Late Jurassic to the early stage of Early Cretaceous paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 15-IV).

1-4. Types of continental facies.

1. Inland fluvial and lacustrine Red Beds.
2. Inland fluvial and lacustrine variegated clastic deposits.
3. Inland lake and swamp coal-bearing clastic deposits.
4. Inland fluvial and lacustrine clastic deposits during dormant stage of volcanic eruption.

5-8. Marine stable types.

5. Alternating marine and continental clastic deposits.
6. Alternating marine and continental coal-bearing clastic deposits.
7. Shallow-sea clastic and carbonate deposits.
8. Shallow-sea clastic and carbonate deposits during late sea regression.

9. Sedimentation of active marine trough.
10. Volcanic rock.
11. Boundary of sedimentation types.
12. Boundary fault and late transcurrent fault.
13. Earth's crust suture zone.
14. Plant demarcation line.

I. Temperate plant area.
II. Plant area of tropical zone and subtropical zone.

a. Eastern plateau
b. Western mountainous region.
c. Ancient Kunlun Mountain.
d. Ancient Tianshan.
e. Ancient Qilian Mountain.
f. Ancient Qinling.
g. Ancient Yanshan.

Cretaceous

The Cretaceous System of the study region consists of undifferentiated continental red beds and, locally, volcanic rock. These rocks are present only in the areas of western Guangxi and western and south-central Guizhou (Institute of Geology Academia Sinica, 1956, p. 453 and p. 506) (fig. 37).

In south-central Guizhou, the Cretaceous strata consist of continental deposits of pinkish-red, quartzose sandstone in the lower part, and reddish-brown and grayish-green shale in the upper part locally intercalated with beds of light-gray algal limestone and clay. This sequence is well exposed in the southwestern part of Guiyang, Xifeng, and the southwestern part of Dushan. The thickness ranges from 200 to about 600 m.

In western Guizhou, the Cretaceous System is probably represented by the Old Red Beds Series, which consists of a 200-m thickness of interbedded red and purple, soft sandstone and shale. It is well exposed in the vicinity of Shuicheng.

In western Guangxi, the Cretaceous System is represented, in ascending order, by a volcanic rock series and the Nazhen Series. The volcanic rock series consists of a thickness of 300 to 500 m of dark-gray or black, aphanitic and crystalline basaltic flows; purplish-gray, tuffaceous sandstone; and breccia. This series is well exposed in the areas of Longjin, Ningming, and on the north of Zuojiang Stream and the city of Chongzuo.

The Nazhen Series in the lower part is made up of interbedded red, quartzose sandstone and yellow sandstone with a basal conglomeratic sandstone and conglomerate; in the middle part, of red sandstone and shale intercalated with yellow, soft sandstone and green shale; and, in the upper part, of red and yellow shale and sandstone interbeds. This series is exposed in the areas of Longjin, Chongzuo, and Ningming. The thickness ranges from 1,000 to 1,500 m.

General paleogeography and deposition of the Cretaceous System.

During the Cretaceous period, the study region was still largely an emergent highland, and basaltic flows erupted locally in west Guangxi. The volcanic activity resulted from the intense deformation of the Yanshanian (Yenshanian) orogeny during Late Cretaceous time throughout the Chinese continent. Scattered inland basins were filled with continental deposits of red beds throughout the study region in the latest stage of the Yanshanian movement (fig. 37).

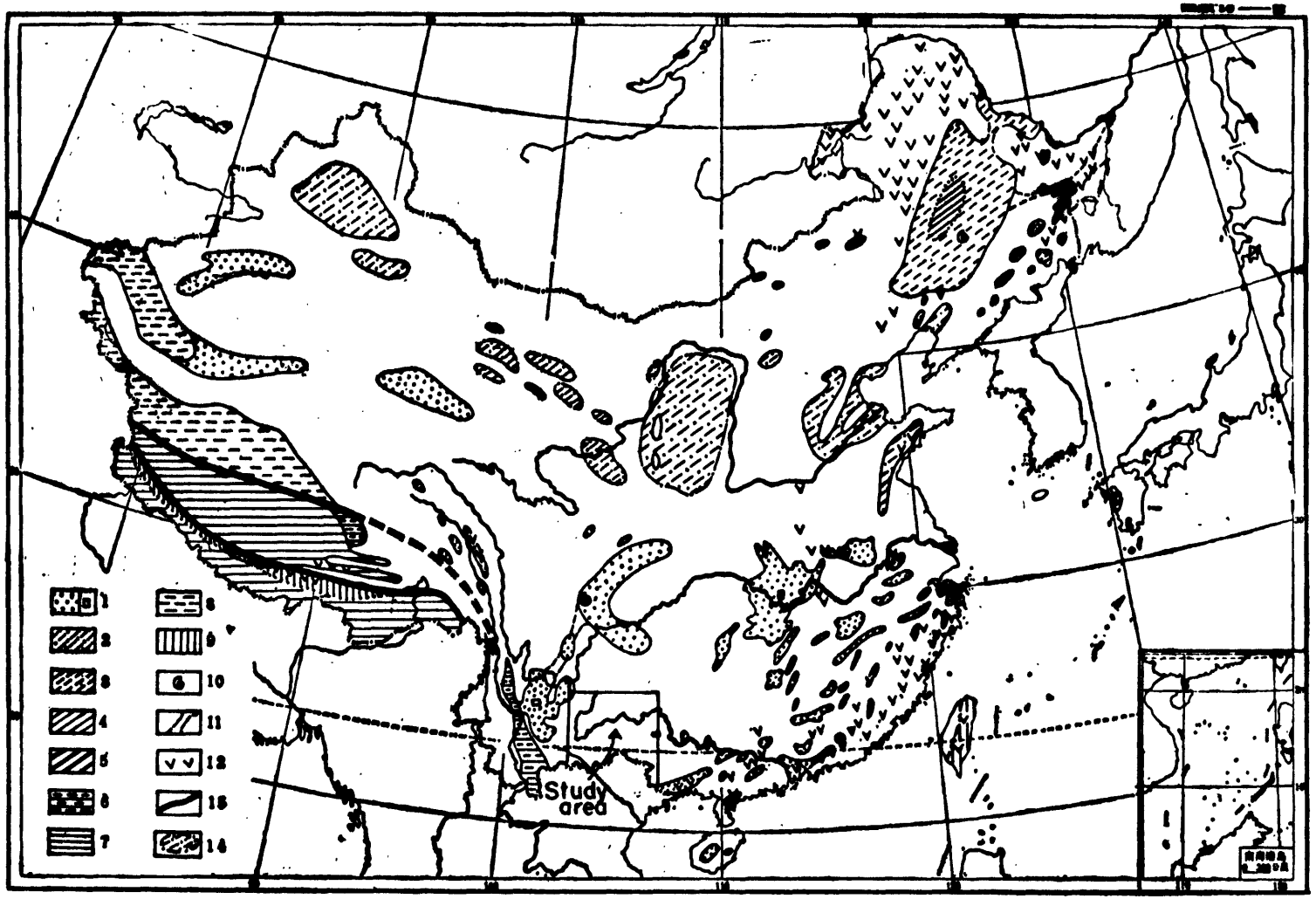


Figure 37.--Late stages of Early Cretaceous to Late Cretaceous paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 16-III).

1-5. Types of continental facies.

1. Inland fluvial and lacustrine Red Beds and evaporites.
2. Inland fluvial and lacustrine variegated clastic deposits.
3. Nearshore shallow-lake variegated clastic deposits.
4. Nearshore deep-lake dark-colored argillaceous deposits.
5. Inland lake and swamp coal-bearing clastic deposits (K_1^2).

6-8. Shallow marine stable types.

6. Alternating marine and continental clastic deposits.
7. Shallow-sea clastic and carbonate deposits.
8. Shallow-sea clastic and carbonate deposits, K_2 is area of sea transgression.

9. Sedimentation of active marine trough.
10. Location of marine fauna distribution (K_1^2 to K_2).
11. Possible sea thoroughfare.
12. Volcanic rock.
13. Earth's crust suture zone.
14. Inland fluvial and lacustrine variegated clastic deposits, and later changed to area of denudation.

Cenozoic

The Cenozoic stratigraphy of the Dian-Qian-Gui region consists chiefly of continental sedimentary sequences locally intercalated with marine facies in western Guangxi Province (Wang and Liu, 1980, p. 304) (Cheng and Wang, 1980) (Liang, 1982).

Tertiary

The Tertiary stratigraphy of the study region consists chiefly of detrital, continental sedimentary sequences, which locally contain marine facies in the sedimentary rocks of Eocene to Oligocene age in the Baishai (Baise) Basin (Liang, 1982). Outcrops are scattered.

The Tertiary stratigraphy has been subdivided into a Lower Tertiary and an Upper Tertiary Series (table 1). The Lower Tertiary strata are in eastern Yunnan, western Guizhou, south-central Guizhou, and western Guangxi. Upper Tertiary sedimentary rocks are only in southeastern and eastern Yunnan and western Guangxi. The Upper Tertiary sedimentary rocks consist of fluvial and lacustrine sedimentary facies.

In southeast Yunnan, there are no Lower Tertiary rocks. The Tertiary is represented by the Pliocene Buzhaoba Formation in the lower part and the Xinglongzhai Formation in the upper part.

The Buzhaoba Formation comprises fluvial and lacustrine yellowish-brown, coarse-grained sandstone, conglomerate and yellowish-gray shales intercalated with clay, thin-bedded marl, lignite beds, limonite layers and andesite flows. Locally it has a basal conglomerate. This unit is well exposed in the areas of Kaiyuan, Gejoiu, and Mengzi. The thickness ranges from 60 to more than 500 m.

The Xinglongzhai Formation consists of yellow, sandy clay, calcareous clay, and nearly horizontally-bedded limestone conglomerate locally intercalated with yellow, soft sandstone. It varies greatly in lithofacies. The thickness is estimated to be from 7 to 12 m.

In eastern Yunnan, the Lower Tertiary is represented by the Upper Eocene Lunan Formation and the Oligocene Caijiachong Formation. The Upper Tertiary is represented by the Pliocene Ciyang Formation.

The Lunan Formation consists of red, fine- to coarse-grained, locally blocky calcareous sandstone intercalated with clay, fine-grained sandstone and marl. It has a basal limestone conglomerate or limestone beds. This unit is well exposed in the Lunan Basin. The thickness is more than 350 m

The Caijiachong Formation is made up of green marl, light-gray, dense, fresh-water limestone, and gray, sandy, massive siltstone, which contains brachiopods - Planorbis, Melaniids, Chara spores; and vertebrate fauna of Cadurcotherium sp., and Crocodillus sp. This formation is well exposed in the Yuezhou basin, about 20 km southeast of the city of Qujing. The thickness is about 200 m.

The Pliocene Ciyang Formation consists chiefly of lacustrine and swamp deposits of marl, clay, sand, gravel, and lignite or bog iron. Clay and marl contain viviparus, Aplexa, Bulimus, and fish and plant fossils. This unit is well exposed in the lowlands of Qujing, Luliang, and Zhanyi counties. The thickness ranges from 90 to more than 165 m.

In western Guizhou, the Lower Tertiary is represented by the so-called "New Red Beds Series," which consists chiefly of a conglomerate of red limestone and limonite-bearing fragments in a silt and clay matrix, firmly cemented by silica. It is well exposed on terraces along the sides of streams in the counties of Shincheng, Panxian and Xingyi. The thickness is about 10 m.

In south-central Guizhou, the "New Red Beds Series" consists of brick-red shale and sandstone with a basal conglomerate and limonite layers. It is scattered throughout the area. The thickness is about 160 m.

In western Guangxi, the Lower Tertiary is represented by the Yongfu Series, and the Upper Tertiary is represented by the Pliocene Yongning Series.

The Yongfu Series generally consists of red, soft shale, sandstone, oil-sand and gravel, and is well exposed in the drainage areas of Zuojiang and Mingjiang streams. In the Baishai basin, Wang and Liu (1980, p. 309, table 17-II) subdivided the Lower Tertiary into, in ascending order, the Liuzui, Dongjun, Nadu, and Gongkang Formations, of which the Eocene to Oligocene Nadu Formation contains marine sedimentary sequences (Liang, 1982, p. 99, table 1). A lithologic description of Lower Tertiary formations in the Baishai Basin is not available.

The Pliocene Yongning Series in the lower part is comprised of light-gray and brownish-light-gray marl and clay; in the middle part of black or gray clay, which is fossiliferous and is intercalated with thin-bedded, fossiliferous siderite beds; and in the upper part of interbedded gray, soft sandstone and clay, which contain thin-bedded siderite layers and seven lignite seams, with a basal oil-sand. This series is well exposed in the drainage areas of Zuojiang, Mingjiang, and Youjiang streams. The thickness in the areas between Tiandong and Baise reaches a maximum of about 1,000 m. Fossil collections have yielded the fossil plants: Quercus sp., Rhus sp., Populus latior Bronn. Heterocalyx sp., Taxus sp. and undifferentiated fauna of Kwangsispira grabaui Hsu, Tulotoma Kwangsiensis Hsu, T. lii Hsu, Paracampeloma paucilineata Hsu, Melania aubriyana Heuda, M. turita Hsu, Vivipora dispiralis Hsu, V. leei Hsu, and Nematara parriglohosa Hsu.

General paleogeography and deposition of the Tertiary System

The Dian-Qian-Gui region was a highland area in the Early Tertiary, and subsequently inland basins of this region subsided because of the effects of an early stage of the Himalayan orogeny at the end of Middle Eocene time. Large inland basins, such as the Baishai basin, were filled with Eocene to Paleocene red beds and then by the fine detrital continental and marine sediments that were deposited throughout most of South China (Liang, 1982, p. 97-100) (Cheng and Wang, 1980, p. 208-218). During stages of the Himalayan movement from Middle Miocene to Quaternary time (Huang and others, 1980, p. 27-28), uplift of the highland mass in the study region was greater than subsidence and accompanied by andesitic flows in southeast Yunnan; and sedimentary rocks of continental facies were deposited over a wide area in western Guangxi during Pliocene time (fig. 38).

Quaternary

The Quaternary sedimentary sequence of the study region consists of continental deposits, glacial till, outwash, residual detritus, tufa, and lacustrine clay and silt of Pleistocene age; and residual detritus, loess, and alluvium of Holocene age.

In southeastern Yunnan, the Pleistocene sedimentary sequence consists of Mazu beds in the lower part, which consist of clay, sand, and gravel; and red clay from weathered carbonate rocks in the upper part. The Mazu beds contain abundant plant remains and gastropod fossils near the base and are well exposed in the county of Kaiyuan. The thickness ranges from 1 to 20 m. The red clay is widely distributed in the carbonate rock terranes. The thickness is unknown.

The Holocene deposits in southeastern Yunnan are clay, sand, gravel, and, locally, tin-placers along sides of stream terraces and near lakes and swamps. The thickness is unknown.

In eastern Yunnan, the Pleistocene deposits consist of four stratigraphic units, in ascending order: 1) Red clay and gravel. The red clay is generally soft and contains basal rounded to subrounded basalt and chert gravel. This unit is on terraces and well exposed in the areas of Kunming, Lunan, and Chenggong. The thickness is unknown. 2) Cavern accumulations of travertine layers, limestone breccia, and clay, in part sandy. This second unit contains an abundant fauna of Cyprinidae; Uraus angustidens Zdansky, Alluropus fovealis Matthew et Granger, Ailurus fulgens Thomas, Arctonyx sp., Hayena ultima Matsumoto; Hystrix sp; Rhinoceros sp., Tapirus (Megatapirus) cf. auoustus Matthew and Granger; Sus sp., Crebus (Rusa) sp., Crevulus sp., Elephas cf. namadicus F. & C., Stegodon sp.; and Macacus sp., Simia cf. satyrus L., etc. A cave with this fauna is located 50 m above the left bank of the Tanglang stream, which is about 10 km southwest of Fumin City. Thickness of this unit is unknown. 3) Travertine deposits, which were formed in stream courses and along hilly slopes, contain plant remains and gastropod fossils. Such Travertine is common in the Lunan Basin. Thickness is unknown. 4) Lacustrine deposits of green, calcareous clay, which occur around the Kunming Lake and contain abundant Margraga melanioides Nevill. The thickness is unknown.

