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Geology of the Chaidamu Basin, Qinghai Province, Northwest China

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ABSTRACT

This report is based chiefly on generalized available published literature; a detailed statement of the geology is not available. The Chaidamu basin is an intermontane depression in the northwestern part of Qinghai Province, Northwest China. The depositional framework of the basin was initially formed on the Paleozoic basement of the Variscan eastern Kunlun Fold System during the late episode of Indosinian orogeny from late Late Triassic to early Early Jurassic. This basin evolved to its present form during the Tertiary Eocene and Oligocene-Miocene Himalayan orogeny.

Jurassic sedimentary rocks are well developed in the northern and northeastern parts of the basin. Tertiary Oligocene, Miocene, and Pliocene strata are well developed in the northern part. The thickest Quaternary sedimentary sequences, however, occur in the south-central part of the basin. Deposition of these sedimentary sequences was controlled by tectonic movement during the Indosinian, Yanshanian, and Himalayan orogencies.

The source rocks of petroleum and natural gas deposits are confined to the lacustrine deposits of organic-matter-rich clay, shale, and mudstone of the Lower and Middle Jurassic, Oligocene, Miocene, Pliocene, and Pleistocene age. Burial depth and geothermal temperature control the conversion of soluble organic matter to oil and gas.

Throughout the basin, 15 oil and gas fields have been developed during the past several decades. The reservoir rocks are chiefly fluvial sandstone and conglomerate. The oil or gas pools occur in dome and anticline structures and locally in fracture zones. Evaporite beds and shales are the sealing rocks.

Three types of crude oil in the reservoir rocks of Chaidamu basin are defined by chromatographic analyses. The first type of Middle Jurassic crude oil has C_{15} as the main peak carbon of normal paraffin and is characterized by the pristane to phytane ratio, which varies from 2.44 to 2.90. The second type of Oligocene to Lower Pliocene crude oil shows C_{22} as the main peak carbon of normal paraffin, and the pristane to phytane ratio varies from 0.86 to 0.52. The third type of upper Pliocene crude oil is characterized by a dominant light fraction of hydrocarbons, of which C_{13} is the main peak carbon of normal paraffin. The pristane to phytane ratio of this type of crude oil is 1.26. Microbe degradation of Oligocene to lower Pliocene crude oil is common.

Coal deposits occur in the Lower and Middle Jurassic sedimentary strata. The best quality coal is in the Dameigou Formation of Middle Jurassic Dameigou age. The coal bed is as much as 27.97 m thick and is mined locally.

INTRODUCTION

General Statement

The Chaidamu basin is an intermontane depression in the northwestern part of Qinghai Province, Northwest China (fig. 1). The initial depositional framework of the basin was formed on the Paleozoic basement of the Variscan eastern Kunlun Fold System during the late episode of Indosinian orogeny from late Upper Triassic to early Lower Jurassic (figs. 2 and 3) (table 1). This basin developed to its present form during the Jurassic to Cretaceous Yanshanian (Yenshanian) orogeny and the Tertiary Eocene and Oligocene-Miocene Himalayan orogeny (table 1). It was filled chiefly with continental fluvial and lacustrine detrital sediments of Lower Jurassic to Holocene age (fig. 4). Salty lakes and intermittent streams are scattered throughout the basin.

Regional Setting

The Chaidamu basin is a northwest-southeasterly rhomboid elongated depression with maximum width in the northern part of the basin, and covers about 120,000 square kilometers at an altitude in excess of 2,600 m. The basin is generally confined within lat 36 30'-39 00" N. and long 90 30'-98 00' E. and is bordered by the Aerjin Mountain Range on the northwest, the Qilianshan Range on the northeast, and the Kunlun Mountain Range on the south (fig. 4).

Within the basin, the Paleozoic basement rocks are covered by sedimentary sequences of Early Jurassic to Holocene age. Triassic sedimentary rocks occur only near the border areas of the basin. Since 1954, numerous oil and gas fields have been found in the Oligocene-Pleistocene strata of surface anticlinal structures. Generally, the thickest sedimentary cover, more than 12,000 m, occurs in foredeeps along the marginal zones of the basin; in the basin center, the sedimentary cover is thinner but is commonly in excess of 5,000 m. The Jurassic to Holocene sedimentary rocks are generally deeply dissected.

Purpose, Scope, and Method of the Report

The primary purpose of this report is to provide a digest of the available literature on the geology of energy mineral deposits in the Chaidamu basin to aid geologists in studying petroleum and natural gas deposits throughout the basin. Most of the geologic information is synthesized. No attempt is made to estimate the mineral resources. For the Chinese name transliteration, the Pinyin System is used. In some cases, a conversion of the Wade-Giles System to Pinyin is made in parentheses to aid the readers in understanding some of the cited references.

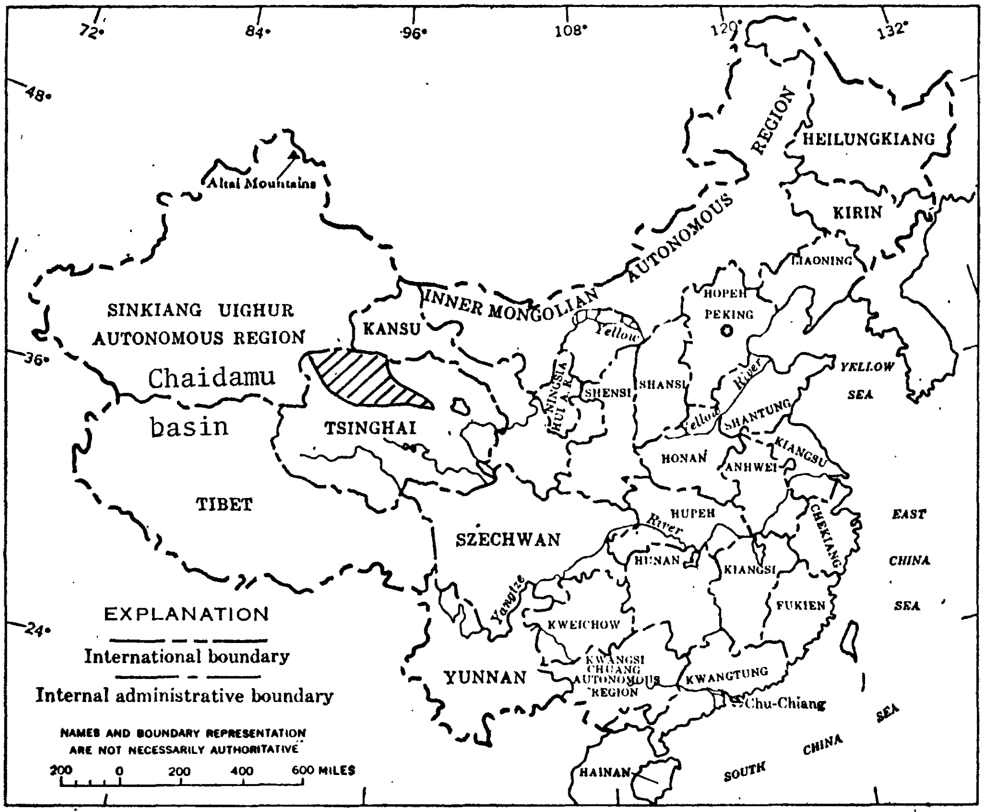
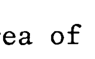


Figure 1.--Index map of China showing the location of Chaidamu basin (provincial names are in Wade-Giles spelling) (modified after K. Y. Lee, 1970, USGS Bulletin 1312-N, fig. 2).

Area of study



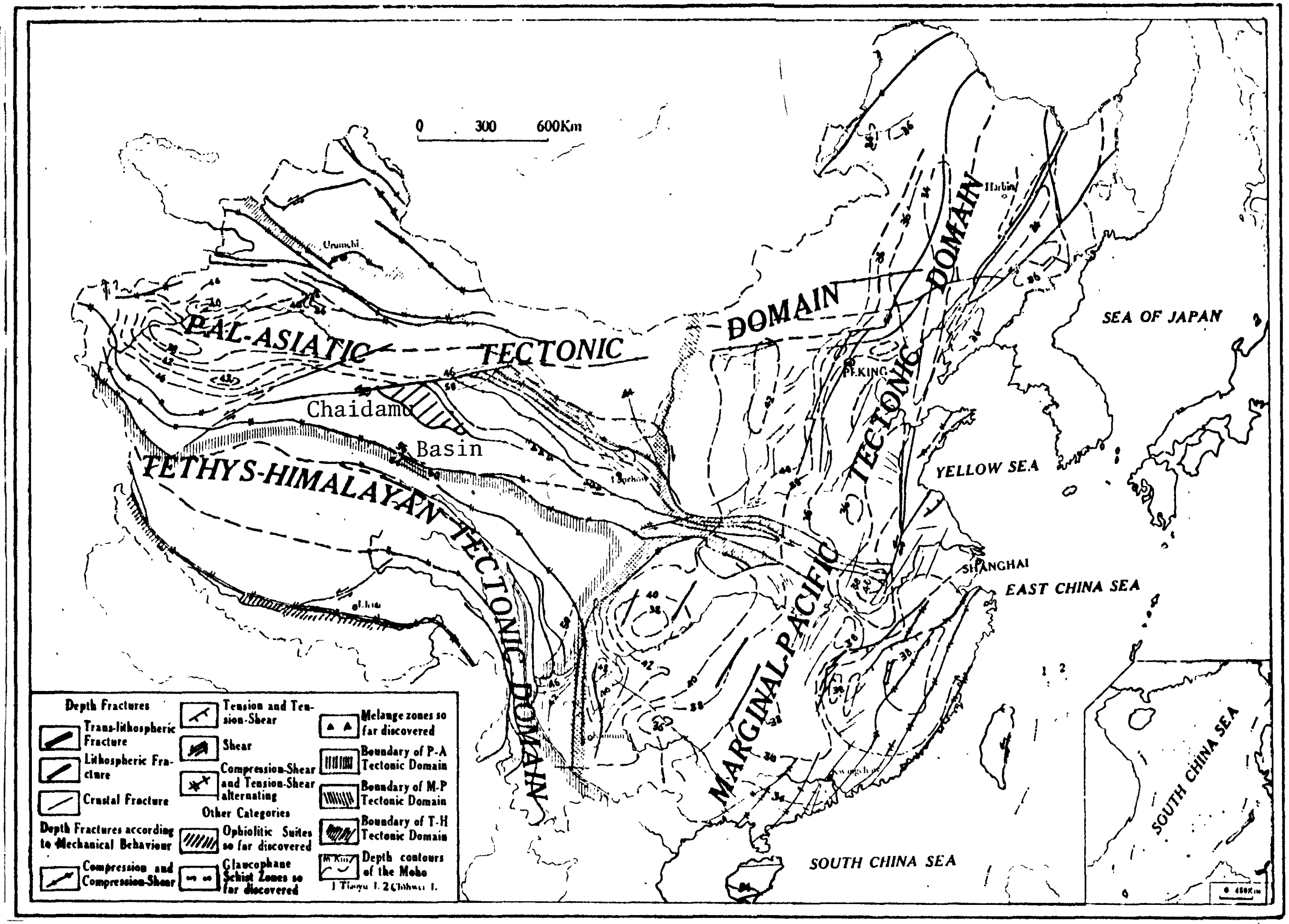


Figure 2.--Generalized map showing depth fractures and tectonic domains of China (adopted from Group of Tectonics, Institute of Geology and Mineral Resources, Academy of Geological Sciences, 1977, figure 2, p. 8).