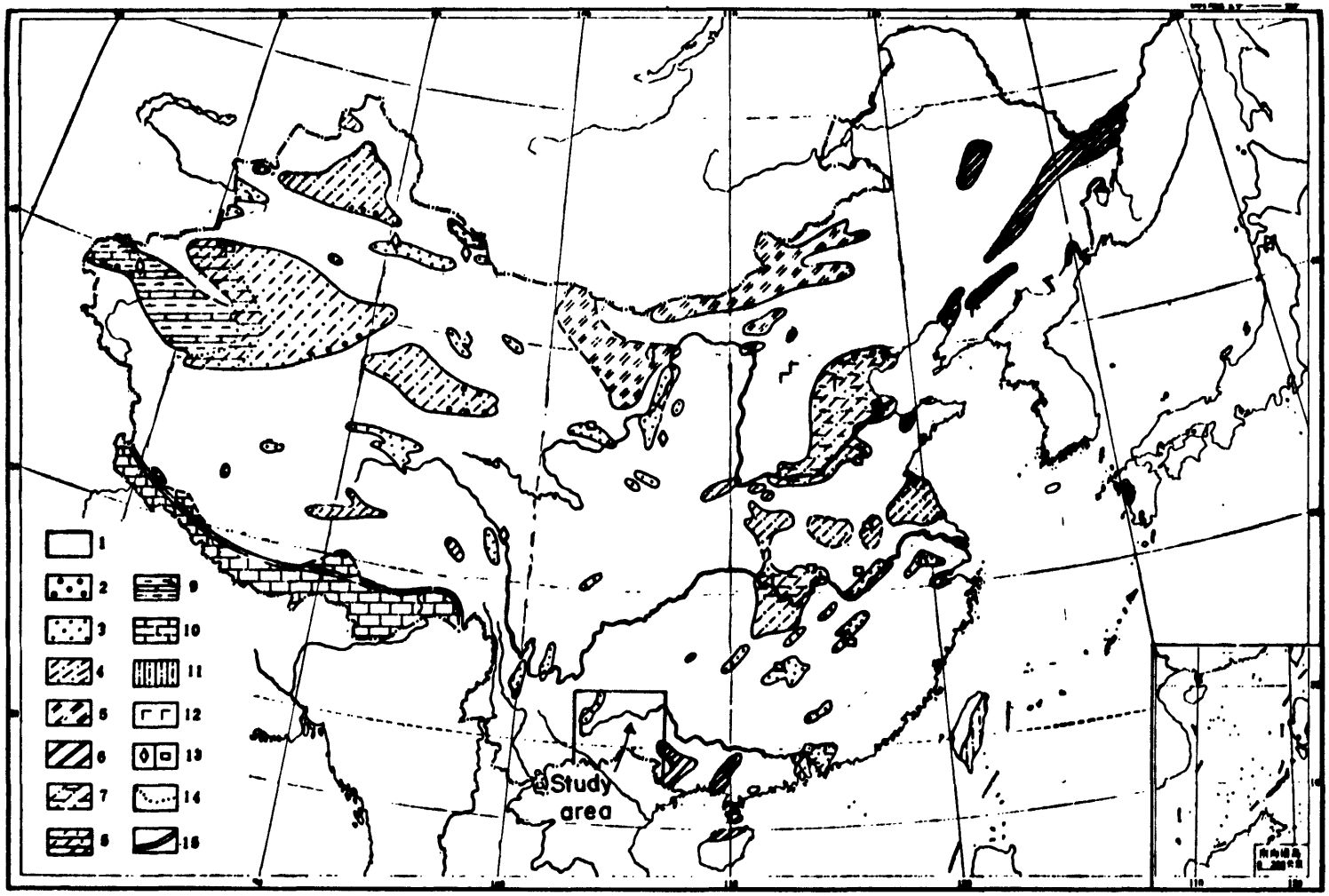


Figure 38.--Early Tertiary paleogeography and types of sedimentation of China (after Wang and Liu, 1980, plate 17-IV).

1. Area of denuded old landmass.

2-7. Types of continental deposits.

2. Coarse clastic deposits of the foot of a mountain.
3. Red Beds of intermontane basin.
4. Inland fluvial and lacustrine argillaceous-arenaceous deposits.
5. Migrating fluvial-lacustrine argillaceous-arenaceous deposits on peneplain.
6. Inland lake and swamp coal-bearing organic rock deposits.
7. Fluvial and lacustrine argillaceous-arenaceous deposits of inland subsident basin with marine ingression.

8-10. Marine stable types.

8. Alternating marine and continental argillaceous-arenaceous deposits.
9. Shallow-sea and lagoonal argillaceous-calcareous deposits.
10. Shallow-sea carbonate intercalated with argillaceous-arenaceous deposits.

11. Shallow-sea clastic deposits of active marine trough sedimentation.
12. Basic volcanic rock.
13. Evaporite and rock salt.
14. Boundary of lithofacies.
15. Earth's crust suture zone.

In western Guizhou, glacial outwash represents the Pleistocene deposits on terraces 20 to 30 m above the present stream beds. The clay is red and sandy and contains detrital quartzose sandstone and quartzite fragments with a maximum diameter of 50 cm. Concave and striated surfaces are common on the fragments. The thickness is unknown.

Holocene deposits are represented by residual detritus and alluvium. The residual detritus is variegated and contains limestone fragments and limonite. Generally the thickness is about 10 m. The alluvium consists of sand and gravel. The thickness is unknown.

In south-central Guizhou, Pleistocene deposits are represented by glacial till in the lower part and gravel in the upper part. The glacial till consists of striated gravel, 10 to 30 cm in diameter, intermixed with brownish-yellow clay and fine-grained sand. This unit is widely distributed on 10- to 80-m high terraces along the sides of streams and along the slopes of the mountains.

The gravel of the upper part is named the Matouzhai Gravel. It is made up of rounded to angular rock fragments, which have diameters ranging from 5 to 20 cm, intermixed with yellow clay. This unit is well exposed on terraces 30 m high above present streams in the counties of Kaiyang and Xiuwen. Locally, this unit is 2 m thick in Kaiyang county.

The Holocene deposits in south-central Guizhou are represented by alluvium and scree. The alluvium consists of sand and gravel and is distributed along the sides of streams. The scree is common along slopes and at the foot of hills. The thickness is unknown.

In western Guangxi, the Pleistocene sedimentary sequence is represented by cavern accumulations in the lower part and by glacial till and glaciofluvial deposits in the upper part. The cavern accumulations comprise an intermixture of fine-grained quartz sand, red clay, and gravel, which contains potassium or sodium nitrate. The thickness is unknown.

The glacial till and glaciofluvial deposits consist of an intermixture of reddish-yellow and brown, clayey gravel, red clay, and striated rock fragments. Rock fragments are chiefly of quartzose sandstone, grayish-green sandstone, sandstone, and shale. The diameter of fragments generally ranges from 4 to 5 cm with some as large as 40 cm long. Clayey gravel and gravel deposits have yielded placer gold. The total thickness ranges from 2 to 12 m.

The Holocene sedimentary sequence of western Guangxi consists of eolian and residual detritus in the lower part and alluvium in the upper part. The eolian and residual deposits are comprised of grayish-yellow loam; light-gray fine-grained sandy clay; red and yellow clay; white, fine-grained sand and basal gravel; limonite concretions are common locally. The thickness is unknown. Alluvium is made up of gray and grayish-yellow clay and sand, which are mixed with gravel. Locally the alluvium has yielded placer tin and tungsten. The thickness is unknown.

General paleogeography and deposition of the Quaternary System

The Himalayan orogeny controlled the development of Pleistocene paleogeography throughout the Chinese domain. Generally, four major glacial stages and three interglacial stages were the principal factors involved in the formation of the distinct continental depositional environments of the Quaternary System. In the study region, the Quaternary sedimentary sequences were generally deposited along stream beds in the inland plateau basins, in lowland areas, and as cavern accumulations.

GEOTECTONICS AND DEVELOPMENT OF DEPRESSIONS

General Statement

The Dian-Qian-Gui region is mainly situated in the southwestern part of the South China Fold System and covers part of the southwestern Yangzi (Yangtze) (Chang Jiang) paraplatform (figs. 5 and 6). The Yangzi paraplatform evolved during the period from Middle Proterozoic to Upper Proterozoic and integrated into the present tectonic framework in the Late Upper Proterozoic Yangzian (Yantzeian) orogeny (table 2) (Huang and others, 1980, p. 35-36). This paraplatform borders the Red River (Yuanjiang or Honghe) fault zone on the southwest and the South China Fold System on the south (fig. 6) (Huang and others, 1980, p. 61). The South China Fold System, a miogeosynclinal fold system, was established during the Late Caledonian orogeny (table 2) and consists chiefly of flysch facies of the Sinian to Silurian sedimentary sequences. The Red River fault zone is a deeply seated fracture zone and has been active since the Late Proterozoic. This fault zone separates the Yangzi Paraplatform and the South China Fold System on the east and the north, and the Sanjiang (Sankiang) Fold System on the west (Huang and others, 1980, p. 91-92) (fig. 6). In addition, Huang and others (1980, p. 83-85) mentioned four more deeply seated fracture zones in the study region: the Baishai (Baise) fracture zone, the Funing fracture zone, the Wenshan fracture zone, and the Nanpanjiang fracture zone (fig. 39). These fracture zones were all active in the Paleozoic, but the Nanpanjiang fracture zone was probably active as early as Late Proterozoic. Subsequently, they were the principal dynamic factors controlling the formation of the Nanpanjian depression and the Baishai Basin.

Nanpanjiang Depression

The Nanpanjiang depression is located in the central part of the study region and trends northeasterly (fig. 1a). The Nanpanjiang fracture zone is situated approximately in the central portion of the depression and was formed by shearing compression stress (Huang and others, 1980, p. 85). This depression is a faulted basin and contains chiefly broken regional scale blocks of the Upper Paleozoic marine sedimentary sequence. It developed on the Caledonian folded basement during the Variscan and Indosinian orogenies (Wang, 1982, p. 81). Zhang and others (1980, p. 1-18; 1981, p. 13-25) classified the Nanpanjiang depression as an intracratonic, single-cycle basin that formed during the Variscan deformation (table 2) and subsequently further subsided during the Indosinian orogeny. It is equivalent to the interior simple basin type of Klemme (1980, p. 188-193).

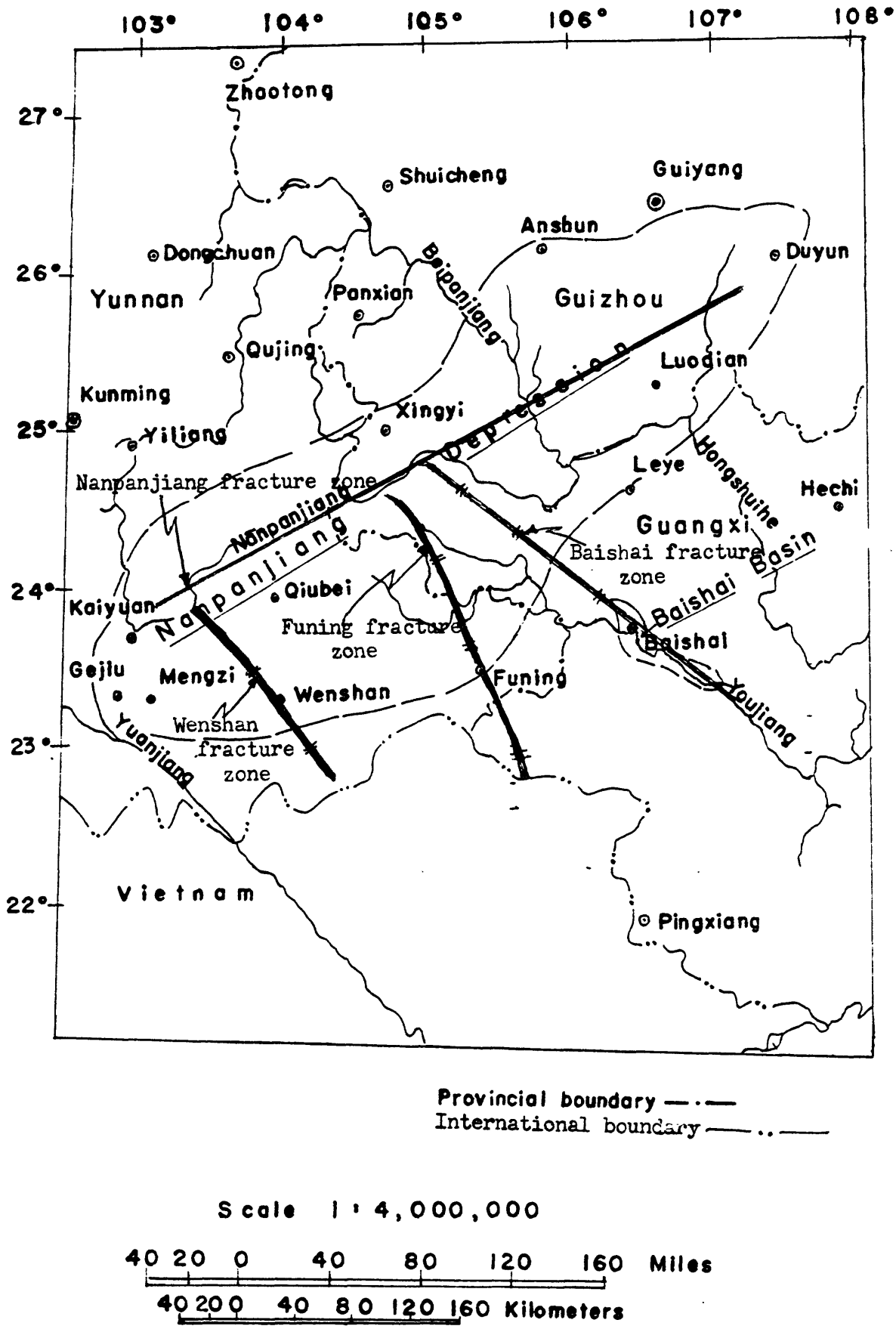
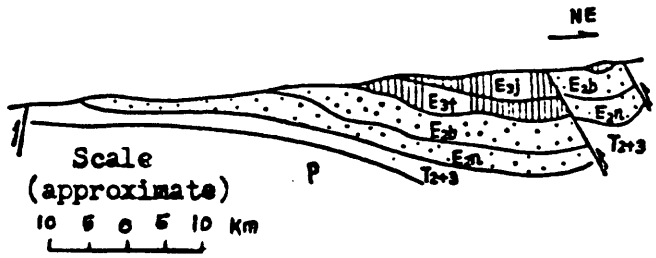


Figure 39.--Index map of Dian-Qian-Gui foldbelt, Southwest China, showing the location of deeply-seated fracture zones (after Huang and others, 1980, fig. 22, p. 88-89).

Bashai Basin

The Bashai (Baise) Basin is located in the southeastern part of the study region (figs. 1a and 39) and trends northwesterly. The Baishai fracture zone has the same trend approximately as the basin and was formed by shearing compression stress (Huang and others, 1980, p. 83). The Baishai is a graben-faulted basin whose genesis is similar to the Xingxi Basin of Hebei Province, North China (Zhang, Wenyou and others, 1982, p. 9); it developed on the Caledonian folded basement during the Variscan and Indosinian deformation (table 2). Initially the basin was filled with marine Permian and Triassic sedimentary rocks. The basin was an emergent landmass from Jurassic through Cretaceous time. During the Yanshanian (Yenshanian) orogeny in the Early Tertiary, the basin was subjected to a phase of intense rejuvenated faulting and then again subsided to receive deposits of sedimentary sequences of the Paleocene Liuzui Formation, the Lower- to Middle-Eocene Dongjun Formation, the upper-Eocene to Middle-Oligocene Nadu Formations, and the Middle-Oligocene to Upper-Oligocene Gongkang Formation. Zhang, Wenyou and others (1982) considered that the rejuvenated faulting in the basin was caused by relatively weak compressive stresses (fig. 40).



P. Permian

T. Triassic

E_2. Eocene

E_3. Oligocene

Figure 40.--Structural cross section of the Baishai Basin, Guangxi (after the Composite Team of Petroleum Geology of the Ministry of Geology and Mineral Resources) (adopted from Zhang, Wenyou and others, 1982, fig. 5, p. 9).

ENERGY MINERAL DEPOSITS

General Statement

The energy-mineral deposits of the Dian-Qian-Gui foldbelt include coal, petroleum, and natural gas in the Nanpanjiang depression and the Baishai (Baise) Basin. Detailed information on the prospecting and development of these resources, however, is generally lacking. The discussion on occurrence and depositional environment of energy-mineral deposits is herein based on generally available information.

Coal Deposits

The coal deposits of the Dian-Qian-Gui foldbelt are chiefly in the Lower Carboniferous, Lower and Upper Permian, and Upper Triassic sedimentary sequences. The coal beds of these sedimentary rocks are mined locally. Stone coal has been reported from the Upper Sinian and Lower Cambrian sedimentary strata throughout South China. The "stone coal" is a highly metamorphosed anthracite in which the organic components are mainly present as non-structured bacterial and algal remnants, and the debris of vitrinite and fusinite has not been found (Fu, 1980; p. 40). Fu further suggested that these stone coals represent a typical sapropelic organic matter, and the ash-content of silica and calcium oxide generally ranges from 20 to 40 percent. Detailed information on the occurrence of stone coal in the study region is not available.

The following discussion of the Carboniferous, Permian, and Triassic coal deposits is based on the descriptions given by Han and Yang (1980, p. 160-222; p. 252-260), and by the Department of Coal Teaching and Researches, Wuhan Geologic College (1980, p. 34-45; p. 68-86; p. 88-95).

Lower Carboniferous coal deposits

Lower Carboniferous coal deposits of the Fengninian Series have been reported throughout the study region. Generally, the mineable coal beds are confined in southeastern and eastern Yunnan and the northern part of south-central Guizhou. Detailed information on coal geology is, however, not available.

Occurrence

The coal-bearing sequences of the Lower Carboniferous are assigned to the Weixian Formation in southeastern Yunnan, the Shangsi-Jiusi Formation in eastern Yunnan, the Fengning Limestone sequences in western Guizhou, the Tangbagou, Jiusi and Shangsi Formations in south-central Guizhou, and the Laoxu Shale in western Guangxi.

The Weixian Formation contains thin coal beds, carbonaceous shale, and argillaceous limestone in the lower part. This sequence grades upward into dark-gray, thick-bedded, dolomitic limestone. It is well exposed in the areas of Mengzi and Jinpeng.

The Shangsi-Jiusi Formation of eastern Yunnan contains the principal coal beds in this region. The coal-bearing sedimentary sequence is in the lower part of this formation and consists of black shale, carbonaceous shale, quartzite, sandstone, coal beds, and, locally, bauxitic clay beds. The thickest coal bed is 1.5 m thick. It is well exposed in the areas of Yiliang and Songming.

The Fengning Limestone sequence of western Guizhou contains thin bituminous coal beds intercalated with black, calcareous, silty shales. Pyrite crystals and nodular limestone are common. It is well exposed in the area between Shuicheng and Weining.

The Tangbagou, Jiusi, and Shangsi Formations contain several thin bituminous coal beds with thicknesses generally ranging from 0.5 to less than 2 m. Coal beds are generally bedded and lenticular in association with bauxitic layers. Coal beds are generally extensive in the areas southeast of Guiyang and Guiding.

The Laoxu Shale sequence of western Guangxi consists of dark-gray, thin-bedded limestone, carbonaceous shale, and traces of coal. It is well exposed in the areas of Hechi and Nandan.

Deposition

The sea in which the Fengninian Series was deposited transgressed from south of the study region. This sea passed through seaways of the old Vietnam landmass on the south and invaded the Chuan-Dian landmass on the west, the Yangzi (Chang Jiang) and Jiangnan landmass to the north, and the Yunkai landmass to the east (figs. 14 and 16). During a regression in the middle part of Fengninian deposition, coal formed in the coastal delta, lagoon, bay, and coastal plain environments (Han and Yang, 1980, p. 160-163).

The Weixian Formation and Laoxu Shale were probably deposited in bay and lagoon environments dominated by accumulations of argillaceous rocks. The Shangsi-Jiusi Formation of eastern Yunnan formed in a coastal delta environment as indicated by the extensive shoreline of sandy detrital rocks. The Fengning Limestone sequence of western Guizhou formed chiefly in a coastal-plain environment characterized by fine-grained detrital rocks. The coal beds of the Tangbagou, Jiusi, and Shangsi Formations were deposited in coastal delta and coastal-plain environments as indicated by the prominent arenaceous and detrital rocks in association with bauxitic layers.

Permian coal deposits

Permian coal deposits have been reported in eastern Yunnan, western Guizhou, and south-central Guizhou; mineable coal beds are confined to the Lower and Upper Permian sedimentary sequences of eastern Yunnan and western Guizhou. Detailed data on coal geology generally are not available.

Occurrence

In eastern Yunnan, a coal-bearing sequence is in the Upper Permian Laoping Series. In western Guizhou, coal-bearing sequences are, in ascending order, the Coal-bearing Formation and the Qixia Limestone of the Lower Permian and the Longtan Formation of the Upper Permian. In southcentral Guizhou, the coal deposits are in the Coal-bearing Formation and the Qixia Limestone of the Lower Permian, and in the Zhutang Formation of the Upper Permian.

The Laoping Series of eastern Yunnan in the middle part contains five mineable coal beds. The coal-bearing sequence generally consists of coal beds that are interbedded with shale and sandstone. Thickness of the coal beds ranges from 3 to 16 m. Generally, the coal beds are 2 m thick and locally average as much as 4 m thick. They are well exposed in Mile County.

The Coal-bearing Formation of Western Guizhou occurs beneath the Qixia Limestone and consists of a series of gray quartzose sandstone, sandstone, and grayish-black shale beds intercalated with coal beds. Thickness of the coal beds is generally about 2 m. The Upper Permian Longtan Formation contains 15 coal beds in a shale and sandstone sequence. The thickness of individual coal beds ranges from 0.1 to 2 m, and locally is in excess of 4 m. The Longtan coal bed is generally extensive and exposed in Shuicheng County.

The Coal-bearing Formation of south-central Guizhou consists of a series of brownish-gray quartzose sandstone, clayey sandstone, and black, silty shale beds intercalated with several thin coal beds, and locally impure limestone. The Upper Permian Zhutang Formation contains several thin coal beds in a shale, mudstone, and sandstone sequence, which changes into a carbonate facies south of Guiyang.

Deposition

During the Lower Permian the sea transgressed from the northeast, the northwest, and the southwest (figs. 18, 19, 21, and 23) (Han and Yang, 1980, p. 168-171), and most of the old landmasses were submerged and covered by shallow marine waters. The Permian coal deposits of eastern Yunnan, western Guizhou, and south-central Guizhou formed chiefly in coastal delta and coastal plain environments. Along the eastern flank of the Chuan-Dian old landmass in eastern Yunnan and western Guizhou, the coal-bearing sedimentary sequence developed in a marine and continental transitional zone (figs. 19, 21, and 23), which was bordered by land on the west and by shallow offshore marine waters on the east. Generally, the coal-bearing zone attains a thickness of 10 to 30 m, and locally is up to several hundred meters thick. It contains several coal beds and is characterized chiefly by arenaceous and argillaceous rock types.

The Lower and Upper Permian coal deposits of south-central Guizhou generally accumulated in shoreline environments and are associated with clay and calcareous mudstone with marl and ferruginous and argillaceous deposits.

Upper Triassic coal deposits

The Upper Triassic coal deposits are chiefly in the Huobachong Formation of southeastern and eastern Yunnan and western Guizhou, and the Sile Series of western Guangxi. Mineable coal beds are confined to the Huobachong Formation.

Occurrence

The coal-bearing Huobachong Formation of southeastern Yunnan consists of a sequence of variegated shale, sandstone, and quartzose sandstone intercalated with lenticular coal beds. Individual coal beds are generally less than 1 m thick. This formation is well exposed in the vicinity of Gejiu.

The Huobachang Formation of eastern Yunnan and western Guizhou contains a coal-bearing sedimentary sequence of gray sandstone and black, calcareous, argillaceous shale, which is intercalated with several lenticular coal beds. The thickness of individual coal beds is generally less than 1 m. This formation is well exposed in Luoping County of eastern Yunnan and Zhenfeng County of western Guizhou.

The coal beds of the Sile Series in western Guangxi are in the lower part of this series and are associated with gray shale and fine-grained sandstone. The thickness of the coal beds ranges from 0.1 to 0.2 m. This series is well exposed in the northwestern part of Guangxi Province.

Deposition

During the early part of the Upper Triassic, the sea regressed extensively in southwest China because of the effects of the Indosinian orogeny. Over most of the region, alternating marine and continental coal-bearing clastic deposits accumulated (fig. 35). The Huobachong Formation was deposited chiefly in delta and lagoon environments. Although the coal beds are relatively thin, the coal is bituminous, which is characterized by low-sulfur content.

Jurassic Coal Deposits

Thin coal beds and traces of coal are common in the continental Xiangxi Series of Western Guizhou. Scattered outcrops are located in areas of Shuicheng on the north and Zhenfeng on the south.

Tertiary coal deposits

Tertiary lignite deposits have been reported in the Ciyang Formation of eastern Yunnan and the Yongfu and Yongning Series of Western Guangxi. The lignite is in thin beds, most of which are less than 1 meter thick. In western Guangxi, lignite is associated with oil shale and oil sand and is in beds 0.3 to 0.5 m thick. Locally, beds are in excess of 1 meter thick.

Petroleum and Natural Gas Deposits

Although the petroleum and natural gas deposits of the Dian-Qian-Gui foldbelt, southwest China, have been studied since the late 1950's, only scattered geologic information has been published in the past several years (Cheng, 1977; Robertson Research International Ltd, 1978; Masters and others, 1980; Zhan, 1980; Zhang and others, 1980 and 1981; and Wang, 1982). The rocks of this region consist chiefly of marine carbonate sedimentary sequences assigned to the Upper Proterozoic to Lower Paleozoic and the Upper Paleozoic to Triassic (Masters and others, 1980), as well as Tertiary marine and continental fine detrital facies (Liang, 1982, p. 97-100) (Hu, 1983).

Because of scattered geologic information concerning the oil and gas deposits in this region, the following discussion on the occurrence of oil and gas, source rocks of oil and gas, and properties of reservoir rocks is herein generalized.

Source rocks

Source rocks in the study region have been identified in the Proterozoic Upper Sinian Series in the Dengying Limestone, in the Middle and Upper Devonian shale and carbonate-reef facies, in the Carboniferous and Permian reef and shale facies, in the Middle Triassic bioherm and shale facies, and in the Tertiary fine detrital facies.

The Dengying Limestone is extensively distributed throughout the region and consists chiefly of algal dolomite intercalated with clay and shale (table 1 and fig. 8). The algal dolomite consists of dolomite in association with calcite, quartz, chalcedony, collophane, and gypsum (Tang and others, 1981). The principal textural types of the Dengying are the mineral and clay grains. Grain types are sand grain, spherical grain, nuclear, algal bit, and algal granular. Locally, oolitic grain is commonly present in the poorly developed algae beds, probably due to the control of shallow water shoreline environment. These textural grains were cemented by dolomite. The clay grain and microlite of the Dengying sequence are widely distributed and attain a relatively thick layer. Rhombic crystals of dolomite are absent.

The Dengying Limestone sequence was deposited as an algal barrier bar in shoreline and shallow-shelf environments on a platform (fig. 6). The sedimentary structures commonly are lamellar, banded, bird's-eye, inclined laminar layer, and scouring surface. Botryoidal-band structure is the characteristic of the algae-rich dolomite. The algae consisted of red and blue-green algae. Algal stromatoliths consist of Baicalia, Boxonia, Gymnosolen, and Kussielida, etc. Ranges in chemical composition of the Dengying carbonate sequence in the Guizhou-Sichuan region, as determined from 710 samples of the Lower Member and 213 samples of the Upper Member, are: $CaCO_3$ - 0.87 to 1.97 percent in the Lower Member and 2.99 percent in the Upper Member; $CaMg(CO_3)_2$ - 88.54 to 96.90 percent in the Lower Member and 74.02 in the Upper Member. The insoluble residues range from 0.79 to 8.30 percent in the Lower Member,

and 20.17 percent in the Upper Member (Tang and others, 1981, p. 14-16). The depositional environments of the Dengying Limestone in South China are shown in figure 8. The Dengying attained a thickness of up to 1,000 m.

Middle and Upper Devonian carbonate, shale, and reef facies are thick and extensively distributed in this region. The reef facies consisted chiefly of coral reefs, which were associated with the shell, plankton, and benthonic facies in the gray, black, argillaceous, cherty limestone, marl, and carbonaceous shale. The maximum thickness of Devonian shale and carbonate-reef facies is about 1,000 meters in the vicinity of Dushan, South Guizhou.

The development of marine organisms during an extensive transgression of the Carboniferous generally reached the culminating stage. The Carboniferous coral reef and black, carbonaceous shale sedimentary sequences of this region were extensively deposited under marine shoreline and shelf environments and are widely distributed in the Lower Carboniferous Fengninian Series. The thickest deposits of this period have been located in southern Guizhou Province, where the Lower Carboniferous strata attained a thickness in excess of 2,000 m in the vicinity of Dushan (Wang and Lui, 1980, p. 186-187).

During the Permian period, the extent of the marine transgression was similar to that of Carboniferous time. Carbonate reef development with an associate black carbonaceous shale facies reached another flourishing period throughout South China. In the Nanpanjiang area, He and others (1981, p. 1-10) conducted detailed investigations of the Upper Permian bioherms. They traced bioherm development from the areas of Guangnan, southeastern Yunnan Province, and of Longlin, and northwestern Guangxi Province to the area between the cities of Ceheng and Guiyang, southern Guizhou Province (figs. 25 and 27). The depositional environments of the Upper Permian in southern and western Guizhou were classified by He and others (1980, fig. 27) as subaerial-fluvial, delta-plain, subaqueous-delta, inner-continental shelf (delta slope carbonate), and outer-continental shelf (prodelta tuffaceous clastic and siliceous sediments). The Upper Permian bioherms consist chiefly of sponges and siphono-conches in a micrite matrix and are thick at the contact zone between the inner- and outer-continental-shelf facies. In southwestern Guizhou, the reef zone trends generally northeasterly.