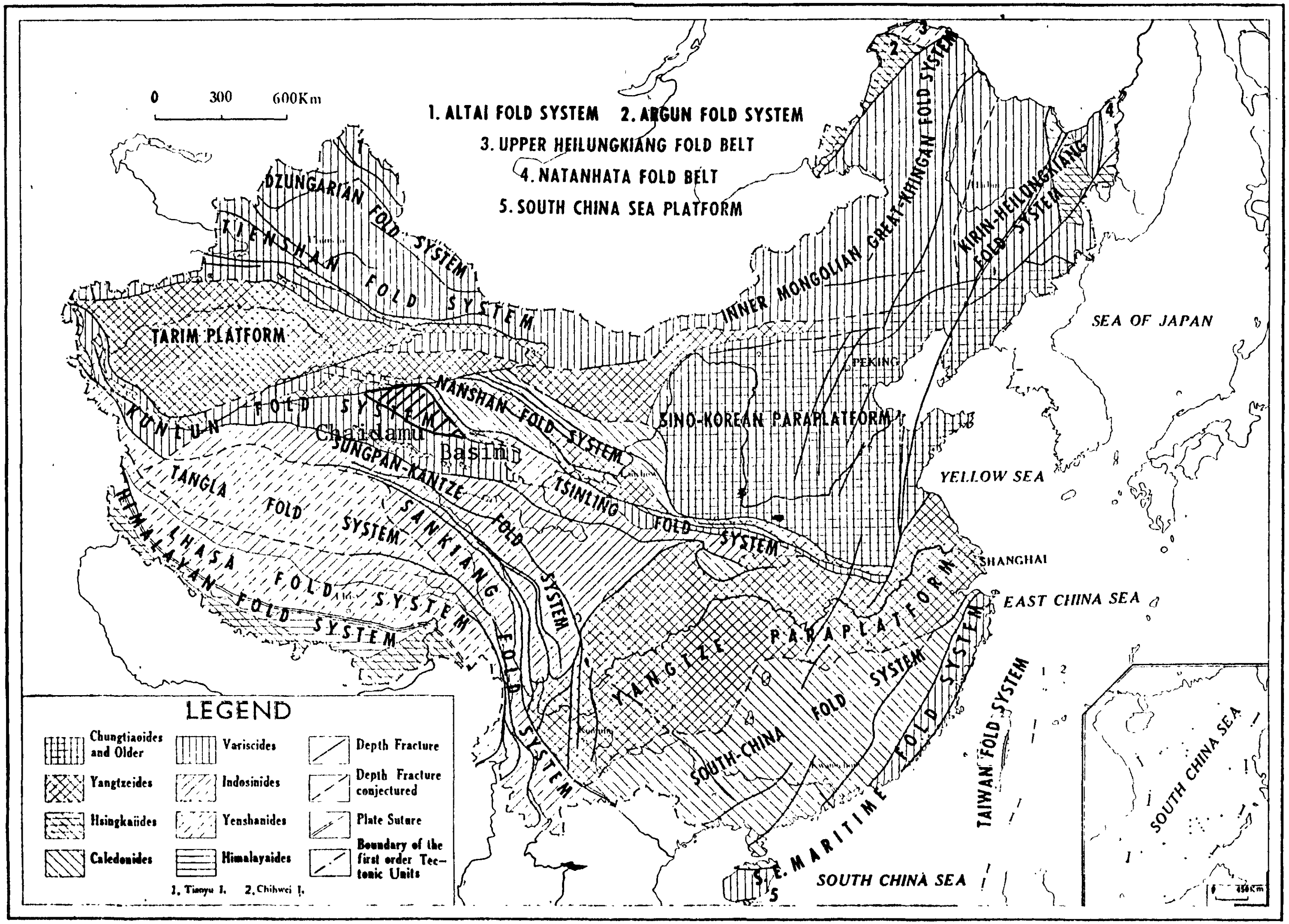


Figure 3.--Generalized tectonic map of China (adopted from Group of Tectonics, Institute of Geology and Mineral Resources, Academy of Geological Sciences, 1977, figure 1, p. 3).

Table 1.--Subdivision of orogenic cycles and important events of the tectonic development of China (adapted from Group of Tectonics, Institute of Geology and Mineral Resources, Academy of Geological Sciences, 1977, Table 3, p. 14).

Era	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
Cenozoic	Tertiary	67	Yenshanian			Cimmerian
Mesozoic	Cretaceous	137				
Mesozoic	Jurassic	190	Indosinian	Destruction and disintegration of parts of P-A; intensive activity of M-P & T-H ***		
Mesozoic	Triassic	230	Variscan	Consolidation of Central Asiatic-Mongolian . . . geosynclines; cementation of Siberian Platform with Sino-Korean & Tarim platforms; formation of P-A **		
Palaeozoic	Permian	280				Variscan
Palaeozoic	Carboniferous	350			Formation and development of P-A	
Palaeozoic	Devonian	405	Caledonian	Formation of South China Platform		Caledonian
Palaeozoic	Silurian	440				
Palaeozoic	Ordovician	550				
Palaeozoic	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		
Late Proterozoic (Sinian Subera)*	Sinian s.s.					Assyntian
Late Proterozoic (Sinian Subera)*	Chingpaikou	1000	?			Dalslandian
Late Proterozoic (Sinian Subera)*	Chihsien	1400				
Late Proterozoic (Sinian Subera)*	Changcheng	1700*	Chungtiaoian	Formation of Sino-Korean Paraplatform		Svecofennian
Early Proterozoic	Huto	2000	Wutaiian			Karelian
Early Proterozoic	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 & T - H, Marginal Pacific Tectonic Domain and Tethys-Himalayan Tectonic Domain.

STRATIGRAPHY

The basement of Chaidamu basin consists of Precambrian to lower Paleozoic metamorphic complexes and upper Paleozoic sequences of the marine-shelf sedimentary rocks. Since the latest episodes of the Variscan deformation (table 1), these basement rocks emerged as a landmass and subsequently subsided during the late stage of Indosinian deformation. Generally the Jurassic to Quaternary sedimentary cover has been well developed in the basin, and the Triassic rock exposures are scattered throughout areas near the basin margin. The stratigraphy of this basin is described, in ascending order, as: Pre-Triassic basement, Mesozoic, and Cenozoic (table 2), (fig. 4).

Pre-Triassic Basement

The stratigraphy of the Pre-Triassic basement consists of the Precambrian, lower Paleozoic, and upper Paleozoic sedimentary sequences. Those sequences are exposed only in areas outside the basin. A general stratigraphic discussion of these units is given below.

Precambrian

The Precambrian stratigraphy is herein subdivided into the Sinian and the pre-Sinian units. These units are well exposed along the northern and northeastern borders of the Chaidamu basin.

The pre-Sinian unit consists of a metamorphic complex and is occasionally exposed along the northern border of the basin. The metamorphic complex is made up of granite gneiss, hornblende gneiss, and mica schist, which are cut by granitic intrusions and numerous quartz veins. The unit is covered unconformably by the lower Paleozoic and, locally, by the Sinian sedimentary strata. The thickness is unknown.

The Sinian stratigraphic unit is represented by the Quanji Group along the northern border of the Chaidamu basin. The Quanji consists of the Lower Sinian conglomeratic sandstone and the Upper Sinian shale and carbonate rock. These rocks are disconformably overlain by tillite (Wang and Liu, 1980, p. 91 and table 7-1). The conglomeratic sandstone grades upward into siltstone and shale, which change into argillaceous, *Linella*- and *Boxonia*-bearing dolomite and manganese shale. This carbonate sequence is succeeded by variegated tillite and dolomite. The unit is disconformably in contact with Lower Cambrian *Kutorgina*-bearing phosphorous shale (Wang and Liu, 1980, p. 95).

The Sinian is well developed throughout this region, and good exposures occur in the northern and southern border areas of the basin. The total thickness along the northern border is about 2,000 m.

page 10 follows

Lower Paleozoic

The lower Paleozoic sedimentary sequences of the Chaidamu basin are reported to be well developed along the basin border areas of the Aerjin Mountain range and the Qilian Mountain range on the north and northeast, and the Kunlun Mountain range on the south.

The areas on the northern and northeastern basin border contain 500 meters of Cambrian marine shale, mudstone, siltstone, sandstone, and carbonate rocks, which are interbedded with basaltic and andesitic flows in the upper part; 700 meters of Ordovician marine limestone and shale; and 6,700 meters of of Silurian marine sedimentary sequences (Wang and Liu, 1980, p. 70-157).

The Lower Paleozoic strata in areas of the Kunlun Mountain range consist of approximately 5,000 meters of green schistose quartzite sandstone, phyllite, shale, limestone, dolomite, and marble in the lower part; approximately 8,000 meters of grayish-green phyllite, yellowish-gray marble, and green sandstone, with interlayers of black, cherty limestone, which grade down into green sandstone, green slate, marble, quartzite, phyllite, and basal conglomerate in the middle part; and approximately 10,000 meters of green sandstone and grayish-green slate, which locally contain limestone and sandstone and grade down into slate, sandstone, marble and basal conglomerate in the upper part (Institute of Geology, Academia Sinica, 1958, p. 20).

Throughout the region, the lower Paleozoic sedimentary strata folded and faulted during the latest stage of the Caledonian movement.

Upper Paleozoic

The depositional pattern of the upper Paleozoic sedimentary sequences is generally similar to that of the lower Paleozoic sedimentary sequences throughout this region.

According to Wang and Liu (1980, p. 170 and fig. 11-6), 450 meters of Devonian detrital sedimentary rocks were deposited in the Chaidamu basin. The areas of the northern and northeastern basin borders contain several thousand meters of Devonian detrital rock, limestone, dolomite, marble, and slate, with a great amount of volcanic and pyroclastic rock; 1,700 to 2,400 meters of Carboniferous limestone, dolomite, shale, gypsum, and coal beds; and 580 to 740 meters of Permian yellowish-green micaceous sandy shale, sandstone, and shale with oil and asphalt traces (Wang and Liu, 1980) (Institute of Geology, Academia Sinica, 1956).

The upper Paleozoic strata in areas of the Kunlun Mountain range consist of more than 800 meters of Upper Devonian grayish-brown marl and shale, and grayish-green slate, which yields *Cystospirifer sp.*; more than 4,800 meters of Carboniferous marine fossiliferous limestone, shale, basal conglomerate, and locally, diabasic and andesitic rocks; 40 to 4,200 meters of Lower Permian shale, sandstone, blocky limestone, and coal beds; and approximately 8,900 meters of Upper Permian gray, fine- to coarse-grained sandstone, shale, dense limestone, and coal beds in the lower part, of which five coal beds have thicknesses ranging from 2 to 4 m (Institute of Geology, Academia Sinica, 1958, p. 19-20).

An erosional hiatus generally occurs between the Paleozoic and Mesozoic strata throughout the region.

Mesozoic

The Mesozoic stratigraphy of the Chaidamu basin consists of 3,500 meters of Triassic, Jurassic, and Cretaceous sedimentary sequences (fig. 5) and is well exposed in the northern, eastern, and southern basin border areas of the region. The Triassic strata are exposed only at the Datouyanggou coal mines (figs. 4 and 5; table 2). The Jurassic and Cretaceous beds are extensively exposed on the northern, northeastern, and eastern rims of the basin along the fronts of the Aerjin Mountain range and the Qilianshan range. Scattered outcrops occur in the areas of Shetoushan and Yikegaoli, east of Geermu on the southern rim of the basin.

Triassic

During the Triassic period, the Chaidamu basin emerged as an eroded landmass. Locally, continental sedimentary sequences comprising red and purple detrital rocks were deposited in lowlands around the present eastern and southern border areas under arid climatic conditions, such as prevailed for the Triassic continental deposits in the areas of Wucaishan and Datouyanggou along the northeastern border of the basin (fig. 4).

Jurassic

During the Jurassic period, most of the east half of the Chaidamu basin subsided by block-faulting during the late stage of the Indosinian deformation (Yan, 1980) and received a considerable amount of Jurassic detrital sediment in the foredeep of the Qilianshan range. In ascending order, the Jurassic sedimentary sequences are subdivided into Lower, Middle, and Upper stratigraphic units, chiefly in the northern and eastern parts of the basin (figs. 4 and 5).

In the western part of the basin, the Jurassic System is represented by the Hongliugou Series, but it is undifferentiated. This series, approximately 400 to 1,500 meters thick, consists of gray, grayish-green and red mudstone, which is intercalated with shale, sandstone, and conglomerate (table 2).