During the Triassic period, the vast Tethys ocean covered most of South China, and the development of Middle Triassic algal bioherms again flourished and several facies zones developed adjacent to them. The bioherms developed in the border zone between the algal flat and the ocean basin margin (Ho and others, 1980, p. 256-264) (figs. 31 and 33) and are classified by Ho and others (1980) into seven facies zones: ocean-basin, basin-margin, carbonate-platform slope, carbonate-platform reef-ridge, algal-flat, restricted-lagoonal carbonate-platform, and tidal-flat of carbonate platform. The bioherms and associated facies extended about 1,000 km and trended southwest-northeast from the Luoping and Guannan areas of the Nanpanjiang depression in southeastern Yunnan, via the area south of Guiyang, to the southwestern part of Hunan province. Most organisms are the red algae, Solenopracae. The back reef consisted chiefly of a blue-algal sheet. The growth base of the reef is composed of algal fragments and nodules upon which the thick layer-by-layer growth developed on older algal mats. In southwestern Guizhou, the Middle

Triassic carbonate sequences attain a total thickness of 3,500 m (Wang and Liu, 1980, p. 290-330). In addition, throughout the study region, the Middle Triassic and Upper Triassic black, carbonaceous shale facies are generally extensive and were deposited in the shoreline environment.

As a result of researches on the evolution of organic matter in carbonate rocks of the Southern Sichuan Province, Fu (1980, p. 39) mentioned that the Sinian to Triassic marine carbonate source rocks of South China are generally characterized by a low content of organic carbon (less than 0.20%), high content of hydrocarbon, and high organic maturity at the late stage of evolution. As the study of the methanization evolution trend in natural gas proceeded, evidence indicates that with the increasing geological age, the heavy hydrocarbons of natural gas and oil-generating layers gradually decrease as well as increasing the maturity of organic matter. When the H/C atomic ratio reached 0.8 and bitumen reflectivity was at 10-11, the evolution stage of crude oil was at a high maturity (Fu, 1980, p. 49). At the late stage of organic evolution of carbonate rocks, all biomarkers to distinguish terrestrial organic precursors from marine organic precursors had almost disappeared with liquid hydrocarbons, which were completely composed of hydrocarbons with C - number less than 22. As the H/C atomic ratio and bitumen reflectivity reached 0.4 and 14, respectively, the evolution of gas hydrocarbons nearly approached the end status of methanization with a maximum temperature of 350°C and a time duration of about 700 m.y. (Fu, 1980, p. 49-50).

The Tertiary fine detrital facies occur in the Baishai (Baise) basin of the Youjiang valley northwestern Guangxi and consist of Paleocene to Miocene sedimentary sequences. Liang (1982) and Wang and Lui (1980) stated that the Lower Tertiary of the Baishai includes the Paleocene Luchon Formation, the Lower to Middle Eocene Dongjun Formation, the Upper Eocene to Middle Oligocene Nadu Formation, and the Middle Oligocene to Upper Oligocene Gongkang Formation. Cheng and Wang (1980) considered that the red beds of the Luchon Formation indicate that the depositional climatic condition was semi-arid. Subsequently, the climate changed into semi-moist and moist conditions. The remaining younger Tertiary Formations were made up of dark-colored oil and lignite-bearing fine detrital sediments, of which the Nadu Formation shows the marine facies of the Chunhuazhen and Shahejie transgressions (Liang, 1982, p. 97-100). Hu (1983, p. 2) stated that the Nadu and Baigang (probably Gongkang) Formations contain the source beds, which attain a thickness of 1,200 m and contain C, 1.03 percent, and "A" (asphalt), 0.06 percent, with a geothermal gradient of 3.76°C/100 m. The thickness of the source beds is unknown.

Reservoir rocks

Information on occurrence of oil and gas deposits in the oil fields of the Dian-Qian-Gui region is generally lacking. Fragmental reports on physical properties and structural characteristics of reservoir rocks are available, but detailed descriptions as to locations are commonly not given. Generally, the location of oil and gas deposits in the reservoir rocks appears to have been controlled by textural properties of host rocks as well as by diastrophic movements. Successful hydrocarbon exploration in carbonate rocks has been a

difficult and complex problem. During their geologic history, the carbonate rocks were not only deposited with different depositional patterns in the various environments but also were altered by extensive diagenetic changes during and after deposition. Generally, the timing of diagenetic alterations and diastrophic movements has been the chief factor controlling the oil and gas migration and accumulation in reservoirs.

In the Dian-Qian-Gui region, descriptions of the textural properties of reservoir rocks are scarce. Preliminary study of porosity and permeability of carbonate reservoir rocks in China was done by Luo and others (1981, p. 40-51), who concluded that the most favorable reservoir rocks are dolomitic limestone and dolomite. Cheng and others (1977) conducted rather detailed research on the reservoir behavior of Lower Triassic oolitic carbonates of the Triassic basin of South China. The oolitic carbonates consist of oolitic limestone and oolitic dolomite that developed in the upper part of the evaporite sequence and on oolitic beaches in the intertidal and subtidal shallow-water zones. The oolitic beaches formed successively as the result of diastrophic movements during marine regression. As the beaches emerged above sea level, they were weathered, and the raised bar, shoals, and ridges were eroded by fresh water (fig. 29). Generally, the leached oolitic limestone is widespread but oolitic dolomite is locally restricted. The reservoir behavior of these rocks was hence controlled by the bars, shoals, and ridges. Therefore, searching for this type of oil and gas deposit of the oolitic beaches should be confined to the shoreline environment.

Structurally, the Nanpanjiang and Baishai (Baise) lowlands are faulted depressions. The Nanpanjiang depression trends northeasterly and was formed during the Caledonian deformation. This depression contains thick Devonian and Carboniferous carbonate and carbonaceous shale sequences, and Permian and Triassic bioherms and shale facies, which are covered by the Upper Triassic shale facies. Zhan (1980) suggested that exploratory efforts should be directed towards the areas along carbonate platform margins and algal banks. Wang (1982) favors the dome and synclinal structural feature for prospecting for oil and gas deposits throughout the region. A deep well was drilled in the vicinity of Luoping, Yunnan, in the northern part of the Nanpanjiang depression (fig. 2). This well is reported to be 6,000 m deep and to have penetrated Triassic to Devonian beds with gas shows in the Permian rocks; further details were not reported (personal communication with Chinese Petroleum geologists to the 1983 AAPG Annual Convention at Dallas).

The Baishai (Baise) basin trends northwesterly in northwestern Guangxi and covers an area of 830 km (Hu, 1983, p. 1). This basin was probably formed during the Indosinian-Yanshanian orogenies and contains four oil fields (figs. 41 and 42): Lunxu, Xinzhou, Naman, and Linpeng, of which the Lunxu is the largest. Pay zones are in anticlines, stratigraphic traps, and faulting-lithologic traps (figs. 43 and 44). The crude oil is high in parafin (wax, 14-29 in weight percent) and pour point (25-35° C). Daily yield at the Lun-2 well, Lunxu field, is 27 tons (300 bbls) per day.

In the northern flank of the Baishai basin, the Lun 4 well was tested for oil flow at a rate of 16 m^3/day (120 BO/d) from a pool on Middle Triassic limestone at a depth of 604.1 to 662 m.

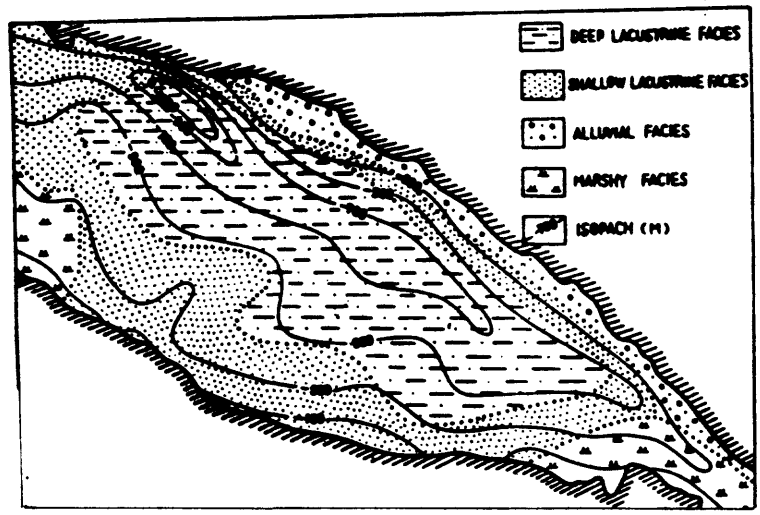


Figure 41.--Lithofacies of the Upper Eocene to Middle Oligocene Nadu Formation, Baishai (Baise) Basin (adopted from Hu, 1983, fig. 4).

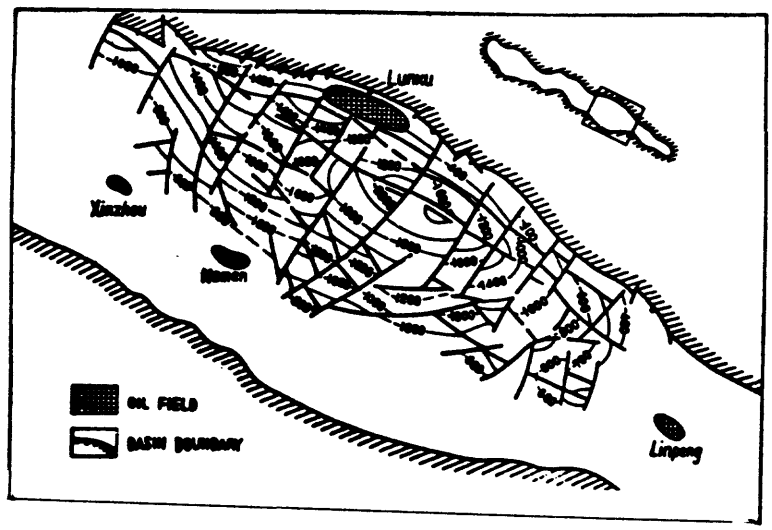
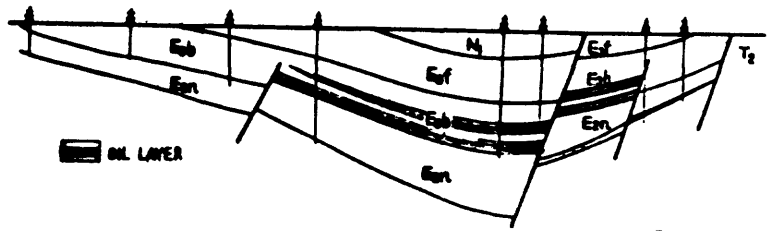


Figure 42.--Generalized structure map and oil fields, Baishai (Baise) Basin (adopted from Hu, 1983, fig. 5).



T. Triassic

E_2. Eocene

E_3. Oligocene

N. Neogene (Upper Tertiary)

Figure 43. Schematic profile across the Baishai (Baise) basin (adopted from Hu, 1983, fig. 7).

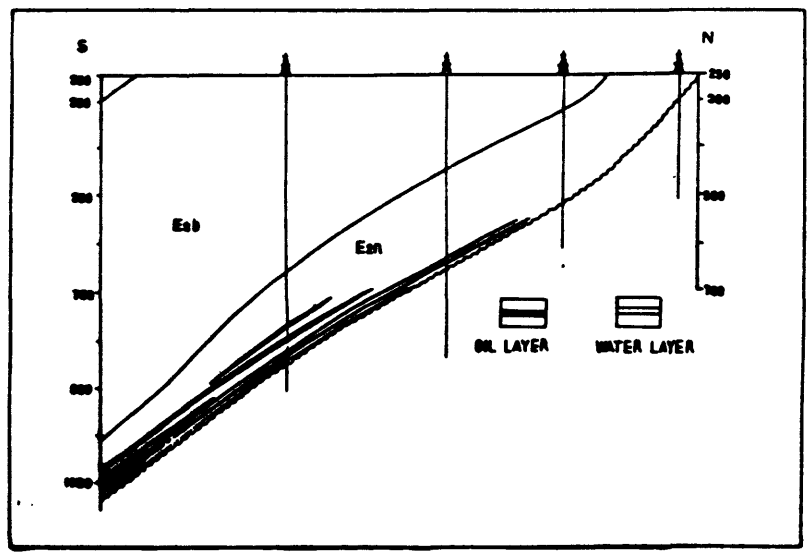


Figure 44. Stratigraphic profile of the Lunxn oil field (adopted from Hu, 1983, fig. 11).

SUMMARY

The Dian-Qian-Gui foldbelt, Southwest China, is an integral tectonic unit of the South China fold system and borders the southern margin of the Yangzi paraplatform. During most of the Precambrian, this region was a landmass. Middle- and Upper-Proterozoic marine and continental sedimentary sequences are known. In Paleozoic time, marine facies were characterized by thick fossiliferous carbonate sequences and extensively distributed. In the Mesozoic, the Lower-Triassic sea gradually covered most of South China and retreated during the latest part of Middle Triassic time. Since then, marine transgressions are recorded locally by Tertiary rocks only in the southern part of this region.

Coal deposits are chiefly in the Lower-Carboniferous, Lower- and Upper-Permian, and Upper-Triassic sedimentary sequences. Locally, coal beds are mined.

Oil and gas deposits are known throughout the region. Favorable source rocks are reef and carbonaceous shale facies preserved in Upper-Sinian, Devonian, Carboniferous, Permian, and Triassic sedimentary rocks. Favorable reservoir rocks of the carbonate rock terrains of the Nanpanjiang depression are oolitic, dolomitic limestone, dolomite, and arenaceous detrital-bioherm sedimentary strata on the shorelines of shallow marine platforms and reef banks adjacent to the margin of the ocean basin. Dome and syncline structural features have generally proven favorable for prospecting.

The Tertiary Baishai (Baise) basin contains oil and gas deposits in the detrital continental and marine facies with fine clayey detritus of the Nadu Formation considered as the source beds.

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APPENDIX

The following is intended to provide the available detailed stratigraphic and fauna content information for the Devonian, Carboniferous, Permian, and Triassic systems of the study area. Some duplication of materials in text is included for convenience.

Devonian

Lower Devonian.--The Lower Devonian strata of this region generally consist of shale, marl, and sandstone. Local names are designated to represent stratigraphic units. On the basis of regional distribution, a descriptive statement of the Lower Devonian strata is given below.

In southeastern Yunnan, the rocks assigned to Lower Devonian are represented by the Pojiao Shale. This shale is well exposed in the vicinities of Guangnan and Wenshan. It is made up of fossiliferous, brown, reddish-yellow, and gray shale intercalated with greenish-gray, clayey shale, and gray, silty shale. An abundant fossil fauna has been collected and consists of: Hadrophyllum brancai (Frech), H. intercalare Yin, Caleeda sandalina sinensis Mansuy, C. sandalina acuminata Mansuy, Thiemella? communis Yin, Stropheodonta (Douvillina) inaequistsiata var. patti Yin. S. (Douvillinella) annamitica (Mansuy), Chonetes cf. zeili Mansuy, Arypa reticularis (Linne), Spirifer tonkinensis Mansuy, Calymene maloungkaensis Mansuy, and Proetus indosinensis Mansuy. Although the base of the Pojiao Shale is not exposed, the exposed part is more than 100 m thick. The exact age of the shale, as a whole, has not yet been established (Institute of Geology, Academia Sinica, 1956, p. 98).

The clastic Lower Devonian rocks of eastern Yunnan are assigned to the Cuifengshan Group in the vicinity of Huaning (Chinese Academy of Geological Sciences, 1973, p. 140). This group is probably equivalent to the Chanyi Series, which was designated as Early Devonian in age (Institute of Geology, Academia Sinica, 1956, v. 2, p. 98).

In western and south-central Guizhou, Lower Devonian rocks consist of sandstone and conglomerate, and locally, in south-central Guizhou, shale intercalated with thin-bedded limestone in the areas of Dansai, Sandu, and Dushan. The thickness of these rocks in south-central Guizhou ranges from about 5 m to more than 30 m (Institute of Geology, Academia Sinica, 1956, p. 464).