Lower Jurassic

The Lower Jurassic sedimentary rocks are represented by the Xiaomeigou Formation (table 2), which lies unconformably on the Proterozoic metamorphic complexes. This formation, about 88 to 480 meters thick, consists of grayish-black, gray, carbonaceous shale and conglomeratic sandstone, intercalated with conglomerate, grayish-black, gray, and carbonaceous mudstone, clayey siltstone, and sandstone in the lower part; conglomerate, feldspathic and quartzose sandstone, blackish-gray, light-brown carbonaceous shale, which are interbedded with argillaceous siltstone and coal beds, in the middle part; and compact feldspathic and conglomeratic sandstone in the upper part.

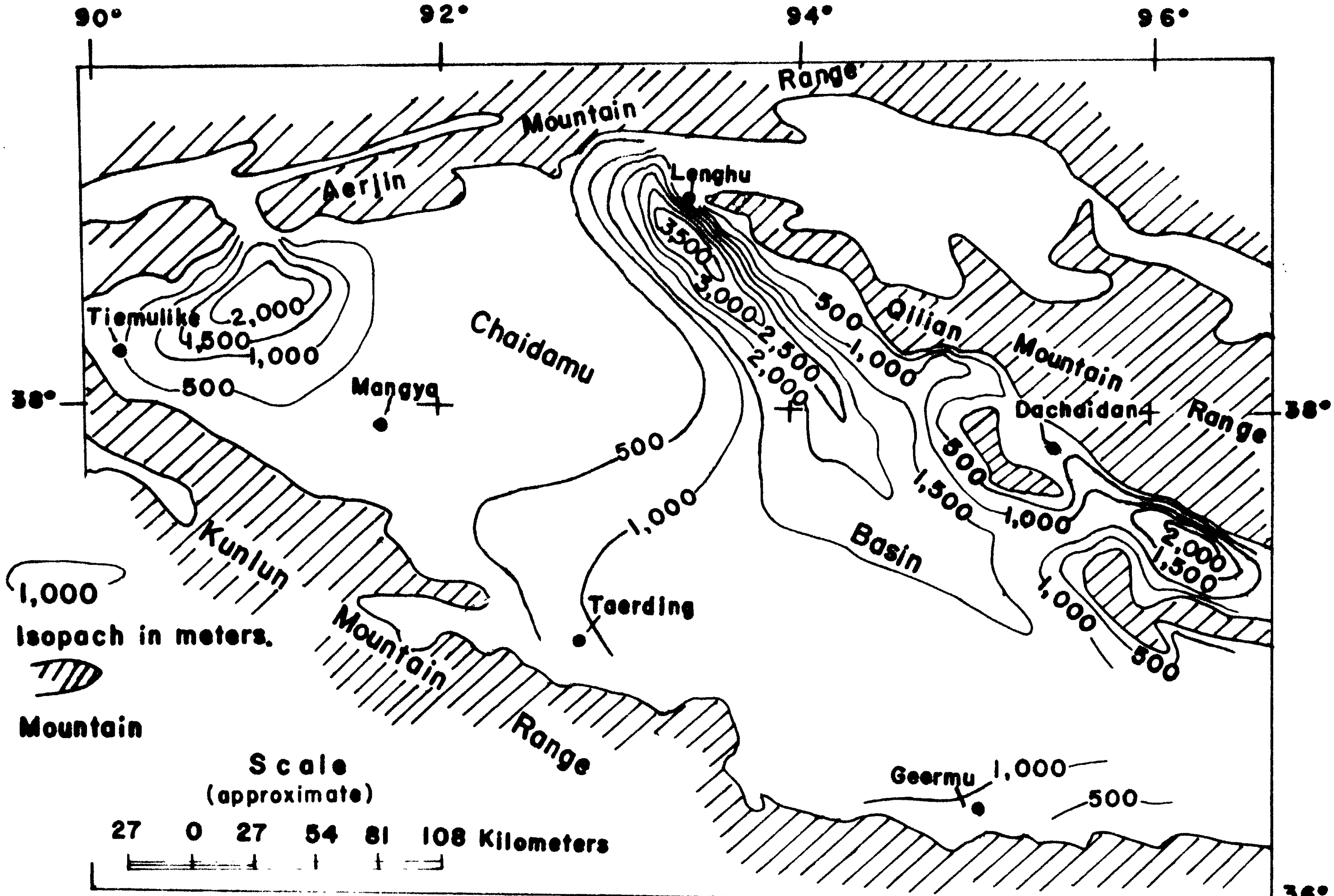


Figure 5. Isopachs of the Mesozoic deposits in the Chaidamu basin. (data after Song and Liao, 1982; Wang, 1981; Wang, 1982; and Zhang, 1983)

Middle Jurrasic

The Middle Jurassic sedimentary sequences lie unconformably on the Lower Jurassic strata and are represented by the Dameigou Formation (table 2). This formation is subdivided into four informal stratigraphic units in the northeastern and eastern parts of the basin and are described in ascending order. The first unit consists of black, blackish-gray carbonaceous shale and siltstone, which are intercalated with coal beds and a small amount of oil shale and siderite layers and is about 263 meters in thickness. The second unit is made up of yellowish-green, purplish-red mudstone, which contains sandy mudstone, conglomeratic sandstone, and gray conglomerate. The sandstone and conglomerate increase upwards and are devoid of coal beds. This unit is about 412 meters thick. The third unit is a coal-bearing series of three cyclothems that is about 131 meters thick. The lower part of the unit consists of conglomerate, conglomeratic sandstone, and sandstone with carbonaceous shale and siderite lenses or concretions; the middle part is chiefly carbonaceous shale, which is intercalated with clayey sandstone, siderite concretions, and poor quality coal; and the upper part includes coal beds that contain carbonaceous mudstone partings. The fourth unit is about 223 meters thick that consists of conglomeritic sandstone, sandstone, black fissile shale, and carbonaceous mudstone, which are intercalated with siderite concretions and thin- to very thin-bedded limestone and coal beds. The shale yields fish fauna.

In the Lenghu area, the Middle Jurassic strata are assigned to the Dameigou Formation but are undifferentiated. In this area the formation consists of gray, dark-gray, yellowish-green, purplish-red, and carbonaceous shale, siltstone, and coal and is about 2,700 to 3,000 meters thick (table 2).

Upper Jurassic

The Upper Jurassic sedimentary sequences are represented, in ascending order, by the Yuandingshan Formation and the Hongshuigou Formation (table 2). The Yuandingshan Formation lies disconformably on the Dameigou Formation. The stratigraphic relation of the formation is conformable at Dameigou, but the Upper Jurassic strata are generally disconformable underlying the Upper Cretaceous sequences (table 2).

The Yuandingshan Formation, in the northeastern and eastern parts of the basin, consists of 274 meters of interbeded conglomerate, sandstone, siltstone, purplish-red and orange-red mudstone, and sandy mudstone in the lower part; and orange-red, purplish-red, and brownish-red mudstone, which is intercalated with small amounts of sandy mudstone and siltstone, in the upper part.

The Hongshuigou Formation in this area is of Late Jurassic age (Wang, 1981, p. 21) and consists of 113 to 523 meters of conglomerate and purplish-red, brownish-red mudstone, which grades upward into clayey shale and contains ostracod and estherian (crustaceans) fauna.

In the Lenghu area, the Upper Jurassic strata also are represented by the Yuandingshan Formation and the Hongshuigou Formation, respectively. The Yuandingshan sequence consists of about 230 meters of purplish-red, brownish-red mudstone and conglomeratic sandstone. The Hongshuigou Formation, however, is made up of about 200 meters of red conglomeratic sandstone, mudstone, and siltstone.

Cretaceous

The Cretaceous sedimentary sequences are represented by the Upper Creteaceous Quanyagou Formation in the northeastern and eastern parts of the basin and by the Caishiling Series in the western part of the basin. These Cretaceous strata are sporadically exposed along the foothills of the Aerjin Mountain range and in the areas of Lulehe, Hongshan, and Dameigou along the southern foothills of the Qilianshan range (figs. 4 and 5).

The Quanyagou Formation consists of 303 to 772 meters of conglomerate, conglomeratic sandstone, and sandstone, which are intercalated with siltstone and sandy mudstone. These rocks become coarser upwards.

The Caishiling Series generally consists of 300 to 2,000 meters of red-brown sandstone and conglomerate, which are interbedded with siltstone and sandy mudstone.

Cenozoic

The Cenozoic stratigraphy of the Chaidamu basin consists chiefly of continental Tertiary and Quaternary sedimentary sequences, of which the Oligocene, Miocene, Pliocene, and the middle Pleistocene are well developed and extensively distributed throughout the basin. Paleocene and Eocene sedimentary rocks are undifferentiated and occur in the western, northwestern, and northern parts of the basin. Chen and others (1982) indicate a marine and continental Eocene transitional facies occurring in the northwestern part (fig. 4) (table 2).

Tertiary

During the early stage of the Himalayan movement in late Eocene (tables 1 and 2), the Chaidamu basin began to subside at a relatively increasing rate with development of the basin, culminating in the periods from the Oligocene to the Miocene (figs. 6 and 6a).

Paleocene and Eocene

The Paleocene and Eocene sedimentary sequences are represented by the Luluohe Formation in the western part of the basin and the Lenghu area (Chen and others, 1982; table 2). The Luluohe Formation is unconformably overlain by the Oligocene Xiaganchaigou Formation and consists chiefly of 200 to 1,500 meters of red mudstone, sandstone, conglomeratic sandstone and conglomerate. They are well developed and exposed in the vicinity of Luluohe. The Paleocene and Eocene strata are absent in the eastern part of the basin.

Oligocene

The Oligocene sedimentary sequences are represented by the Xiaganchaigou Formation throughout the basin (Wang, 1982, p. 24). This formation is made

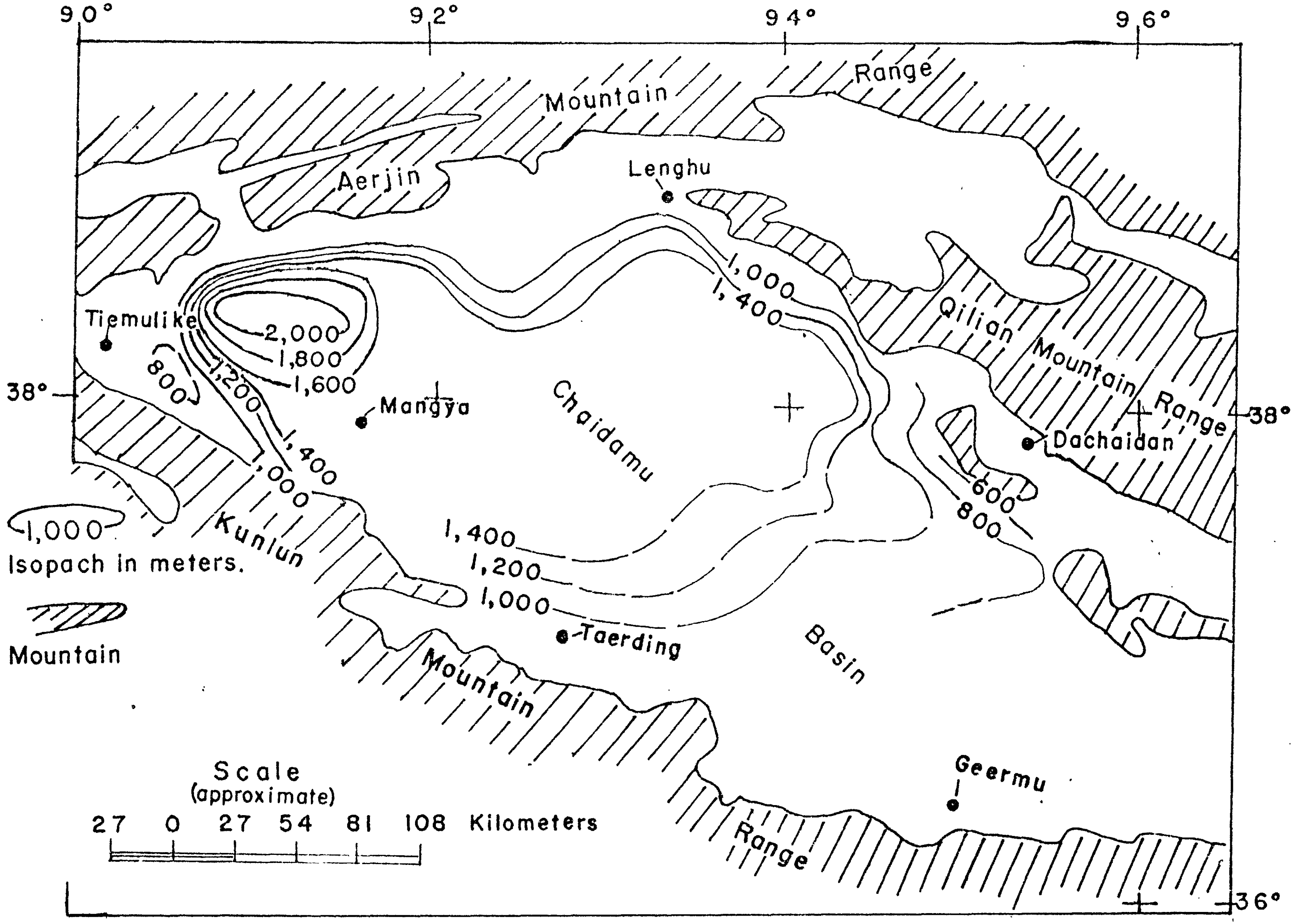


Figure 6. Isopachs of the Oligocene Xiaganchaigou Formation in the Chaidamu basin (modified after Wang, 1982; fig.2, p.24).

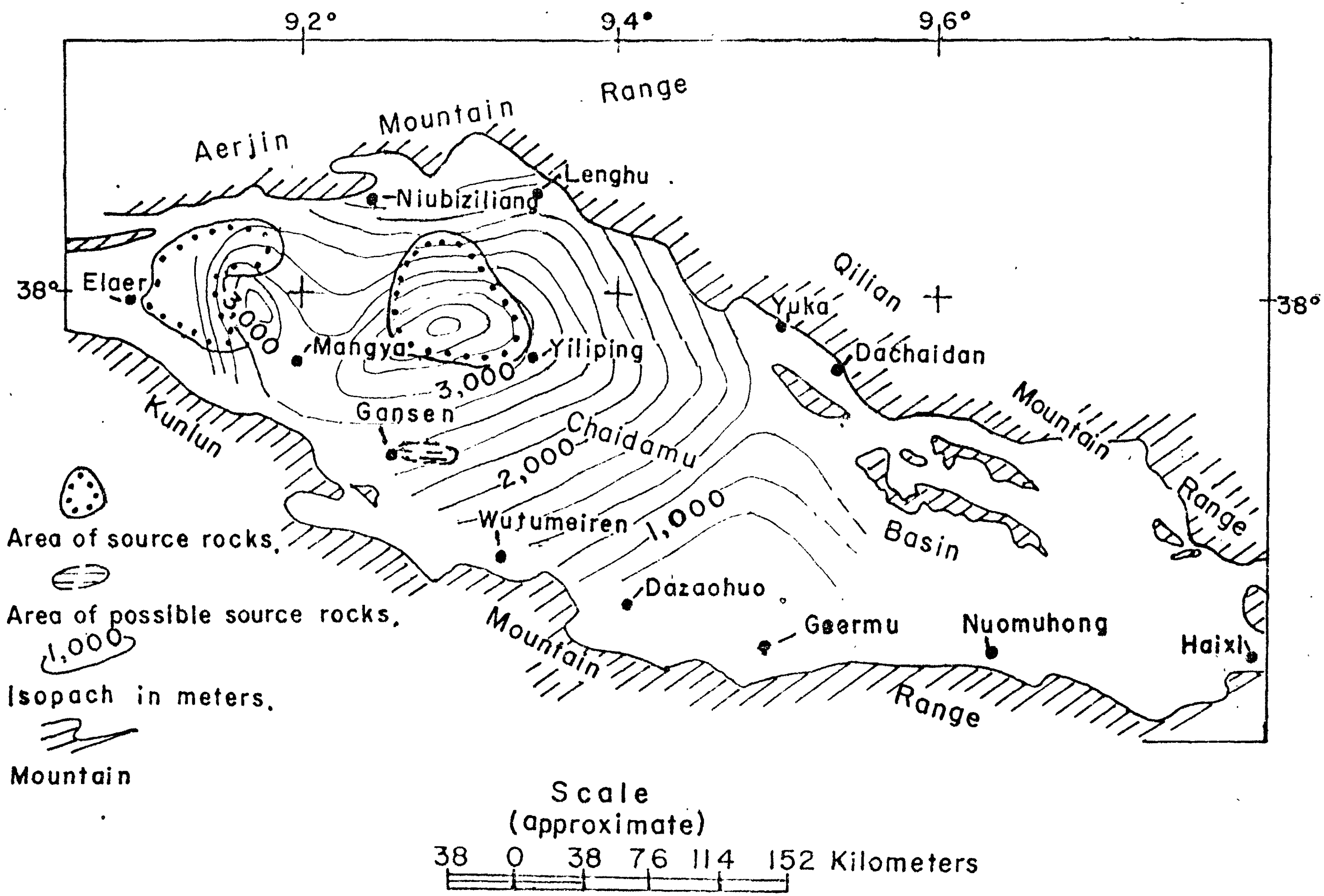


Figure 6a. Isopachs of the Oligocene - Miocene and source rock distribution in the Chaidamu basin (after Song and Liao, 1982; fig.3, p.16).

up of gray conglomerate, greenish-gray calcareous and sandy mudstone, which is interbedded with yellowish-brown sandstone and light-yellowish-green siltstone in the lower part; and grayish-green mudstone and siltstone, which are intercalated with orange-red and light-gray mudstone, thin-bedded sandstone, light-gray carbonaceous marl, grayish-black asphaltene limestone, and scattered pyrite crystals in the upper part (Huang, 1959, p. 6-7) (Song and Liao, 1982). Toward the center of the basin, such as in the Fenghuang area east of Mangya, the Xiaganchaigou consists chiefly of dark-gray carbonaceous compact mudstone, which is locally intercalated with a considerable amount of asphalt-bearing and oolitic, thin-bedded limestone (fig. 6a).

The Xiaganchaigou Formation is well developed and exposed in the areas of Ganchaigou, Youshashan, Tiemulike, Mangya, Taerding, Eboliang, and Lenghu (fig. 6). The thickness of the formation ranges from 200 to 2,800 m (Song and Liao, 1982, p. 15), and the thickest beds probably occur in the vicinity of Mangya (figs. 6 and 6a).

Miocene

The Miocene sedimentary sequences of the Chaidamu basin are represented, in ascending order, by the Shangganchaigou Formation and the Xiayoushashan Formation, respectively (Compilation Group of the Geological Map of Asia, Chinese Academy of Geological Sciences, 1982, table 13), but Huang Difan and Li Jinchao (1981, p. 100-112) designated a Lower Pliocene age for the Xiayoushashan Formation.

The Shangganchaigou Formation consists chiefly of 50 to 900 meters of gray, brown, yellowish-green, and orange-red mudstone, which is interbedded with brown sandstone and locally contains argillaceous, lenticular limestone.

The Xiayoushashan Formation is generally made up of 150 to 1,500 meters of grayish-green, gray, yellowish-green and orange-red sandstone, which is, in part, conglomeratic and is interbedded with orange-red mudstone and locally lenticular limestone layers.

The Miocene strata are generally extensively distributed throughout the basin. The maximum thickness is 2,400 meters in the western part of the basin (table 2) (fig. 6a).

Pliocene

The Pliocene sedimentary sequences are the best developed stratatigraphic series in the Chaidamu basin. They are represented, in ascending order, by the Shangyoushashan Formation and the Shizigou Formation (Compilation Group of the Geological Map of Asia, Chinese Acadmey of Geological Sciences, 1982, table 13).

The Shangyoushashan Formation consists of 200 to 2,000 meters of orange-yellowish-gray and grayish-orange mudstone and shale, orange-yellow sandstone, conglomeratic sandstone, and conglomerate, which contain *Trilophodon sp.* (Song and Liao, 1982, table 1, p. 15) (table 2).

The Shizigou Formation is made up chiefly of 200 to 2,700 meters of orange-yellowish-gray, orange-yellow and gray mudstone, sandstone, and conglomerate in the lower part; and as much as 1,500 meters of light-yellow, orange-yellow, and yellow mudstone and sandstone in the upper part. The Shizigou beds contain *Cyprideis sp.* and *Gyraulus sp.*

The thickest Pliocene sedimentary rocks are in the areas of Youshashan, Xichagou, and Ganchaigou of the northwestern part of Chaidamu. The total thickness of Pliocene sedimentary sequences ranges from 1,000 to 6,700 meters (Song and Liao, 1982; table 1 and figure 4) (fig. 7).

Quaternary

During the Quaternary period, the depositional center of the Chaidamu basin was shifted from the western and northern parts of the basin to the central part, Sanhu (Three Lakes) area, because of the rapid subsidence of the basin in the east; this was accompanied by a rejuvenated uplifting and folding along the foothills of the Aerjin Mountain range on the north and the Kunlun Mountain range on the west. Generally, the Quaternary Pleistocene and Holocene deposits are extensively developed throughout the Chaidamu.

Pleistocene

The Pleistocene sedimentary sequences are represented by the Qigequan Formation in the Chaidamu basin. This formation consists of as much as 3,000 meters of light-yellowish-gray conglomerate and gray, grayish-yellow mudstone and siltstone, which contain *Stegodon sp.* (Song and Liao, 1982, table 1, p. 15). Locally, this formation overlies glacial deposits of till and outwash sand and gravel (table 2).

Holocene

The Holocene sedimentary sequences contain four stratigraphic units, in ascending order: glacial deposits, lacustrine deposits, fluvial deposits, and alluvial, eolian, and lacustrine deposits. The glacial deposits comprise 200 meters of yellowish-green clay, which is intermixed with rounded pebbly rock fragments and outwash sand and gravel. The lacustrine deposits generally consist of 15 to 30 meters of sandy clay and gypsum layers, which are commonly present in the center of the basin. The fluvial deposits are composed of more than 100 meters of clayey detrital sediments, which are intermixed with gravel. The alluvial, eolian, and lacustrine deposits are generally widely spread throughout the basin and make up 5 to 80 meters of clay, silt, sand, and gravel, which are locally intercalated with evaporites.

The total thickness of the Quaternary sedimentary rocks is probably more than 3,300 m (fig. 8).