In western Guangxi, the Lower Devonian rocks are represented by two formations, in ascending order, the Lianhuashan Formation and the Sipai Shale. The Lianhuashan Formation consists of purple, finegrained, quartzose sandstone, yellowish-brown sandstone, and purple shale. It is well exposed in the areas of Longan, Zhendu, Daxin, and Chongzuo. The thickness is about 100 m. This formation is in South China and contains vertebrate fauna at Xiangzhou, central Guangxi: Galeaspis, Polybranchiaspis, Asiaspis expansa, Lianhuashanolepis, and Yunnanolepis (Chinese Academy of Geological Sciences, 1979, p. 19-22).

The Lianhuashan grades upward into the Sipai Shale, the upper unit of the Lower Devonian. The Sipai Shale consists of gray, yellowish-brown, and red shale, interbedded with dark-gray, clayey, fossiliferous limestone. A 10-meter thick grayish-green shale bed is the youngest unit of the Sipai. The clayey limestone contains the following brachiopods: Spirifer tonkinensis Mansuy, S. speiosus Bronn, S. sp., Stropheodonta inaequistriata Conrad, pterinaea cf. Tineata, and Proetus sp. It is well exposed in the areas of Debao, Daxin, and Fusui. Thickness is estimated to be more than 200 m (Institute of Geology, Academia Sinica, 1956, p. 509).

Middle Devonian.--Middle Devonian strata are extensively distributed in western Guangxi, south-central Guizhou, eastern Yunnan, and western Guizhou. Generally, they are relatively poorly developed in southeastern Yunnan.

The Middle Devonian rocks of western Guangxi are subdivided, in ascending order, into the Majiaao Limestone, the Lazhutai Formation, the Wuzhishan Formation, the Tongchejiang Formation, the Chehe Formation, the Liangshuiao Formation, and the Kengma Formation (Institute of Geology, Academia Sinica, 1956, p. 508-509).

The Majiaao Limestone is blackish-gray, impure, thin- to thick-bedded, and in part clayey, and weathers dark-purple. The clayey variety is generally intercalated with black shale. The limestone is well exposed in the vicinities of Tiane, Nandan, and Hechi, northwestern Guangxi, but the base of the unit is concealed. Thickness is about 250 m.

The Lazhutai Formation consists, in the upper part, of light-gray or brownish-gray, dense, laminated chert layers which are locally intercalated with black, carbonaceous shale and lenticular clayey limestone; and in the lower part, of black carbonaceous or grayish-black shale. Generally, a pitted surface has developed on weathered limestone. The unit is well exposed near Tiane, Nandan, and Hechi. Thickness is estimated to be 87 m.

The Wuzhishan Formation is comprised chiefly of light-gray and greenish-gray, very thin-bedded or lenticular limestone, intercalated with very thin chert layers. It is well exposed near Tiane, Nandan, and Hechi, northwestern Guangxi. The unit is 55 m thick.

The Tongchejiang Formation is made up of black shale intercalated with sandy and carbonaceous shale. This shale grades upward into black, laminated limestone, and downward into light-gray chert layers. It is well exposed in the vicinities of Tiane, Nandan, and Hechi, northwestern Guangxi. This unit is 230 m thick.

The Chehe Formation consists in the upper part of gray, thick-bedded, quartzose, brownishgray sandstone; and in the lower part brown and gray shale, intercalated with limonite-bearing sandstone, and lesser amounts of quartzose sandstone, black shale, and dark-gray, clayey, thin-bedded crinoidal limestone. The unit is well exposed near Tiane, Nandan, and Hechi, northwestern Guangxi. Thickness ranges from 100 to 150 m.

The Wuzhishan Formation, Tongchejiang Formation, and Chehe Formation are equivalent to the Yujiang Beds (Institute of Geology, Academia Sinica, 1956, p. 508).

The Liangshuiao Formation and the Kengma Formation are equivalent to the "Donggangling Limestone" (Institute of Geology, Academia Sinica, 1956, p. 508). The Liangshuiao Formation is made up of dark-gray, dense, thin-bedded limestone intercalated with chert nodules and shale, and is generally equivalent to the lower part of the Kengma Formation. This unit is 400 m thick. The Kengma Formation consists chiefly of yellow, light-purple shale intercalated with carbonaceous, sandy shale. Thickness of the Kengma ranges from 100 to 150 m. Both formations are well exposed near Tiane, Nandan, and Hechi, northwestern Guangxi, and in the vicinities of Debao and Jingxi, western Guangxi. Identified fossils from these two units are: Atrypa desquamata Sowerby, A. desquamata var. hunanensis Grabau, A. reticularica Linn., Spirifer cf. officialis Kays., Reticularia maureri Holea, R. pachyrhynchoides Grabau, Spiriferina octoplicatoides Grabau, Meristella sp., Cryptonella sp., Comerotoechia sp., Stringochephalus burtini Defrance, Amplexus sp. Pachpora sp., Camarotoechia sp., Athyris sp., and Othoceras sp.

In south-central Guizhou, the Dushan Series contains all the Middle Devonian sedimentary sequences. This series is subdivided, in ascending order, into: the Bangsai Sandstone, the Jipao Limestone, the Songjiaqiao Sandstone, and the Jiwosai Limestone (Institute of Geology, Academia Sinica, 1956, p. 463-464).

The Bangsai Sandstone is made up chiefly of light-red and brownish- or grayish-yellow, light-gray, fine- to medium-grained, clayey, dense, and thick-bedded, quartzose sandstone and quartzite with a basal, coarse-grained sandstone. Locally, the upper beds of the sandstone are intercalated with silty, carbonaceous shale containing abundant euhedral pyrite. Fossils are Leptostrophia maccarthyi Grabau, Atrypta sp., Schizophoria sp., and Spirifer sp. The Bangsai Sandstone has also been termed the "Mangshan Quartzite." Thickness ranges from 10 to about 350 m.

The Jipao Formation is chiefly dark-gray, clayey, dolomitic, and cherty limestone with a basal dolomite. It contains an abundant fossil fauna of: Rugosa: Campophyllum, Favosites, Disphyllum, Prismatophyllum, Pachypora and Syringopora; Brachiopods: Chonetes orientalis Loczy, Productella productoides var. sinensis Grabau, Schizophoria striatula (Schl.), S. plicatostriata Grabau, Plectospirifer fongi Grabau, Spirifer platysellus Grabau, Reticularia cf. Waureti (Holzapfel) Emanuella takwanensis (Kayser), Athyris stringocephali Formis Grabau, A. cf. concentrica V. Buch, A. Vittata var. antecidens Grabau, Atrypa aspera var., A. aspera var. retziformis Grabau, Stringocephalus latus Grabau, S. obesus Grabau, S. magnoseptatum Grabau, and Uncites sp.; and the Pelecypode, Conocardium compressum Grabau. Thickness ranges from 40 to 200 m.

The Songjiaqiao Sandstone is coarse-grained and calcareous and intercalated with thin-bedded, silty shale. It has a great variation in thickness ranging from zero to about 150 m.

The Jiwosai Limestone is grayish-black, fine-grained, siliceous, clayey in part, dolomitic, and crytalline limestone. It is brittle and much jointed and contains chert bands and coral fossils in the middle of the upper part. Locally, it is intercalated with small amounts of black, carbonaceous, and variegated shale. The following fauna has been identified: Rugosa: Campophyllum cylindricum Yoh, Disphyllum breriseptatum Yoh, D. geinitzi Goldf., Favosites cf. digitalis, Amplypora sp. Actinostroma asiatica Grabau, Springopora sp., Prismatophyllum junghsienense Yoh, P. Pentagonum Goldfuss, Cyathophyllum heterophyllum E. et H., C. Yunnanense Wang, Sunophyllum elegantum Wang, Temeniophyllum poshiense Wang, T. Leei Wang, T. Kueichowense Wang. T. Waltheri Yoh. Brachiopods: Productella productoides var. sinensis Grabau, Plectospirifer takwanensis (Kayser), P. cf. fongi Grabau, Retcularia tuchanensis Grabau, Atrypa desquamata Sowerby, A. desquamata var. auriculata Hayasaka, Schizophoria/excellens Grabau, Stringocephalus burtini De france. Pelecypods: Lophospirina angustipegmalis Grabau, and Hormotomina tushanensis Grabau. Thickness of this limestone ranges from 100 to about 200 m.

In eastern Yunnan, rocks of Middle Devonian age are assigned, in ascending order, to the Longhuashan, Poxi, and Qujing Formations. The Longhuashan consists chiefly of brownish-yellow, brownish-purple, gray sandstone and shale intercalated with dark-gray, thin-bedded and nodular, fossiliferous limestone. It is about 60 to 200 m thick. The Poxi Formation is comprised chiefly of dark-gray, in part clayey and cherty, thinbedded limestone, containing scattered breccia and abundant brachiopods. It is about 80 to 270 m thick. The fossiliferous Qujing Formation consists chiefly of gray, impure, blocky, clayey, dolomitic and cherty limestone interbedded with shale. Thickness ranges from 150 to 550 m.

Detailed information is generally lacking about rocks of Middle Devonian age in western Guizhou, but they are similar in lithology to the Middle Devonian strata of eastern Yunnan and consists chiefly of marl, impure limestone, dolomite, and shale.

In southeastern Yunnan, Middle Devonian rocks consist in the lower part of interlayers of gray and grayish-brown, clayey, thin-bedded limestone and shale; in the middle part of dark-gray and dark-blue, thick-bedded limestone; and in the upper part of light-gray, blocky, siliceous, and crystalline limestone. These rocks are well exposed near Mengzi, Wenshan, and southeast of Jianshui. Thickness is about 400 m.

Upper Devonian.--The rocks of the Upper Devonian are widely exposed in eastern and southeastern Yunnan, south-central Ginzhou, and western Guangxi (Chinese Academy of Geological Sciences, 1973, p. 93, 137, and 140).

The Upper Devonian rocks of eastern and southeastern Yunnan and western Guizhou are tentatively represented by the Yidade Formation (Chinese Academy of Geological Sciences, 1979, p. 137 and 140). This formation in eastern Yunnan consists in the upper part of light-gray, blocky, siliceous, crystalline limestone; in the middle part of dark-gray and dark-blue, thick-bedded limestone; and in the lower part of gray, grayish-brown, clayey, thin-bedded limestone locally interbedded with shale. Excellent exposures are known near Mengzi, Wenshan, and along the border between Jianshui and Gejiu. A complete stratigraphic section is located between Yidade and Dalila, about 10 km north of Panxi; a lithologic description is quoted hereafter, in descending order (Institute of Geology, Academia Sinica, 1956, p. 428-429).

5. Limestone, blackish-gray; yields a fauna of Alveolites, sp., Amphipora sp., Gypidula planisinosa Grabau, and Camarotoechia sp.; 20 m thick.

4. Limestone, dark-gray, clayey; contains a fauna of Schizophoria macfarlanii var. galeatiformis Grabau, Productella subaculeata Murch., Camarophoria huotiformis Grabau, Leiorhynchus deprati var. obesus Grabau, Hypothyridina parallelepipedo (Bronn), Yunnanellina uniplicata Grabau, Tenticospirifer sp., Atrypa desquamata Sow., Bellerophon sp., and Manticoceras Wedekindi Sun; 5 m thick.

3. Limestone, black, light-gray on weathered surfaces, thin- to thick-bedded, banded in upper part; containing Schizophoria cf. macfarlanii (Meen), Atrypa desquamata Sow., Ambocoelia sinensis Tien; 80 m thick.

2. Limestone, dark-gray, black, and clayey intercalated with shale in lower part; contains a fauna of Alveolities sp., Hypothyridina parallelepipeda (Bronn), Atrupa desquamata Sow., Ambocoelia sinensis Tien; 40 m thick.

1. Shale, brown and dark-gray; interbedded with clayey limestone; identified fauna is Lingula sp. Hypothuridina parallelepipeda (Bronn.), and prptplepidodendron-like plant remains; 180 m thick.

In south-central Guizhou, the Upper Devonian sedimentary sequence consists chiefly of clayey limestone and limestone locally intercalated with small amounts of dolomite and shale (Chinese Academy of Geological Sciences, 1973, p. 137). These rocks are well exposed near Dushan and Sandu and generally pinch out to the north and east. The Maosai Series confirms the Upper Devonian strata of south-central Guizhou and is subdivided, in ascending order, into the Wangchengpo Formation and the Yaosuo Limestone (Institute of Geology, Academia Sinica, 1956, p. 462-463).

The Wangchengpo Formation is made up of dark-gray to blackish-gray limestone, intercalated with variegated clayey shale. The formation in the upper and middles parts contains bedded dolomitic, blocky limestone. Fossils are abundant and consist of a fauna of Rugosa: Disphyllum varium Schliuter, Campophyllum sp., Pachypora sp., Centiophyllum sp., Ensophyllum sp., Phacellophyllum iregulare Grabau, Fasciphyllum breviseptum Frech, and Syringopora sp. Brachiopods: Schizophoria macfarlanii var. Gypidula simplex Grabau, Gypidula subglobosa Grabau, Spirifer multistriatus Grabau, Sinospirifer sinensis Grabau, Sinospirifer subextensus Martelli, Sinospirifer yunnanensis (Mansuy), Tenticospirifer vilis Grabau, Reticularia cf. maureri Holz, Atrypa subreticularis Grabau, A. apsera Mansuy, A. Shetienchiaoensis Tien, A. aspera var. minor Grabau, A. cf. whidbornii, Productella subaculeata Murchison, Meristella flagellifornis Tien, Ambocoelia cf. Sinensis Tien, and Emanuella sp. Gastropod: Gellerophon cf. striatus de Vern. Thickness of this formation ranges from 100 to 200 m (Institute of Geology, Academia Sinica, 1956, p. 462-463).

The Yaosuo Limestone is gray, siliceous, thin-bedded limestone intercalated with gray, brown, thin-bedded shale. Fossils are generally scarce. Thickness of this unit is about 140 to 340 m.

In western Guangxi, the Upper Devonian strata are assigned to, in ascending order: the Huiluo Formation and the Shiti Limestone (Institute of Geology, Academia Sinica, 1956, p. 508).

The Huiluo Formation in the upper part consists of gray limestone and grayish-black, impure limestone; in the middle part of yellow to gray, siliceous shale; and in the lower part of yellow, sandy, siliceous and banded shale. It yields the following fossil fauna: Uncrinulus tournorensis Beyrich, Amphipora sp., Atrypa bodini Mansuy, and Sinospirifer sp. This formation is well exposed near Nandan and Hechi and stratigraphically is correlated with the Guilin Limestone to the east. Thickness is about 200(?) m.

The Shiti Limestone is light-gray or gray, thick-bedded limestone, and gray, grayish-green, light-gray, thin-bedded, lenticular limestone locally intercalated with black limestone containing Amphipora sp. and Athyris sp. This unit is equivalent to the Rongxian Limestone to the east of Nandan. Thickness ranges from 150 to 200 m in the vicinity of Shiti.

Carboniferous

Lower Carboniferous.--The Lower Carboniferous rocks of this region are assigned to the Fengning Series and consist of littoral-marine shelf to neritic-open marine sedimentary sequences.

In southeastern Yunnan, the Fengning Series is subdivided into the Dunei and the Weixian Formations in ascending order (Institute of Geology, Academia Sinica, 1958, p. 97-98).

The Dunei Formation is made up of dark-blue, thin-bedded limestone and is exposed in the northern part of Shippingxian and along the banks of Yuanjiang Stream. This formation contains Pseudoralinia, Zophiertis, and Cyathophyllum, etc. Thickness measurements are not available.

The Weixian Formation consists chiefly in the lower part of dark-gray, dense, thick-bedded, dolomitic limestone intercalated locally with sandstone and mudstone; in the middle part of chert bands and purplish-green shale; and in the upper part of limestone-breccia. In the vicinities of Mengzi and Jinping, the thick-bedded limestone of the upper part is dense and brittle and contains fossil fauna of corals, crinoids, blastoids, and fusulinids. This limestone grades downward into gray, thin-bedded limestone, or interbedded shale and sandstone. The thin-bedded limestone commonly contains coarse-grained sand and an abundant fossil fauna of corals, crinoids, and brachiopods. The shale is black and is interlayered with carbonaceous shale, thin-bedded marl, and coal. Thickness is estimated to be more than 500 m.

The stratigraphy of the Fengning Series of eastern Yunnan is generally similar to that of southeastern Yunnan. In eastern Yunnan, the Fengning is divided, in ascending order, into the Gelaohe Formation, the Shangsi-jiusi Formation, and the basal portion of the Upper Limestone (Weining Limestone) (Institute of Geology, Academia Sinica, 1956, p. 426-427).

The Gelaohe Formation is comprised chiefly of pale-gray or grayish-black, planar-laminated, sandy dolomite and dolomite, which contain small amounts of pure limestone. Locally this formation has a distinctive lithologic progression. Generally, the dolomite in the basal part of this formation contains more quartz sand and clay; is intercalated in the middle part with bands of chert and bluish-green, thin-bedded shale; and limestone near the top which is yellowish-gray and marly, as it is in the vicinity of Kunming. To the north of Zhanyi, this formation consists chiefly of blocky dolomite and attains a maximum thickness of 400 m. Thickness of this unit increases northeasterly and ranges from less than 20 to about 400 m. Lithostrotion (Siphonodendron) irregulare (Phillips), Lophophyllum sinense Y. et H., and Caninia sp. have been identified from the upper part.

The Shangsi-Jiusi Formation consists of a coal-bearing facies and a basin-margin facies. The coal-bearing facies is made up of black, carbonaceous shale, light-gray, quartzose sandstone, bauxite-beds, and several beds of anthracite and attains a thickness of more than 50 m. West of Yuxi, Anning, and Luquan, the coal-bearing facies changes into the limestone breccia of the basin-margin facies and attains a thickness of less than 35 m. The coal-bearing facies has yielded a fossil fauna of Lepidodendron sp. and Stigmaria sp.; and a coral fauna of lithostrotion (Siphonodendron) irregulare (Phillips) L. irregulate var. juntungense Yu, Kweichouphyllum sinense Yu, Lophophyllum sinense Y. et H., Aulina carinata Yu, Thysanophyllum asiaticum Yu, Syringopora cf. reticulata Goldf., Zaphrentis sp. Chaetetes thomsoni Reed, Lithostrotion platycystratum, L. satangense Yu, and Gigantella giganteus Martin.

The basal part of the "Upper Limestone" conformably overlies the Shangsi-Jiusi Formation in several places in eastern Yunnan. Locally this unit consists of a 1- to 8-m thick limestone which contains basal chert concretions and yields a coral and brachiopod fauna of Stratifera strata (Fischea), S. undata (De France), Dibunophyllum bipartitum (McCoy), D. bip. Konincki (E. et H.), Squamularia chouniukouensis Chao, Sq. pustula Chao, Yuanophyllum kansuense Yu, Lophophyllum sinense Y. et H., Palaeosimilia murchisoni E. et H., Corwenia rugosa (McCoy), Aulina carinata Yu, and chaetetes thomsoni Reed. Thickness is unknown.

The Lower Carboniferous Fengninian Series in south-central Guizhou is subdivided, in ascending order, into the Gelahoe Formation, the Tangbagou Formation, the Jiusi Formation, the Shangsi Formation, and the Laoganzhai Limestone. It is well exposed in the area of Dushan.

The Gelaohe Formation is made up in the lower part of light-gray to gray, very fine-grained, thick-bedded, dolomitic limestone and dolomite, and in the upper part of dark-gray to black, thin- to thick-bedded, very fine-grained limestone intercalated with black shale. This limestone and shale unit has a fossil coral and brachiopod fauna: corals - Cystophrentis kolaohoensis Yu, and C. pinnatea Yu; and brachiopods - Camarotoechia kin ingensis Grabau, Martiniella nasuta Grabau, Reticularia nonconforma Grabau, Neoproductella tenuistriata Grabau, N. kolaohoensis Grabau, Eochoristites neipentaiensis Chu, Spirifer subduplicosta Grabau, S. chichaensis Grabau, Productus inflatiforms Grabau, Cryptospirifer orientalis Grabau, Composita globularia Phillips, C. subtilita var. sinensis Grabau, Schuchertella kolaohoensis Grabau, and S. truncata Grabau. Thickness of this formation is about 280 m.

The Tangbagou Formation consists generally of quartzose sandstone or quartzite and is intercalated with grayish-black and impure limestone, sandstone, shale, carbonaceous shale, and thin coal beds. This unit contains the following fossil fauna: Pseudouralinia irregularis Yu, P. gigantea Yu, P. simplex Yu, P. tangpakouensis Yu, Neoproductella tangpakouensis Grabau, Rhipidomella michelini var. minor Grabau, Leptaena analogo Phillips, Productus praemanchuricus Grabau, Athyris (Cleiothyridina) profundisinosus Grabau, and Spirifer chichaensis Grabau. Thickness varies greatly locally, but in the vicinity of Dushan it is about 190 m thick.

The Jiusu Formation consists of marine and continental deposits of bluish-gray, impure, thin-bedded limestone intercalated commonly in the lower part with black coal-bearing shale between Jiusi and Liuzhai, Datang, southeast of Guiyang. Southeasterly from Datang, the Jiusi changes into quartzose sandstone intercalated with 60 meters of thin-bedded clay and coal-bearing shale; these strata grade upwards into 50 meters of gray, thin-bedded, impure limestone interbedded with shale, which in turn grades upward into 100 meters of quartzose sandstone with a small amount of gray shale in the area between Tangbagou and Heishiguan, Dushan. Northeasterly from Dushan, the Jiusi is made up chiefly of light-gray quartzite commonly intercalated in the upper part of this sequence with grayish-yellow, black shale and fire clay with coal beds in the black shale near Mazonling about 10 km east of Guiyang. In the vicinity of Guiyang the Jiusi consists chiefly of 5 to 10 meters of black, carbonaceous, lenticular shale and anthracite beds, overlying a basal ferruginous sandstone at Yunwushan. The black and carbonaceous shale sequence is overlain by yellow, green, purple, and brittle shale; bauxite beds of 3 to 8 m thick occur in the middle part. Thickness of the Jiusi ranges from 10 to 240 meters. Fossils of this formation are: corals - Thysanophyllum asiaticum Yu, T. pseudovermiculare (McCoy) var. minor Yu, Siphonodendron vurvatum Yu, Yabeella cyathophylloides Yu, Springopora geniculata Phyllips, and S. gracilis Keyserling; brachiopods - Productus inflatiformis Gr., P. yunnanensis Loczy, Cryptospirifer orientalis Gr., C. tatangensis Gr., Reticularia sp., and Orthoteles sp.; and plant fossils Sublepidodron sp. and Calamites sp.

The Shangsi Formation consists of dark-blue, pure, brittle, thin-bedded limestone in the lower part and light-gray, thick-bedded limestone in the upper part. Blocky and banded chert masses are common in the limestone, and the lower thin-bedded part often contains carbonaceous shale, coal, and, locally, thin-bedded quartzose sandstone. In the area of Shangsi, south of Dushan, the thickness of the unit is about 200 m, but it reaches 450 m between Jiusi and Liuzhai, Datang, as shown by the following profile, in descending order:

4. Limestone, light-gray, pure, contains chert bands; fossils are Productus (Grigantella) tingi Gr., Diphyllum convexum Yu, Productus (Kansuella) maximus McCoy, Daviesiella gigas Gr., D. Kueichonensis Gr., D. Comoides Sowerby, Siphonodendron petalaxioides Yu, Arachnolasma vesiculare Yu, and Kueichouphyllum heishihkuanensis Yu; 90 m thick.

3. Limestone, gray to bluish-gray, pure, thin-bedded; intercalated with black shale; contains Yuanophyllum Kansuense Yu Kueichouphyllum

sinense var. gracile Yu Arachnolasma cylindricum Yu, Diphyllum suggestum Yu, Cleiothyridina shangssuensis Gr., Ambocoelia dubia Gr., Martinia shangssuensis Gr., Echinochonchus elegans (McCoy), Productus (Kansuella) edelburgensis Phillips, P. corrugatus McCoy, Chonetes papilionacea Phyllips, and Schellwienella interstrialis Gr.; 90 m thick.

2. Sandstone, brown, quartzose, ripple marked, locally interbedded with shale and clayey limestone; 100 m thick.

1. Limestone, gray to bluish-gray, pure, thin-bedded, intercalated with shale in lower part; contains Kueichouphyllum sinense Yu, Arachnalasma cylindricum Yu, Siphonodendron chachaiense Yu, and Daviesiella llangolliensis Davidson; 125 m thick.

The Laoganzhai Limestone consists of dense, pure, fossiliferous, dolomitic limestone and dolomite in the vicinity of Dushan. Thickness ranges from 15 to about 400 m.

The Lower Carboniferous rocks of western Guizhou are assigned to the Fengninian Series and divided into the Fengning Limestone and Weining Limestone (table 1). The Fengning Limestone consists of shale and coal and is from 100 to 350 m thick. The Weining Limestone consists of limestone, chert, marl, and shale and is from 280 to 800 m thick.

The Fengning Series of western Guangxi consists of the Laoxu Shale in the lower part and the Xinzhoujie Limestone in the upper part (Institute of Geology, Academia Sinica, 1956, v. 1, p. 508).

The Laoxu Shale is black and carbonaceous and is intercalated with black or dark-gray, thin-bedded limestone. It is exposed in the area between Hechi and Nandan. The thickness of this unit is about 200 m.

The Xinzhoujie Limestone is light-gray and thick-bedded. Most of the formation has been metamorphosed where exposed into marble by adjacent intrusive rocks. Cassiterite is common in marble. Stratigera gigantus Grabau occurs in this unit. It is well exposed in the vicinity of Xinzhoujie, Nandan; thickness is 20 m.

Upper Carboniferous.--The Upper Carboniferous rocks of this region are represented by the Hutian Series and consist chiefly of neritic, marine carbonate rocks (Chinese Academy of Geological Sciences, 1979, p. 23-26).

In southeastern Yunnan, the Upper Carboniferous is represented entirely by the Maping Limestone (table 1), which is chiefly in the upper part a light-red to light-gray, brittle, thin-bedded limestone, and in the lower part a yellowish-gray, gray or black, impure limestone interbedded with blocky limestone and some coal. The upper part consists of coral and brachiopod fauna consisting of Duylophyllum compactum Chi, Amygdalophyllum, Caninia (aff. Palaeosimila hammeri Heritoch), Carcinophyllum permicum Chi, Lithostrotion perpetuum chi, Bradphyllum, Choristites cf pavlovi Stuckenberg, and Spirifer sp. The limestone is 300 m thick.

The stratigraphy of the Upper Carboniferous rocks of eastern Yunnan is generally similar to that of southeastern Yunnan, and it has been very well studied. In this region, the Hutian Series is divided locally into an older Weining Group and the younger Maping Group.

The Weining Group consists chiefly of medium-gray or grayish-black, well laminated, sandy, dolomitic limestone, dolomite and rather pure limestone. Most of these carbonate rocks are bioclastic, and a fossil fauna is dominated by corals and brachiopods. In the lower part of the Group, brecciated marlstone occurs locally, such as in the northwestern suburb of Kunming. In the middle part, bauxite is intercalated with marly limestone, and quartzose sandstone is locally prominent along the eastern margin of the ancient central-Yunnan swell. The limestone yields Choristitas weiningensis Grabau, Stafella sphaeroidea (Moeller), Fuslinella bocki Moeller, Girtyina sp., Stylostrotion intermedium Chi, Chaetetes lungtanensis Lee et Chu, C. Thomsoni Reed, Koninckophyllum interruptum Thom. et Nichol., Caninia juddi (Thomson), C. simpliseptata Chi, Campophyllum lipoense Chi, Geinitzella sp., Textularis sp., and Gribrostomum sp. The thickness of this unit ranges from 30 m in the west and south of this region to more than 300 m in the northeast and east of the region.

The Maping Group is composed of marginal-basin and neritic sedimentary facies. The basin marginal facies consists of sandy shale, which is often intercalated with coal beds of poor quality, and bauxite layers. The neritic facies is made up of light-gray and grayish-black, clayey, impure limestone, black shale, thin coal, and bauxitic clay. This unit is sporadically distributed throughout eastern Yunnan and contains a fossil fauna of protozoans, hydrozoan corals, crinoids, blastoids, brachiopods, and pelecypods. The thickness ranges from 10 to 100 m.

The Hutian Series in south-central Guizhou is divided, in ascending order, into the Laoganzhai Limestone and the Maping Limestone (Yang and others, 1979) (Yang, Shipu and others, 1980).

The Laoganzhai Limestone is light-gray and locally light-pink, pure to dolomitic, and thick-bedded. It is distributed in the vicinity of Dushan and Longli and pinches out toward the north. It contains an abundant fossil fauna of Fuoulinella pseudobocki Lee et Chen, Koninckophyllum tushanense Chi, K. grabaui Chi, K. trisectum Chi, Gerthia minor Chi, Caninia simpliseptata Chi, C. nikitini Stuckenberg, Campophyllum lipoense Chi, Clisaxophyllum sp., Lithostrotion (Siphonondendron) Kweichowense Chi, Choristites mosquensis var. latus Fisher, and Striatifera striata Fisher. The thickness of this unit varies from 15 to about 400(?) m.

The Maping Limestone is light-gray to gray, pure, and thick-bedded. It is sporadically exposed in the vicinity of Dushan and contans Pseudoschwagerina princeps Enrenberg. The thickness of this unit varies from zero to about 30 m.

The Hutian Series in western Guizhou is similar to that of eastern Yunnan except that it is much thicker in western Guizhou. It is also divided into Weining Group and the Maping Group.

The Weining Group consists of light-gray to dark-gray, cherty, thin- to thick-bedded limestone and dolomitic limestone, both of which contain abundant fossil corals, fusulinids, crinoids, brachiopods, and cephalopods. It is distributed near Hezhang, Shuicheng, and Puan. The thickness ranges from 280 to 500 m.

The Maping Group consists in the lower part of interbedded dark-gray and yellowish-gray, calcareous shale, and blackish-gray, clayey limestone containing beds of sandstone; in the middle part of blackish-gray, clayey limestone intercalated with light-gray, crystalline and pure limestone, and gray to blackish-gray, calcareous shale; and in the upper part of light-gray and gray, cherty, dolomitic thin- to thick-bedded limestone. It is well exposed near Hezhang, Shuicheng, Puan, Panxian, Zhijin, Zhenfeng, and Cean. This unit contains abundant fossil fusulinids, brachiopods, crinoids, and cephalopods. It ranges in thickness from 40 to 600 m.

The Hutian Series in western Guangxi consists of the Huanglong Limestone and the overlying Maping Limestone (Yang and others, 1979, chart 1).

The Huanglong Limestone is dark-gray, cherty, blocky, and thin- to thick-bedded limestone locally intercalated with beds of cherty nodules. The thickness is 150 m in the vicinities of Hechi and Nandan. A fossil fauna consists of Fusulina cylindrica Fischer and Fusulinella bocki Moller.