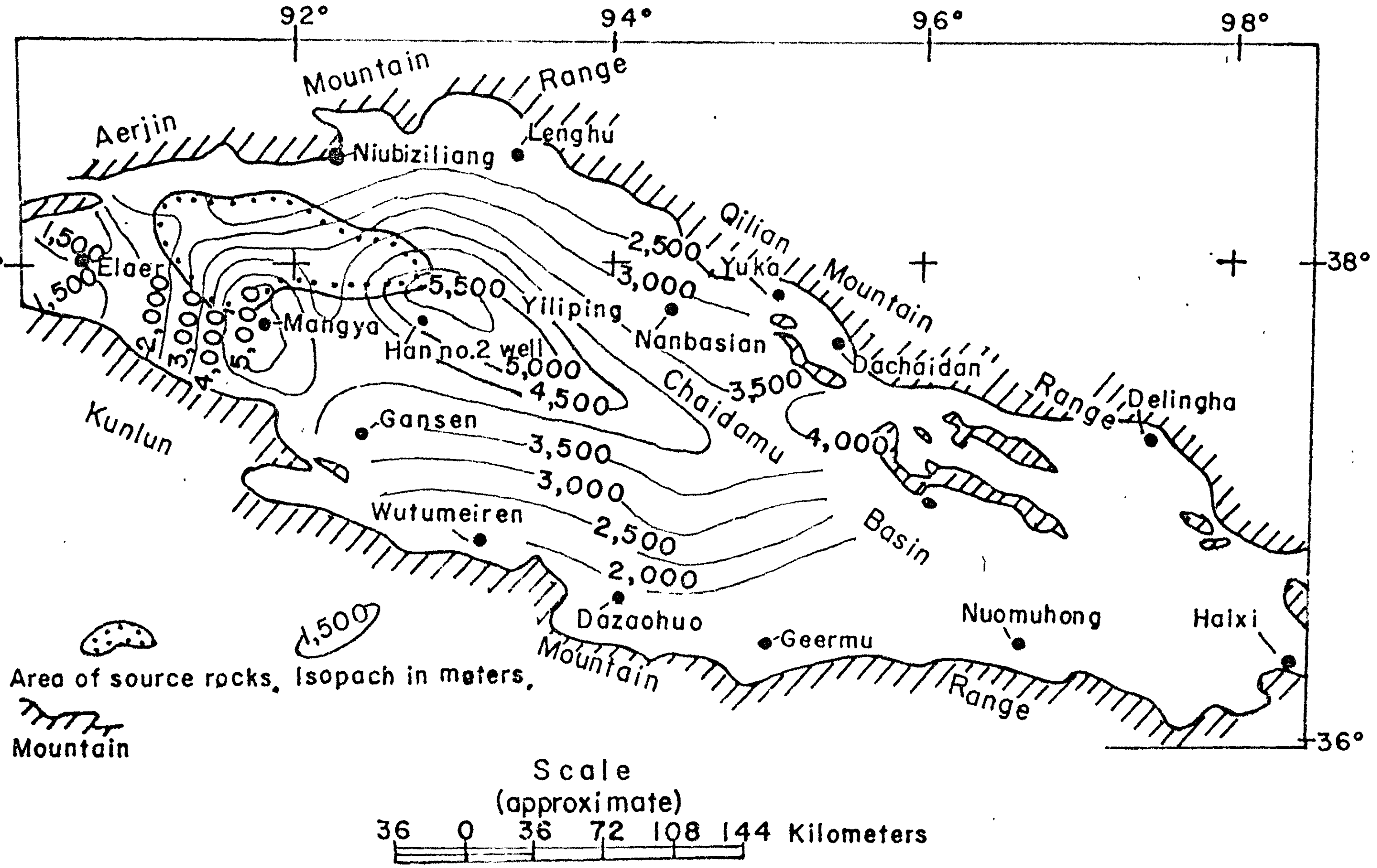


Figure 7. Isopachs of the Pliocene strata and source rock distribution in the Chaidamu basin (adopted after Song and Liao, 1982; fig. 4, p. 17).

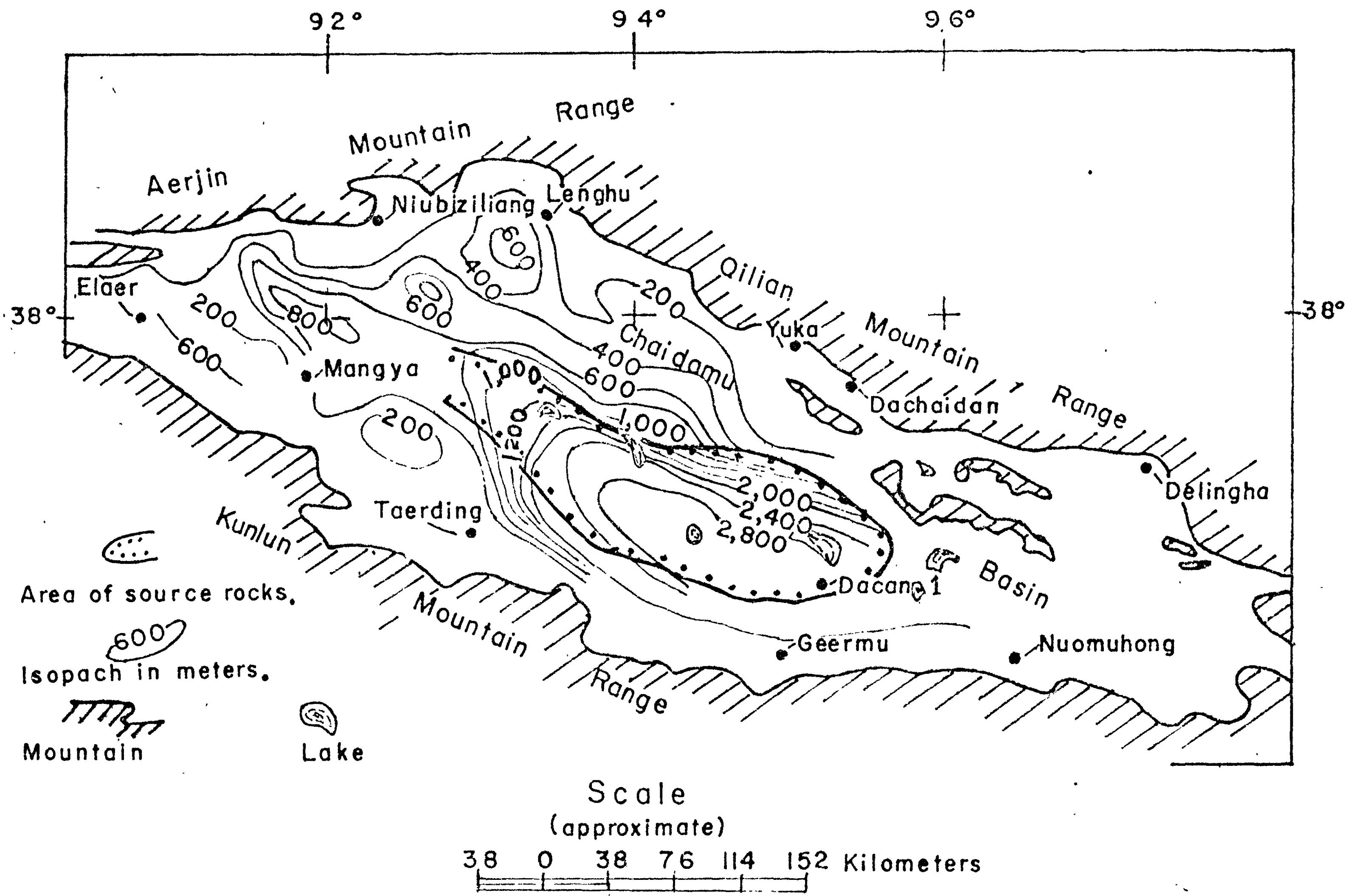


Figure 8. Isopachs of the Quaternary strata and distribution of the gas source rocks in the Chaidamu basin (after Song and Liao, 1982; fig. 5, p. 17).

GEOTECTONICS AND EVOLUTION OF THE BASIN

The Chaidamu basin is a large-scale Mesozoic and Cenozoic intermontane depression (figs. 4 and 9) and has evolved from the Paleozoic basement in the eastern part of the eastern Kunlun Fold System (figs. 3 and 4) (Huang and others, 1980, p. 50-52). During the late stage of the Variscan orogeny, the initial depositional framework of the Chaidamu basin was formed by block-faulting in the northern part of the basin (figs. 9 and 9a) (table 1). Subsequently, during the Indosinian and Yanshanian (Yenshanian) orogenies (table 1), the Chaidamu basin evolved into its present form by rejuvenated faulting in the northeast along the Qilianshan front and by downwarping, block-faulting, and erosion in the south near the front of the Kunlun Mountain range (fig. 9b). Later, this basin culminated its development during the Himalayan orogeny at the end of the Middle Eocene and in the period from the end of the Oligocene to the middle part of the Miocene (fig. 9c).

Principal structural elements of the Chaidamu basin consist of the Mangya (Mangyai) depression, the Chaizhong (Central) uplift, the Lenghu depression, and the Sanhu neodepression (Yan, 1980, fig. 6, p. 124) (fig. 9). Major structural trends are in the northwestern direction. The Mangya depression is located in the northwest part of the basin and was formed during the early episode of the Himalayan deformation. This depression contains 5,200 meters of Oligocene to Miocene sedimentary sequences, and, subsequently, those strata were folded and faulted northwesterly by moderate shearing compression stresses. The axial planes of folding dip gently toward the south. The Chaizhong uplift contains most of the northwesterly trending anticlines, which were broken by local faulting. The Lenghu depression is located in the northern part of the basin and was initially formed by block-faulting during the late episode of the Variscan orogeny and expanded to full development stage during the Indosinian and Yanshanian orogenies. This depression contains 3,500 meters of Middle to Upper Jurassic sedimentary sequences and about 5,460 meters of Tertiary sedimentary beds (table 2). Later, during the Late Mesozoic Yanshanian and Quaternary Himalayan deformation, the Lenghu sedimentary beds were intensely folded and faulted northwesterly, as well as northeasterly, by shearing and rotary compression stresses. The dipping direction of folding axial planes in the Lenghu area is generally oriented with geologic ages. The dipping direction of the Mesozoic folding axial planes is mostly northeast; of the early Tertiary folding axial planes, southwest; and of the early Quaternary folding axial planes, mostly northeast. The Sanhu neodepression is located in the south of the basin and was formed by downwarping during the Pliocene to early Quaternary Himalayan orogeny, accompanied by intense folding west and north of the basin. The Sanhu depression contains more than 2,800 meters of Quaternary sedimentary sequences, which were formed into broad gentle folds during late stages of the Himalayan movement.

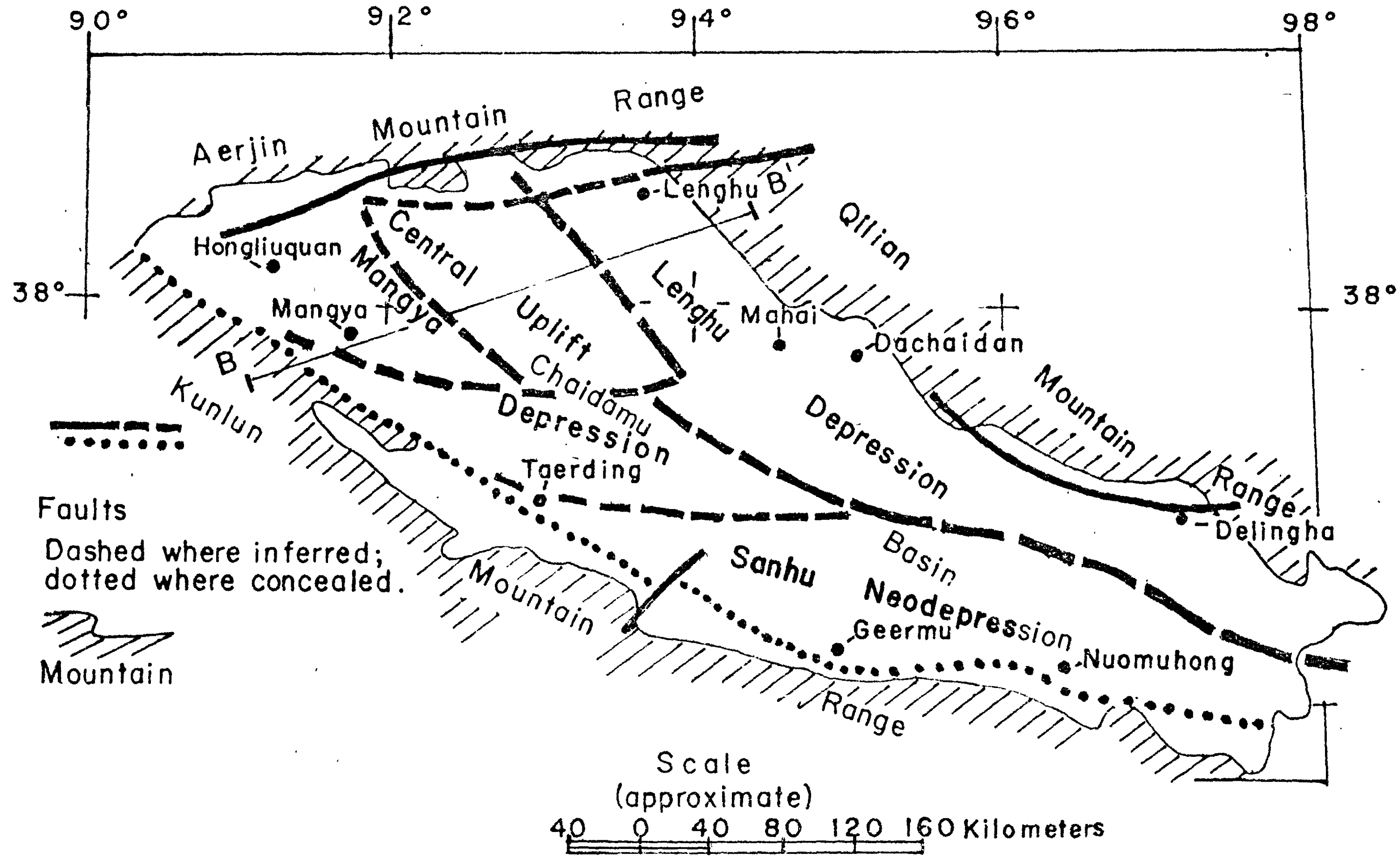


Figure 9. Sketch map of the Chaidamu basin showing principal structural elements, cross-section (B - B'), and development stages (figs. 9a, 9b, and 9c) of the basin (after Yan, 1980; Figure 6, p. 124).

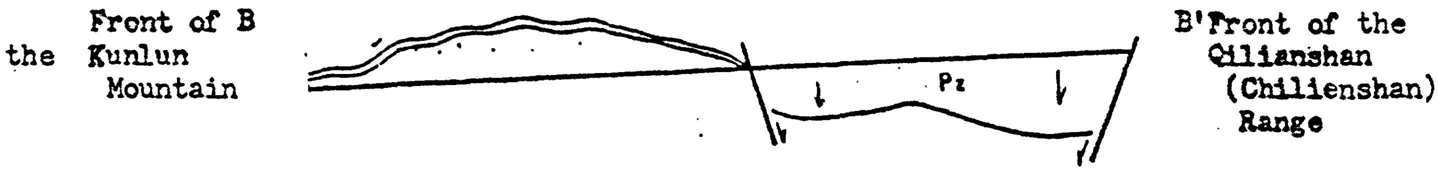


Figure 9a. Generalized structural cross - section (B-B') showing the Variscan faulted depression in the north of Chaidamu basin.

P_z, Paleozoic strata.

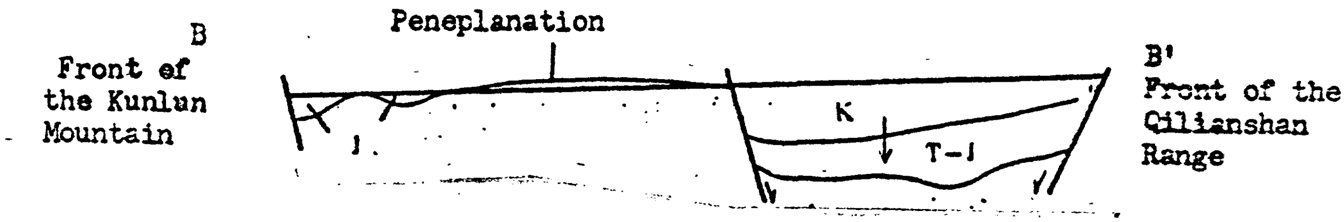


Figure 9b. Generalized structural cross - section (B-B') showing the formation of Chaidamu basin during the Indosinian and Yanshanian orogenies.

T - J, Triassic - Jurassic strata.
J, Jurassic strata.
K, Cretaceous strata.

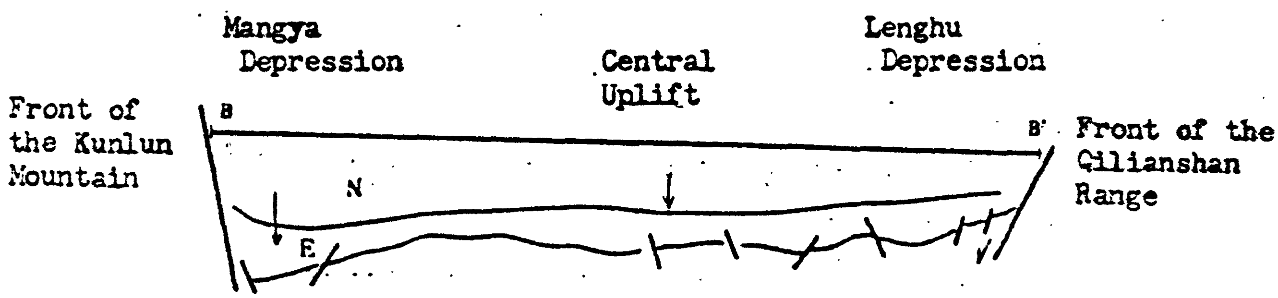


Figure 9c. Generalized structural cross - section (B-B') showing the full-development of Chaidamu basin during the Himalayan orogeny.

E, Eogene (Lower Tertiary).
N, Neogene (Upper Tertiary).

ENERGY MINERAL DEPOSITS

Petroleum and natural gas deposits are the most important energy mineral deposits of the Chaidamu basin. Coal occurs only in the Lower and Middle Jurassic sedimentary sequences along the front of the Qilianshan Mountain range and has been mined locally.

Petroleum

Petroleum deposits are generally concentrated in the Mangya (Mangyai) and and the Lenghu depressions; a gas field has been reported in the Sanhu neodepression (fig. 9).

Source rocks

Source rocks of petroleum in the Chaidamu basin are confined to the fine detrital lacustrine sedimentary sequences of Jurassic, Oligocene, Miocene, Pliocene, and Pleistocene age (Masters and others, 1980, p. 210).

The Jurassic source rocks are in the fine detrital deposits of the Lower Jurassic Xiaomeigou Formation and the Middle Jurassic Dameigou Formation.

The Xiaomeigou Formation consists of about 30 meters of grayish-black, dark-gray, and orange-gray, carbonaceous shale, clayey siltstone, and coal beds, which unconformably overlie the Precambrian metamorphic complexes.

The Dameigou Formation consists of about 600 meters of grayish-black, dark-qray and carbonaceous shale, yellowish-green and carbonaceous mudstone and siltstone, which contain 2.5 meters of oil shale and 57.5 meters of coal beds. Chemical analyses of shale and mudstone show that organic-carbon contents range from 0.38 to 2.77 weight percent, and as high as 2-5 percent, locally; asphalt contents range from 0.5 to 2.5 percent (Wang, 1981, p. 21).

The Tertiary source rocks are confined in the Oligocene Xiaganchaigou Formation, the Miocene Shangganchaigou Formation and Xiayoushashan Formation, and the Pliocene Shangyoushashan Formation and Shizigou Formation. Generally they are well developed in the western part of the basin.

The Oligocene Xiaganchaigou Formation generally consists of about 200 to 1,400 meters of greenish-gray, grayish-green, calcareous, sandy and saprophytic mudstone, light-gray and calcareous marl, and, locally, grayish-black asphaltene and oolitic limestone. The hydrocarbon content of mudstone amounts to 604 ppm (Shang and Li, 1981, table 1, p. 9).

The Miocene Shangganchaigou Formation and the Xiayoushashan Formation consist in total of 200 to 700 meters of gray, sandy and saprophytic mudstone.

The Pliocene Shangyoushashan Formation and the Shizigou Formation contain a total of more than 900 meters of gray and carbonaceous mudstone and shale, which are generally rich in organic matter.

The Quaternary source rocks are confined to the gray mudstone and siltstone sequences of the Qigequan Formation. The mudstone and siltstone are well developed in the Sanhu neodepression and attain a total thickness of more than 2,800 meters (fig. 8). These rocks are generally locally high in organic carbon.

Huang and others (1981) studied the evolution characteristics of the organic matter in the Quaternary and Tertiary Neogene source rocks from the well samples of Han No. 2 in the eastern margin of the Mangya depression (table 3) (fig. 7). From a set of 33 well samples, they determined that the alkalinity of lake water was about 15 percent during the deposition of the Xiaoyoushashan and Shangyoushashan Formations, and later it increased to 40 percent in the late stage of the Shizigou deposition. By means of the group composition, chromatogram and infrared spectrum, those well samples show a low content of organic carbon and asphaltene, which ranks in a non-source-rock status, as compared with other source rocks of continental deposits in China. Nevertheless, this study indicates a unique significance concerning the geochemical criteria for identifying the different stages of conversion of organic matter to hydrocarbons (table 3).

They concluded that during the time span of 6.5 million years, the organic-matter-bearing sediments had undergone fairly complete biochemical and thermal-chemical processes of evolution, through which the organic matter reached a mature stage to generate petroleum deposits at a burial depth of 3,300 meters with a temperature of 126 C; further down to a burial depth of 5,020 meters with a temperature of 172 C, a highly mature stage of the buried organic matter had been formed to generate the condensates and wet gas (table 3).

In a later study of the evolution characteristics and the geochemical significance of the immature, mature, highly mature steranes and polycyclic terpanes from the Han No. 2 well in the Chaidamu basin, Huang and others (1983) further redefined the burial boundary of a turning point at 4,100 meters of depth for the evolution of organic matter from low maturity to full maturity. At this point, the CPI value is less than 1.1, and the geotemperature is 150 C. The main oil generating zone with vitrinite reflectanes of 0.8 to 1.1 percent is in the burial interval between the depths of 4,100 and 4,800 m, in which the composition and configuration of steroidal and terpenoidal compounds encountered distinct changes to reach the climax of oil generation.

Reservoir rocks

Petroleum deposits occur in fine-grained and medium- to very coarse-grained detrital sedimentary rocks and in the fracture zones of deformed sedimentary beds of the Upper Jurassic, Upper Cretaceous, Oligocene, Miocene, Pliocene, and Pleistocene. In the Chaidamu basin, 15 principal oil and gas fields are delineated in figure 10 (Robertson Research International Ltd, 1978; Petroconsultants S.A., 1979-1982; Meyerhoff, 1982, p. 227-231). Four

Table 3.--Evolution characteristics of organic matter in the Quaternary and Tertiary Neogene source rocks from the well samples of Han No. 2, drilled in eastern margin of the Mangya depression (fig. 9) (adopted and modified after Huang and Li, 1981, p. 100-112 and table 5, p. 111).

Stratigraphy			Quaternary deposits and Shizigou Formation	Skangyoushashan Formation	Xiayoushashan Formation (bottom not reached)
Evolution stage			Immature	Mature	Highly mature
Well depth (meters)			0 - 3,300±	3,300± - 5,020	5,020 - 6,018
Geothermal (C)			6.3 - 126±	126± - 172	172 - 198
Asphalt and family composition		Total hydrocarbon (ppm)	< 50 d generally 32±	50 - 80	65 - 100
Asphalt and family composition		Asphalt/organic carbon (%)	< 7	7 - 9	10 - 15±
Asphalt and family composition		Hydrocarbon/organic carbon(%)	< 3	3 - 4	4 - 6
Asphalt and family composition	Family composition	Saturated hydrocarbon/aromatics	7 - 4	1 - 4 (3±)	4±
Asphalt and family composition	Family composition	Total hydrocarbon (%)	30 - 40	40 - 55	40±
Asphalt and family composition	Family composition	Non-hydrocarbon (%)	45 - 60	39±	50 - 55
Alkane hydrocarbon		Principal peak (C no.)	C_{18}, C_{31}	C_{17} or C_{18}	C_{18}
Alkane hydrocarbon		CPI	> 1.3	1 - 1.3	1.0±
Alkane hydrocarbon		Light hydrocarbon/Heavy hydrocarbon	1.0 - 2.0		7 - 20
Alkane hydrocarbon		Pristane/Phytane	0.8±	0.9 - 1.3	0.9 - 1.2
Infrared spectra of armoatics		806 cm^{-1}/750 cm^{-1}	0.4 - 0.5	0.7 - 0.8	0.5 - 0.7
Infrared spectra of armoatics		(880+806)cm^{-1}/750 cm^{-1}	0.6 - 0.8	1.0 - 1.4	0.8 - 1.0
Infrared spectra of armoatics		1460 cm-1/1600 cm^{-1}	4.5 - 6.0	2.5 - 4.5	6.0 - 12.0
Infrared spectra of armoatics		1710 cm^{-1}/1600 cm^{-1}	1.0 - 2.0	0.7 - 1.0	
Infrared spectra of armoatics		1380 cm^{-1}/1600 cm^{-1}	2.0 - 3.0	1.0 - 2.0	2.0 - 50

stratigraphic and structural cross sections across the basin are shown in figures 11 and 12. Although these cross sections generally are not in agreement with current studies by Chinese geologists, their reproduction here is warranted. Geologic characteristics of reservoir rocks in each of 15 fields are stated below.