The Maping Limestone consists in the lower part of black, cherty, thin-bedded limestone, and in the upper part of light-gray and gray, crystalline, fusulinid-bearing limestone. It is well exposed near Hechi, Nandan, Tiane, Fengshan, Lingle, Tianyang, Tiandong, Debao, Longming, Fusui, and Chongzuo. The limestone in the lower and middle parts yields abundant fossils of: Triticites simplex Schellwien, T. parvulas Schellwien, Pseudoschwagerina fusulinoides Schellwien, Pseudoschwagerina princeps Ehrenberg, Qasifusulina longissima Moller, and Caninia mapingense Lee et Yu. The unit is from 250 to 300 m thick.

Permian

Lower Permian.--The Lower Permian rocks of the study region consist of littoral marine shelf to neritic open-marine sedimentary sequences.

In southeastern Yunnan, the Lower Permian Yangxin Series consists in the lower part of alternating dark-gray and light-gray, thick-bedded limestone, with a basal conglomerate; and in the upper part of dark-gray, pure, brittle and blocky limestone. It contains a fossil coral and brachiopod fauna of Waagenophyllum Yunnanense Chi, W. cf. magnificum Douglas, Camarophoria globulina Phill, Spiriferella glandis Waagen, Spirifer (Martinia), and Choristites palotti. This unit is well exposed near Kaiyuan, Guangnan, Yanshan, Wenshan, Mengzi, and Jianshui; the thickness is estimated to average about 100 m.

The Yangxin Series of this area is overlain by the amygdaloidal, dark, and aphanitic Emeishan Basalt. Commonly, the visicles are filled with zeolites. Generally this basalt has distinct flow layers and contains tuffaceous shale

interbeds. The thickness ranges from 50 to 100 m. Formerly this unit was assigned to the upper part of the Yangxian Series but is now assigned to the lower part of the Upper Permian (Wang and Lui, 1980, p. 208-209).

In eastern Yunnan, the Lower Permian consists of, in ascending order, the Qixia Limestone and the Maokou Limestone, which are overlain by the Emeishan basalt.

The Qixia Limestone of eastern Yunnan is mostly light-gray, bluish-gray to blackish-gray, crystalline, blocky or thick-bedded limestone and dolomitic limestone. Parts of this carbonate sequence contain chert concretions or bands. It is fossiliferous and yields fossil coral fauna of: Hayasakaia halysitiformis Yoh, H. aequitabulata Huang, Stylidophyllum Kueichowense Huang, Corwenia chiuyaoshanensis Huang, Michelinia siyangensis Reed, M. abnormis Huang, and Canina sp. This unit is well exposed near Kunming, Luoping, and Chengjian; the thickness is estimated to range from 50 to 300 m.

The Makokou Limestone consists of light-gray to gray, pure to impure, dolomitic, blocky to thick-bedded limestone and commonly contains layers and concretions of black chert. Locally it contains limestone breccia and is intercalated with sandy shale and sandstone near the base. The fossil fauna consists chiefly of fusulinids and corals: fusulinids - Brevaxina (Misellina) douvilei Suller, B. (M.) lepida Schwager, Neoschwagerina craticulifera (Schwager), Pseudofusulina cushmani Chen, P. chihsiaensi Lee, and Nankinella orbicularia Lee; corals - Wentzelella elegans Huang, W. subtimorica Huang, Waagenophyllum cf. indica, Bradyphyllum sp., Hapsiphyllum sp., Michelinia cf. indica Waagen et Wentzel, M. aiyangensis Reed, and Allotropiolphyllum sinense Grabau. This unit is well exposed near Kunming and Luoping. The thickness ranges from 150 to 400 m.

The Emeishan basaltic flows consist of basalt, andesite, tuff, and a few thin layers of rhyolite; locally the flows incorporate tuffaceous shale in the upper part, tuff and agglomerate in the middle part, and sandy or copper-bearing shale in the lower part. The thickness of the unit ranges from several meters to as much as 1,000 meters. The thickest flow sequences are between Chenggong and Jinning.

In south-central Guizhou, the Lower Permian Yangxin Series is represented by three stratigraphic units: the Coal-bearing Formation, Qixia Limestone, and Maokou Limestone (table 1).

The Coal-bearing Formation is made up of yellowish-white or brownish-yellow quartzite, quartzose sandstone, and yellowish-brown and black sandy shale, containing several thin coals, and locally impure limestone. The fossil brachiopod fauna is Spiriferina multiplicata Sowerby, Athyris acutirostris Grabau, and Productus margaritatus Mansuy. The unit is well exposed in lowland areas; thickness ranges from zero to 50 m.

The Qixia Limestone consists mostly of dark-gray or dark-blue, thin- to thick-bedded, cherty limestone; the lower part locally contains bituminous-rich, thin-bedded limestone with black, calcareous, clayey shale or black chert

layers. The fossil fauna is Hayasakaia nankingensis Yoh, Staffella inflata Colani, S. lenticularis Lee, Orthotichia derbyi Waagen, Productus Yantzeensis Chao, P. nankingensis Frech, and P. marginocystosa Huang. Thickness is 120 to 500 m; the thickest sequence occurs near Longli and Guiding.

The Maokou Limestone is light-gray, gray, pure, blocky and contains a small amount of cherty concretions. Where weathered, it generally forms "stone-forest" karst landforms. The identified fossil fauna is Neoschwagerina craticulifera Schwager, Doliolina (Miselina) lepida Schwager, Wentzelella timorica (Gerth), and Waagenophyllum indicum var. kweichowensis Huang. This unit ranges in thickness from 40 to 250 m; the thickest sequence occurs in the vicinities of Longli and Guiding.

The Emeishan basalt is missing throughout this region.

In western Guizhou, the Yangxin Series consists of similar stratigraphic units as in south-central Guizhou, but the total thickness of the series is much greater in western Guizhou than in south-central Guizhou.

The Coal-bearing Formation is comprised of yellowish-gray quartzite, quartzose sandstone, and blackish-gray shale intercalated with blackish-gray, thin-bedded or lenticular, clayey limestone and coal beds. It is well exposed in the vicinities of Shuicheng, Puan, Panxian, Qinglong, Langdai, Guanling, and Cexiang; thickness ranges from 2 to 130 m.

The Qixia Limestone is made up in the lower part of bluish-gray to dark-gray, cherty, thinbedded limestone, and in the upper part of bluish-gray to grayish-black, cherty limestone. The fossil fauna is: Hayasakaia elegantula Y. et H., Polythecalis sp., Stylidophyllum sp., and Corwenia sp. It is about 450 m thick.

The Maokou Limestone is light-gray to dark-gray, dense, thick-bedded, fossiliferous, blocky limestone. Thickness ranges from 200 to 600 m.

The Emeishan Basaltic flow consists of dark-gray, aphanitic, amygdaloidal basalt; locally in the upper part it contains gray rhyolite and a tuffaceous shale. The Maokou ranges in thickness from 50 to 400 m.

In western Guangxi, the Lower Permian is represented by the Qixia Limestone and Maokou Limestone. They are well exposed near Hechi, Jandan, Lingle, Donglan, and Tiandong.

The Qixia Limestone is black, thin- to thick-bedded limestone that contains cherty concretions and lenticular layers. The fossil fusulinid and brachiopod fauna consists of Triticites parvus Chen, Schwagerina vulgaris Schellwien, S. Chihsiaensis Chen, Wentzelella sp., Martinia sp., and Productus sp. The Qixia ranges in thickness from 150 to 200 m.

The Maokou Limestone consists of light-gray to gray, thick-bedded limestone, which contains chert concretions in the lower part and dark-gray, thick-bedded limestone in the upper part. The fossil fusulinids are

Neoschwagerina craticulifera (Schwager), pseudodoliolina lepida Schager, and Schwagerina japonica. The Maokou ranges in thickness from 250 to 300 m.

Upper Permian.--The Upper Permian of the study region consists chiefly of marine coal-bearing and continental sedimentary sequences.

In southeastern Yunnan, the Upper Permian is divided, in ascending order, into the Coal Series and the Laoping Series. The Coal Series consists of interbeds of gray, grayish-yellow shale, light-brown, compact sandstone, and coal beds. Thickness of this series is unknown. The Laoping Series consists of light-gray, crystalline limestone, which contains fossil corals: Sinophyllum pendulum Grabau and S. cf. Kayseri (Huang). Thickness is not available.

In eastern Yunnan, the Laoping Series crops out along the eastern border of the province and consists of continental, coal-bearing, sedimentary strata. Principal rock types are yellowish-green, brownish-green sandstone, shale, and sandy shale. Several mineable coal beds occur in the lower part of the sequence and generally average 3 m thick. Locally, conglomerate occurs near the base. The identified plant fossils are Gigantopteris, Pecopteris, Taeniopteris, Cordaites, Annularities, and Lepidodendron. Locally, fresh-water faunas have been identified. Excellent exposures occur in the Jieqiancun coal field, Milei County. The Laoping ranges in thickness from 50 to 250 m.

In south-central Guizhou, the Laoping Series consists of three formations, in ascending order: the Zhutang Formation, Changxing Limestone, and Dalong Formation. Well exposed beds are common near Guiying, Longli, and Duyun.

The Zhutang Formation consists chiefly of marine sedimentary facies intercalated with detrital continental facies. In south-central Guizhou, the Zhutang Limestone is made up of dark-gray, thin-bedded, cherty limestone with concretions and lenses of chert. This limestone is commonly overlain by brownish-gray, gray, yellowish-gray shale and fire clay; it is underlain by coal-bearing carbonaceous shale, chert beds, coal beds, and ferrugineous sandstone. The fauna collected from this limestone consists of abundant brachiopods: Squamularis aff. elegantula Gemmelaro, Squamulara grandis Chao, S. maequilaterulis Gemmelaro, Productus margaritatus Mans., Oldhamina squamosa var. anshunensis Huang, Lyttonia tenuis Waagen, Schellwienella ruber (Frech), Lyttonia nobitis Waagen, Meekella Kueichowensis Huang, Chonetes substrophomeroides Huang, Productus yangtjeensis Chao, P. gratiosus Waagen, and Lyttonia richthofeni Kayer. The Zhutang beds are well exposed near Guiyang, Longli, Duyun, and Libo; the limestone is 590 m thick.

The Changxing Limestone is gray to dark-gray, thick-bedded, blocky, and, in part, crystalline limestone; it commonly contains nodules and lenses of chert and is intercalated locally with thin-bedded calcareous shale. The fossil brachiopod fauna is Oldhamina decipiens (de Koninck), Squamularia lintugensis Yoh, and Parentcletes sinensis Huang. It is well exposed in the vicinity of Guiyang. Thickness of Changxing ranges from 50 to 120 m.

The Dalong Formation consists of interlayers of yellowish-gray chert and clayey, sandy, calcareous shale or thin-bedded, cherty limestone. At the base of the Dalong, coal beds are prserved locally. The fossil flora

consists of Pseudotirolites asiaticus (Jaekel) P. mapingensis Sun, Grabauites gigas Yoh, Pleuronautilus multicostatum Hsu, Rhynchonella negrii Gemmellaro, and Oxytoma cf. atovum Waagen. Thickness of the Dalong ranges from zero to 35 m.

In western Guizhou, the Upper Permian is represented, in ascending order, by the Longtan Formation, Changxing Limestone, and Dalong Formation.

The Longtan Formation consists chiefly of brownish-yellow, greenish-gray, yellowish-gray, black sandstone and shale intercalated with small amounts of thin-bedded, clayey limestone; locally there is a 10-meter thick basal quartzite. This formation contains numerous coal beds, the thickest of which is 2 m thick. The shale is mostly siliceous or sandy, in part calcareous, and locally contains siderite concretions. The fossil fauna and flora is Gigantopteris nicotianaefolia Schenk, Sphenophyllum sino-coreanum Yabe, Pecopteris hirta Halle, Rhipidopsis lobata Halle, R. baieroides Kawasaki et Konno, Protoblechnum wongii Halle, Lobatannularia ensifolius Halle, L. lingulatus Halle, Streptorhynchus cf. Kayseri Schellwien, Productus gratiosus Waagen, P. margatitatus Mansuy, and Schellwienlla acutangula Hung. The Longtan beds are well exposed near Bijie, Dading, Qianxi, Anshun, Zhening, Zhenfeng, Xingren, Xingyi, Panxian, Puan, Liangdai, and Shuicheng. Thickness of this formation ranges from 10 to 400 m.

The Changxing Limestone is chiefly of dark-gray and cherty limestone intercalated with yellow and dark-green sandstone, shale, and sandy shale. The limestone is generally brittle and the shale is carbonaceous. The fossil fauna consists of Oldhamina squamosa var. Anshunensis Huang, Spinomarginifera kueichowensis Huang, S. chengyaoyenensis Huang, Parenteletes sinensis Huang, Streporphynchus Kayseri Schlotheim, Spiriferina multiplicata Sowerby, and Chonetes soochowensis Chao. Good exposures are in the areas of Zhenning, Guanling, Xingren, and Zhenfeng. Thickness of the Changxing ranges from 30 to 100 m.

The Dalong Formation consists mostly of yellowish-gray and, locally, green shale intercalated with light-gray, thin-bedded limestone. The fossil fauna is Pseudotirolites asiaticus (Jackel), P. liui (Grabau), Gastrioceras liui Grabau, and Chonetes soochowensis Chao. Well exposed in areas of Dushun and Zhenning, the thickness of this unit ranges from 2 to 10 m.

In western Guangxi, the Upper Permian rocks are divided into the Heshan and Dalong Formations (table 1). Exposures are scattered throughout the areas near Duan, Tiane, Donglan, Fengshan, Lingle, and Tiandong.

The Heshan Formation is comprised chiefly in the lower part of dark-gray, black, cherty, thin-bedded limestone that is generally intercalated with thin-bedded shale; it contains red, iron-bearing sandstone at the base. The fossil fauna consists of Oldhamina hoshanensis, Amplysiphonella asiatica, Verbeekina sp. and Waagenophyllum sp. Thickness of the Heshan ranges from 60 to 200 m.

The Dalong Formation is made up chiefly of purplish-black, calcareous shale, which yields a fossil fauna of Ullmannia aff. bronni and Trilobites. Thickness of the unit is about 15 m.

Triassic

Lower Triassic.--The Lower Triassic strata of the study region are extensively distributed. A description of this series is based generally on its areal distribution in the study region.

In southeastern Yunnan, the Lower Triassic sedimentary sequence is assigned to the Red Beds Series, which consists of interbedded purplish-red and gray shale and sandstone intercalated with thin-bedded, clayey limestone. This series is well exposed in the area of Gejiu. It ranges in thickness from 100 to 200 m.

In eastern Yunnan, the Lower Triassic strata are included in the Yelang Series. This series is made up in the lower part of dark purplish-red, greenish-gray, orange-yellow, and, in part, tuffaceous sandstone, shale, conglomerate and basal conglomerate; in the middle part of thin-bedded sandstone and shale intercalated with thin-bedded limestone and marl; and in the upper part of thin- to thick-bedded limestone intercalated with calcareous shale, clayey shale, and sandstone. The fossil fauna consists of Pseudomonotis griescachi Bittner, and P. clarai (Emmerich). This unit is well exposed in the vicinities of Louping, Shizong, Luxi, and Mile; thickness of the Yelang ranges from 150 to more than 400 m.

In south-central Guizhou, the Lower Triassic sedimentary sequence is divided into the Yelang Series, which consists, in ascending order, of the Shabaowan Shale and the Yulongshan Limestone.