Qigequan (Ch'ikuoch'uan) oil field (fig. 10)

The reservoir rocks of Qigequan (Ch'ikuoch'uan) oil field are composed chiefly of fine- to medium-grained fluvial sand, sandstone, and sandy shale of the Oligocene Xiaganchaigou Formation, the Miocene Shangganchaigou Fomation and Xiayoushashan Formation, and the Pliocene Shangyoushashan Formation. The oil pool occurs in a northwesterly elongated narrow anticline, and it is laterally confined by shale facies. Petroconsultants S.A. (1979) provided the following reservoir data:

> "The reservoir sandstone horizons in this field range in thickness between 1 m and 4 m. In some zones the local buildups of individual reservoirs are up to 10-35 m. Depth to top pay - approx. 400 m, approx. 800 m, approx. 1,000 m. Gross pay - 270 m. Net pay - 50 m. Porosity - 16 to 20 percent."

Shizigou (Shihtzukou) oil field (fig. 10).

The reservoir rocks of the Shizigou oil field consist of fluvial fine- to medium-grained sand and sandstone of the Oligocene Xiaganchaigou Formation and the Miocene Shangganchaigou Formation and Xiayoushashan Formation. The oil pool occurs in a dome-shaped anticline, and it is laterally confined by shale facies. Petroconsultants S.A. (1979) provided the following reservoir data:

> "Depth to top pay - approx. 1,000 m, approx. 1,200 m. Gross pay - approx. 200 m. Porosity - 16 to 20 percent."

Youshashan oil field (fig. 10)

The reservoir rocks of Youshashan oil field are composed of fluvial fine- to medium-grained sand and sandstone of the Oligocene Xiaganchaigou Formation and the Miocene Shangganchaigou Formation and Xiayoushashan Formation. The oil pool occurs in a northwesterly elongated faulted anticline, and it is laterally confined by shale facies (figs. 13 and 14). Petroconsultants S.A. (1979) gave the following reservoir data:

> "Depth to top pay - approx. 800 m, approx. 1,000 m. Net pay - 27 m. Porosity - 16 to 18 percent. Twelve productive sandstone horizons, each 1 to 4 m thick, are present in this field."

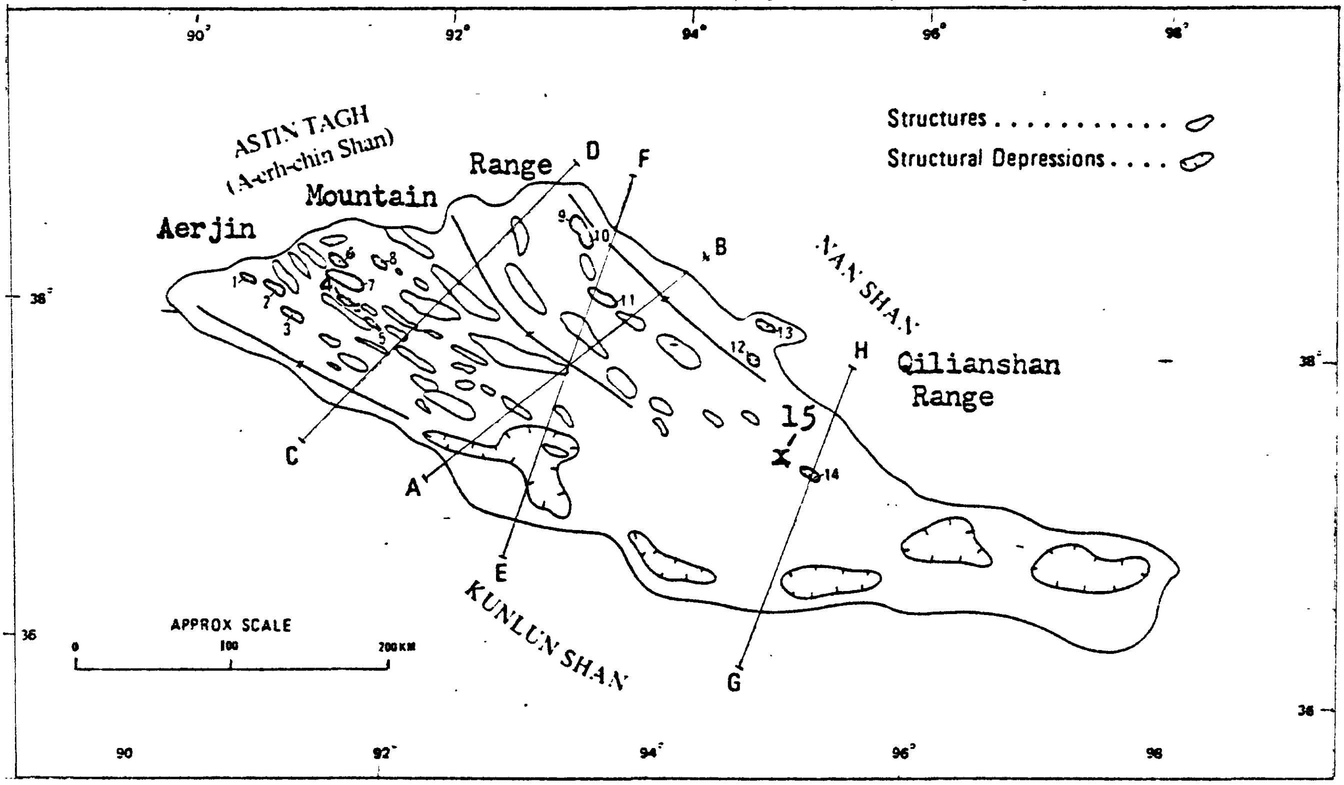


Figure 10. Distribution of oil and gas fields in the Chaidamu basin (after Robertson Research International Limited, 1978).

1. Qigequan (Ch'ikuoch'uan)
2. Shizigou(Shihtzukou) (producing)
3. Youshashan (producing)
4. Youquanzi (Yuch'uantze) (producing)
5. Kaitemilike (Kaitmolik)
6. Xiaoliangshan (Hsiaolienshan) (gas)
7. Nanshan (producing)
8. Jiandingshan (Tsentinshan)
9. Lenghu 3 (producing)
10. Lenghu 4 (producing)
11. Lenghu 5
12. Mahai (gas)
13. Yuka (Yuk'a) (gas)
14. Yanhu(Yenhu) (gas)
15. Sebei (gas) (after Petroconsultants LTD,1982)

Cross - sections: A-B,C-D,E-F, and G-H.

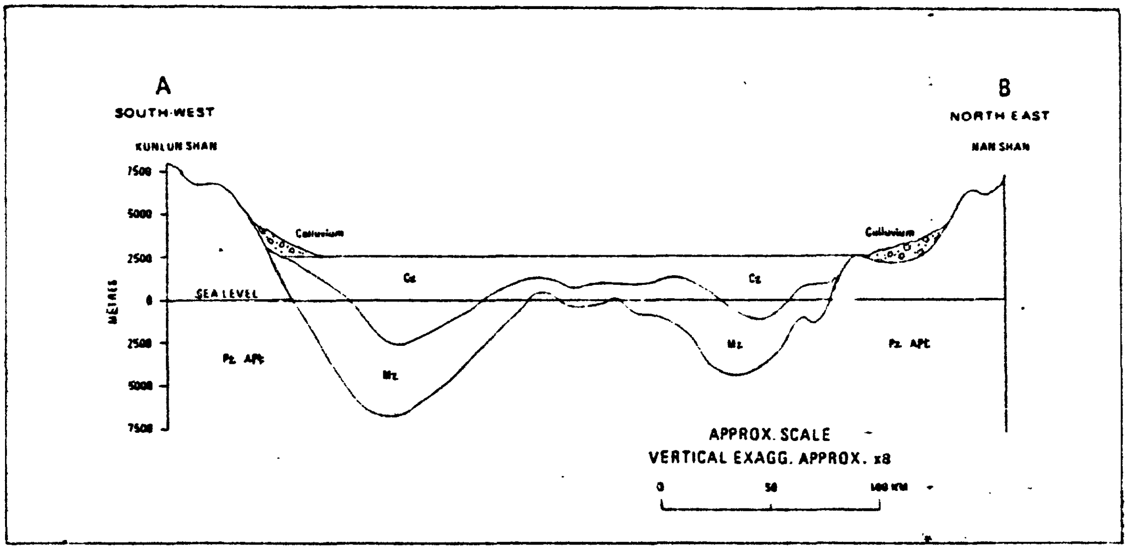


Figure 11. Generalized cross-section, A - B, shown on Figure 10, across the Chaidamu basin (after Robertson Research International Limited, 1978)

Cz, Cenozoic. Mz, Mesozoic.

Pz, Paleozoic. AP_t, Precambrian.

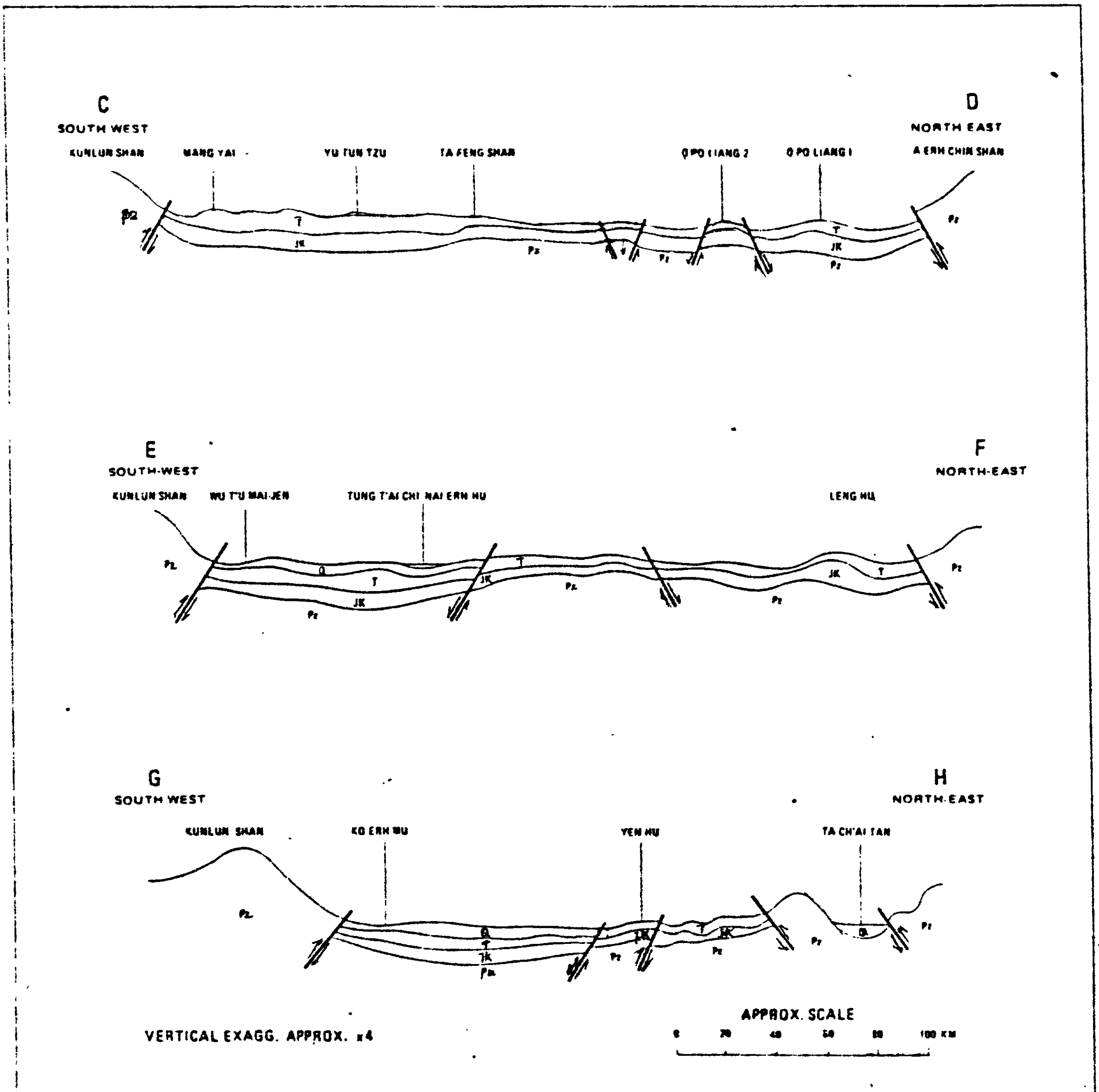


Figure 12. Generalized cross-sections, C-D, E-F, and G-H, shown on Figure 10, across the Chaidamu basin (after Robertson Research International Limited, 1978. Place names are in the Wade-Gile transliteration) Q, Quaternary.
T, Tertiary. JK, Jurassic and Cretaceous. Pz, Paleozoic.