The Shabaowan Shale is light-yellow, yellowish-gray, yellowish-green clayey shale intercalated with thin-bedded and lenticular, clayey limestone. Pseudomonotis (claraia) clarai Emmerich, P. (cl.) wangi Patte, P. (cl.) griesbachi Bittner, P. (cl.) griesbachi var. concentrica Yabe, Ophiceras cf. demissum Oppel, Lingula patti Hsu, and L. tenuissima Bronn have been identified in the fossil fauna. Thickness of the Shabaowan ranges from 10 to 35 m.

The Yulongshan Limestone is gray or pinkish-gray, thin-bedded, blocky crystalline limestone, which locally contains dolomite and calcareous sandy shale. The fossil fauna includes Ophiceras Sinense Tien, Meekocereas Kueichowense Tien, Pleuronautilus sp., Palaeophyllites sp., and Pseudomonotis (Claria) clarai Emmrich. Thickness of the Yulongshan ranges from 160 to more than 500 m.

In western Guizhou, the Lower Triassic sedimentary sequence is assigned to the Yelang Series (Institute of Geology, Academia Sinica, 1956, v. 1, p. 445-446) (Wang and Liu, 1980, p. 229-232). The Yelang is divided, in ascending order, into the Feixianguan and the Yongningzhen Formations.

The Feixianguan Formation consists chiefly of purplish-red sandstone and mudstone intercalated with marl and copper-bearing sandstone. Identified fossils are Ophiceras sp and Claraia Wangi in the lower part and Eumorphotis multiformis and E. inaequicostata in the upper. The thickness ranges from 200 to about 800 m.

The Yongningzhen Formation is comprised of grayish-green, purple shale, marl, limestone, and dolomite, which contain Tirolites spinosus, Eumorphotes telleri, and pteria cf murchisoni. Thickness is about 900 m.

The Yelang Series was described by the Institute of Geology from an exposure in the vicinity of Qinglong about 150 km south, 45° west of Guiyang, in descending order:

9. Shale, purple, sandy; intercalated with limestone. Contains: Pseudomonotis (Eumorphotis) Kittlii Bittner, P. (Eumorphotis) cf. hinnitidea Bittner, and Pecton (Entolium) discites Schlotheim; 80 m thick.

8. Limestone, light-gray, thin-bedded, containing purple shale; 15 m thick.

7. Shale and sandstone, purple, containing Pecten (Entolium) discites Schtotheim; 150 m thick.

6. Limestone, black, blocky; 20 m thick.

5. Sandstone and shale, purple; intercated with yellowish-green sandstone and sandy shale. Yield: Pseudomonotis (claraia) griesbachi Bittner, and Anodontopnona fassaensis (Wissmann); 105 m thick.

4. Limestone, black, blocky, oolitic, containing Myophoria laerigata (Ziethen) and Loxonemo (Polygrina) gracilior (Schanroth); 40 m thick.

3. Shale, grayish-green, sandy, and yields: Oxytoma sp., Pseudomonotis (Claraia) griesbachi Bittner, P. (Claraia) Wangi Patte, P. (Claraia) pecidens Bittner, Pecton (Velopecton) sp., Myocorcha sp., and Loxnema (Ploygrina) gracilior (Schauroth). 200 m thick.

2. Limestone, black and oolitic. 30 m thick.

1. Shale, brownish-yellow and clayey; contains Pseudomonotis (Claraia) Wangi Patte and Pseudomonotis (Claraia) griesbachi Bittner; thickness unknown.

The Yelang Series is well exposed near Dading, Shuicheng, Zhenning, Guanling, Qinglong, Xingren, Zhenfeng, Anlong, Cexiang, and Xingyi. The thickness is estimated to range from 200 to 1,700 m.

In western Guangxi, the rocks of the Lower Triassic are included in the Luolou Formation (Yang and others, 1982, p. 10) (Institute of Geology, Academia Sinica, 1956, p. 506-507). This formation consists of bluish-gray, black, light-gray, thin- to thick-bedded, clayey limestone and pure limestone intercalated in the lower part with light-orange dolomite; and in the upper part bluish-gray, blackish-gray shales intercalated with thin-bedded sandstone. Four ammonite zones are recognized in the lower part of the formation, which are, in ascending order: the Gyronitan zone, Flemingatan zone, Owenitan zone, and Columbitan zone. The Luolou contains Pseudomonotis sp. in the upper part. This unit is well exposed near of Lingyun, Tianlin, Tiandong, Donglan, Fengshan, Tiane, and Lingle. Thickness of the Luolou is 200 m.

Middle Triassic.--the Middle Triassic strata of the study region consist chiefly of neritic marine carbonate rocks. Generally, these rocks are divided, in ascending order, into the Guanling Formation and the Falang Formation in southeastern and eastern Yunnan and in western and south-central Guizhou. In south-central Guizhou, Yang and others (1982, p. 11) replaced the Guanling Formation with the Qingyan Formation, which is probably undifferentiated Falang and Guanling Formations.

In southeastern Yunnan, the Middle Triassic sedimentary sequence is tentatively subdivided, in ascending order, into the Guangling Formation and the Falang Formation (Institute of Geology, Academia Sinica, 1958, p. 96-97) (Wang and Liu, 1980, p. 229-232).

The Guanling Formation consists of gray to dark-gray, thick-bedded, pure and micritic in part, and dolomitic limestone, which contains abundant crinoides and algae. The thickness ranges from 800 to 1,000 m.

The Falang Formation of this area consists chiefly of Wuge shale, which is comprised of interbeds of reddish-yellow, carbonaceous limestone and thin-bedded, clayey limestone, and locally interlayers of yellowish-green, dark-gray shale, sandy shale and brown sandstone. It contains an abundant fauna; thickness is about 200 m.

In eastern Yunnan, the Middle Triassic is represented by the Hongxi Formation, which is equivalent to the Guanling Formation of southeastern Yunnan and western Guizhou, and the Gejiu Formation, which is equivalent to the Falong Formation of western Guizhou.

The Hongxi Formation consists of gray, thin-bedded or blocky limestone, dolomitic limestone and marl, and contains clayey calcareous shale and limestone breccia. The fossil fauna is Myophoria laevigara Goldf., Lima striata var., Pseudomelania haydeni Dien., Cardiomorpha scalata Schl., and Thecosmilia sp. The thickness ranges from 20 to 170 m.

The Gejiu Formation is made up of gray, light-yellow, thin-bedded to thick-bedded, dolomitic limestone, limestone, and marl with intercalated purple, green, light-yellow sandstone and shale in the lower part, and dark-gray and black, calcareous shale and clayey shale in the upper part. The fossil fauna identified consists of Posidonia wangensis Wiss, Anoplophora Lettica Quess, Halobia cf. mengalanensis Volz, H. cf. kwaluana Volz, Gonodon cf. sphaeroldes Root, Trachyceras sp., Myophoria goldfussi (Ziethen), Pseudomonotis illyrica Bitt, P. subillyrica Hsu, and Gervilleia costata Schl. The thickness ranges from 50 to 200 m.

In south-central Guizhou, Middle Triassic strata are completely exposed in the area between the Qingyan and Pingyue; these are assigned to the Qingyan Formation (Institute of Geology, Academia Sinica, 1956, p. 454-456) Yang and others, 1982, p. 11). The Qingyan consists chiefly of clayey limestone intercalated with yellowish-green shale. The thickness is 610 m. A stratigraphic profile in the Qingyan area, about 41 km due south of Guiyang, is described below, in descending order:

7. Limestone, light-pink, blocky, pisolitic. 250 m thick.

6. Limestone, gray, impure, thin-bedded; contains Spiriferina (Mentzelia) mentzellii Dunke, S. (M.) koeveskalliensis (Suess), and Waldheimia angustaeformis Boeckh; 50 m thick.

5. Shale, yellowish-green, bluish-gray, dense; 150 m thick.

4. Limestone, gray, clayey, thin-bedded; intercalated with yellowish-green shale; contains abundant Anthozoa, Crinoidea, Echinoidea, Brachiopoda, Pelecypoda, Gastropoda, and Cephalopoda; 50 m thick.

3. Shale, yellowish-green; 30 m thick.

2. Limestone, gray, thin-bedded; intercalated with yellowish-gray soft shale.

1. Limestone, gray, thin-bedded; 20 m thick.

In western Guizhou, Middle Triassic strata are assigned, in ascending order, to the Guanling Formation and the Falong Formation (Institute of Geology, Academia Sinica, 1956, p. 444-445) (Wang and Liu, 1980, p. 229-230).

The Guanling Formation consists of light-gray, gray, dark-gray, thin- to thick-bedded, blocky, impure limestone interbedded with dark-yellow, dark-purple, and yellowish-green, sandy shale, siliceous limestone, and dolomite. The shale varies greatly in thickness, and the limestone is clayey and contains numerous lenticular clayey bands. Identified fossils are Asoella subillyrica, Modoila triguetra Seebach, Myophoria goldfussi Ziethen, Ostrea sp., Traumatocrinus sp., Spiriferina koeveskalliensis Suess, S. mentzelli (Dunker), Koninekina sp. Conenothyris vulgaris Schlotheim, Pecton alberii Goldfuss, P. cf. reticulatus Schlotheim, Pleuromya rugosior Dienr, P. elongata Schlotheim Gervilleia costata Schlotheim, G. mytiloides Schlotheim, G. murchisoni (Geinitz), Avicula sp., Worthenia sp., Nucula goldfussi Alberti, and Myoconcha roemeri Eck. This formation is well exposed near Zhenning, Guanling, Qinglong, Xingren, and Zhenfeng. Maximum thickness cited by the Institute of Geology, 1956, is 700 m. Wang and Liu (1980, p. 230) report a thickness of more than 1,400 m.

The Falong Formation is made up of light-gray to dark-gray, clayey, siliceous, thin-bedded, blocky limestone, in part, intercalated with variegated sandy shale and shale. This sequence grades upwards into light-yellow and light-gray, fissile shale, and yellowish-brown, dense sandstone, which contains clayey concretions in the uppermost part. This formation yields a fossil fauna: Trachyceras multituberculatum Hsu, Protrachyceras cf. archelaus Laube, P. costalatum Mansuy, P. douvillei Mansuy; Daonella lommeli Wissmann, D. moussoni Merian, D. indica Bittner, Halobia comatoides Yin, H. comata Bittner, H. rugosoides Hsu, H. subcomata Kittl, Posidonia wengensis (Wissmann); Encrinus carnalli Beyrich, Isocrinus tyrolensis (Laube), Traumatocrinus reticulatus (Dittmar), T. ornatus (Dittmar); and Rhynchonella kellneri Bittner, Koninckina sp., and Spiriferina sp. This unit is well exposed in the vicinities of Zhenning, Guanling, Zhenfeng, Anlong, and Cexiang. Thickness ranges from 200 to 350 m according to the Institute of Geology, Academia Sinica

(1956, p. 444). Wang and Liu (1980, p. 230) estimated the thickness of this this formation at more than 1,000 m.

In western Guangxi, Middle Triassic rocks are assigned to the Pingerguan Series. This series consists of grayish-green, yellowish-gray and light brownish-red shale, grayish-yellow and yellow sandstone, and dark-gray and blue, slaty shale intercalated with black, thin-bedded or concretional, and impure limestone. Identified fossils are Myophoria goldfussi Albert, Pecton sp., Lima costata Goldfuss, Daonella elongata Mojsisovics, D. producta Hsu, D. lindstromi Moy, D. dubia Gabb, D. mousseni Merian, Balatonites sp., Posidonomya sp., Posidonia Wengensis var. altior Frech, Ceratites (Paraceratites) ericki Smith, Balatonites cf. shoshonensis Hyatt et Smith, Eutooceras sp., and E. plicatus (Hauer). This unit is well exposed near Donglan, Fengshan, Lingle, and Nandan. The thickness ranges from 510 to about 800 m.

Upper Triassic.--The Upper Triassic sedimentary sequence in most of the study region consists of foredeep molasse red beds and marine and continental coal-bearing deposits. The continental facies is in the upper part of the sequence. Yang and others (1982, p. 3, table 1, and p. 6) subdivided the Upper Triassic, in ascending order, into two formations: the Pingdong Formation and the Fulongao Formation in southern Guizhou, southeastern and eastern Yunnan, and most of western Guangxi (table 1). Wang and Liu (1980, p. 229) had earlier subdivided the Upper Triassic, in ascending order, into three formations: the Banan Formation, the Huobachong Formation, and the Erqiao Formation in the vicinity of Zhenfeng of southwestern Guizhou (table 1). Yang and others (1982) tentatively correlated the Pingdong Formation with the Banan Formation and most of the Huobachong Formation, and the Fulongao Formation with the uppermost part of the Huobachong Formation and the Erqiao Formation.

In southeastern Yunnan, the Pingdong Formation consists of gray, clayey, thin- to thick-bedded limestone containing a basal, yellow, thin-bedded shale. In eastern Yunnan, however, this formation consists chiefly of shale and sandstone locally intercalated with thin-bedded limestone. Fauna are abundant and consist chiefly of Leda (Nuculana) tirolensis Woehrmann, Halobia superba Mojsisovics, H. mullakuana Wann., Myophoria mansuyi Hsu, Anoplophora griesbachi Bitt., Worehenia cf. nuda Kok, Trachyceras sp., and Terrebretula sp. (Institute of Geology, Academia Sinica, 1956, p. 420; 1958, p. 96). Thickness ranges from 250 to 300 m in southeastern Yunnan and 400 m in eastern Yunnan.

The Fulongao Formation in southeastern and eastern Yunnan consists of variegated shale intercalated with fine-grained, carbonaceous shale and lenticular coal beds. Identified fossils are Myophoria napangensis Hore, M. verbeeki var. curva Reed, Andontophora manmuensis Reed, A. Mansuyi Reed, Spiriferina emmrichi Schlotheim, Cassianella gryphacata (Munster), Gervilleia rhomboidalis Hsu, G. cf. wagneri Winkler, Hoernesia filosa Healeg, Myophoria verbeeki curta Reed, and Burmesia lirata Healey. The thickness ranges from 250 to more than 700 m in southeastern Yunnan and 300 to 700 m in eastern Yunnan.

In south-central Guizhou, the Pingdong Formation consists of 40 to 700 m of an overlying fossiliferous, light-gray, pinkish-gray, and gray, thin-bedded,

blocky, dolomitic limestone interbedded with greenish-gray, yellowish-gray, and gray, thin-bedded, micaceous, fossiliferous shale, and a basal limestone conglomerate. The Fulongao Formation, however, consists of interbedded black, fossiliferous shale and sandstone. The thickness is estimated to be more than 300 m.

In western Guizhou, Wang and Liu (1980, p. 229) gave a brief statement of the Upper Triassic stratigraphy from a complete profile at Zhenfeng, consisting of the Banan Formation, Huobachong Formation, and Erqiao Formation. The Banan Formation consists of interbedded grayish-yellow sandstone and shale intercalated with marl, carbonaceous shale, and a trace of coal. This formation is generally fossiliferous and contains Myophoria (Costatoria) Kueichouensis. The thickness is greater than 400 m.

The Huobachong Formation is comprised of interbedded gray sandstone and black shale intercalated with coal beds. Fossils are Yunnanopharus boulei, Lingula sp., and abundant plant fossils. The thickness is greater than 700 m.

The Erqiao Formation is made up of gray, quartzose, medium- and coarse-grained sandstone and conglomeratic sandstone in the lower part, and sandy mudstone intercalated with carbonaceous shale in the upper part. Fossils are clathropteria meniscioides and Gervillia sp. The thickness is greater than 300 m.

In western Guangxi, the Pingdong and Fulongao Formations are combined into the Sile Series which consists chiefly of molasse red beds and coal-bearing continental and marine sedimentary strata. Fossils are generally scarce. Coal beds 10 to 20 m thick occur in the lower part of the Pingdong Formation. The thickness is estimated to be more than 1,000 m near Longle.