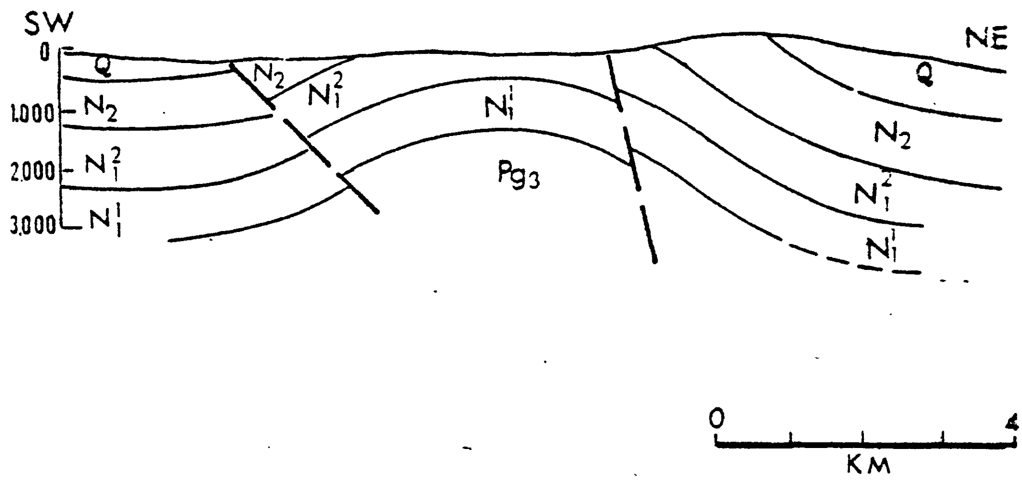


Figure 13. SW - NE cross - section through Youshashan oil field (after Petroconsultants Limited, 1979)

Q, Quaternary

N_2, Pliocene. N_1^2, Upper Miocene. N_1^1, Lower Miocene

P_{g3}, Oligocene.

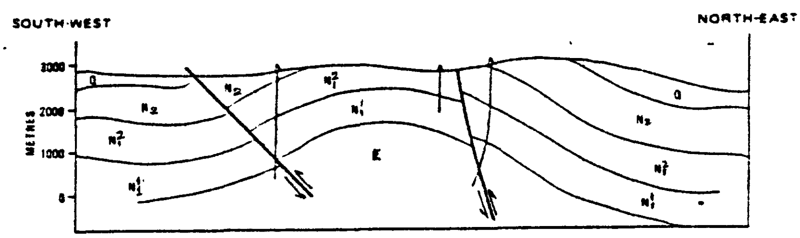


Figure 14. Youshashan anticlinal structure (after Robertson Research International Limited, 1978)

Q, Quaternary. N_2, Pliocene. N_1^2, Upper Miocene. N_1^1, Lower Miocene.

E, Eogene(Lower Tertiary).

Youquanzi (Yuch'uantze) oil field (fig. 10)

The reservoir rocks of Youquanzi oil field consist of fluvial fine- to medium-grained sand and sandstone of the Oligocene Xiaganchaigou Formation and the Miocene Shangganchaigou Formation and Xiayoushashan Formation. The oil pool occurs in a faulted, dome-shaped anticline. Petroconsultants S.A. (1979) gave the following reservoir data:

"Depth to top pay - approx. 800 m, approx. 1,000 m.
Net pay - approx. 40 m. Porosity - 18 to 20 percent.

There are approximately 12 productive sandstones, each 1 to 5 m thick."

Kaitemilike (Kaitmilik) oil field (fig. 10)

The reservoir rocks of the Kaitemilike oil field consist of fluvial sandstone of the Miocene Shangganchaigou Formation and Xiayoushashan Formation. The oil pool is confined in a northwesterly-trending surface anticline. Petroconsultants S.A. (1981) provided the following reservoir data:

"Depth to top pay - 150 m. Gross thickness of reservoir bearing interval - 550 m. Net thickness of reservoir bearing interval - 40 m.

There are 12 productive sandstones present, each 1-5 m thick."

Xiaoliangshan (Hsiaolienshan) gas field (fig. 10)

The reservoir rocks of Xiaoliangshan gas field are composed of fluvial conglomerate, sandstone, and shale of the Pliocene Shanggoushashan Formation and Shizigou Formation. The gas pool is confined in a northwesterly trending surface anticline. Petroconsultants, S.A. (1981) provided the depth to top pay as about 300 m deep.

Nanshan oil field (fig. 10)

The reservoir rocks of the Nanshan oil field consist of fluvial sand and sandstone of the Pliocene Shangyoushashan Formation and Shizigou Formation. The oil pool is probably confined in a northwesterly trending surface anticline. Other informaton is not available. This field is reported to be producing (Petroconsultants S.A., 1981).

Jiandingshan (Tsentinshan) oil field (fig. 10)

The reservoir rocks of Jiandingshan oil field consist of sandstone, siltstone, and shale of the Miocene Shangganchaigou Formation and the Xiayou-shashan Formation. The oil pool is confined in a northwesterly-trending surface anticline. The depth to top pay is reported to be 300 meters (Petroconsultants S.A., 1981). It is believed that there are about a dozen productive sandstones present, which range in thickness from 1 to 5 m each (Petroconsultants S.A., 1981).

Lenghu 3, 4, and 5 oil fields (fig. 10)

The reservoir rocks of Lenghu 3, 4, and 5 oil fields consist of fluvial fine- to coarse-grained sand and sandstone of the Oligocene Xiaganchaigou Formation and the Miocene Shangganchaigou Formation and Xiayoushashan Formation. The oil pools occur in an elongated asymmetrical north-northwesterly trending anticline, and they are confined laterally by shale facies (fig. 15). Petroconsultants S.A. (1979) provided the following reservoir data:

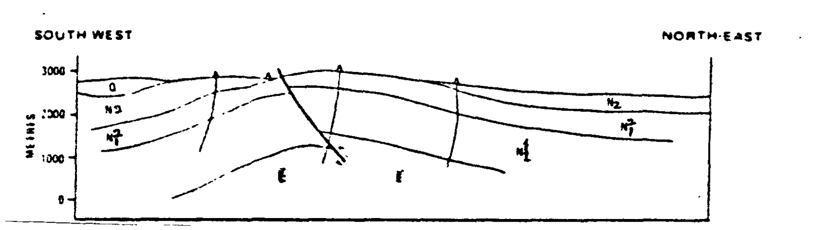


Figure 15. Lenghu No. 5, anticlinal structure (after Robertson Research International Ltd., 1978).

Q, Quaternary. N_2 Pliocene. N_1^2 Upper Miocene. N_1^1 Lower Miocene. E, Eogene (Lower Tertiary).

"Depth to top pay - 100 m. Gross pay - approx. 600-800 m. Net pay - 100 to 120 m, in which individual reservoirs generally are 1 to 5 m thick. The hydrocarbon bearing sequence occurs mainly between 100 m and 900 m depth. The Lenghu 4 and 5 fields produce from Miocene, while Lenghu 3 produces from Oligocene. The Lenghu field represents three separate closures (Lenghu 3, 4, and 5) on a simple anticlinal structure. Lenghu 3 and 4 are producing, while Lenghu 5 is shut in."

Mahai gas field (fig. 10)

The reservoir rocks of the Mahai gas field consist of fluvial sandstone, siltstone, and shale of the Miocene Shangganchaigou Formation and Xiayoushashan Formation, in which at least one oil reservoir is also present (Petroconsultants S.A., 1981). The gas pool is confined in a northwesterly symmetrical surface anticline with flank dips of 4 to 9 and depth to top pay of about 400 m (Petroconsultants S.A., 1981).

Yuka (Yuk'a) oil and gas field (fig. 10)

The reservoir rocks of the Yuka oil and gas field are the fluvial medium- to coarse-grained sandstone of the Cretaceous oil-bearing Quanyagou Formation and the Miocene gas-bearing Shanganchaigou Formation and Xiayoushashan Formation. The gas or oil pool is confined in a northwesterly anticlinal structure. The depth to top pay is approximtely 1,000 m and 2,500 m, respectively, and the porosity of sandstone ranges from 18 to 24 percent (Petroconsultants S.A., 1979).

Yanhu (Yenhu) gas field (fig. 10)

The reservoir rocks of the Yanhu gas field consist of fluvial sandstone and lacustrine clayey siltstone of the Pliocene Shizigou Formation. The gas pool is confined in a northwesterly asymmetrical anticline. The depth to top pay is 70 m. The thickness of gross pay ranges from 60 to 80 m, and porosity of reservoir rock is 20 percent (Petroconsultants S.A., 1979).

Sebei gas field (fig. 10)

The reservoir rock of the Seibei gas field is chiefly terrestrial siltstone of the Pleistocene Qigequan Formation. The gas pool is confined in a northwesterly-trending anticline with two culminations (Petroconsultants S.A., 1982). Petroconsultants (1982) also provided the following reservoir data:

> "Depth to top pay - 500 m. Gross thickness of reservoir bearing interval - 500 m. Porosity - average 32-42.8 percent. Permeability - from several hundred millidarcies to as high as 1,739 md."

Throughout the Chaidamu basin, the deposition of reservoir rocks was generally controlled by the syndepositional tectonics during the evolution of the basin in Jurassic, Oligocene, Miocene, and Pleistocene time. Subsequently, the accumulation and migration of oil and gas also were closely related to the tectonic movements (Song and Liao, 1982; Wang, 1981, 1982; Yan, 1980). In the Lenghu depression, the Jurassic oil and gas deposits are concentrated in the northern and northwestern parts of the depression. In the Mangya depression, the Oligocene and Miocene oil and gas deposits are located in the western and northwestern parts of the depression. The Pleistocene gas pools are generally concentrated in the northern part of the Sanhu neodepression. The evaporite beds and clayey detrital rocks are commonly "seal beds" in oil and gas pools.

Detailed chromatographic analyses of hydrocarbon patterns indicate that three types of crude oil occur in the reservoir rocks throughout the Chaidamu basin (Wang and others, 1983, p. 121-127). The first type of crude oil has been generated from the Middle Jurassic source rocks and shows characteristics of a high mature stage of soluble organic matter evolution, the C_{15} as the main peak carbon of normal paraffins and the pristane to phytane ratio which varies from 2.44 to 2.90. The second type of crude oil evolved from Oligocene to lower Pliocene source rocks and is characterized by a higher phytane peak than those of the other two types of crude oil, the C_{22} as the main peak carbon of normal paraffins and the pristane to phytane ratio which varies from 0.86 to 0.52. The third type of crude oil was generated from upper Pliocene source rocks and contains a dominant light fraction of hydrocarbons, of which C_{13} is the main peak carbon of normal paraffins. The pristane to phytane ratio of this type of crude oil is 1.26. Generally, the crude oil of Oligocene to early Pliocene age consists chiefly of isoprenoid-hydrocarbons, in which most of the normal paraffins were degraded by microbes.

Coal

The Lower and Middle Jurassic coal-bearing sedimentary sequences are well developed and widely distributed in the border areas of the northern and northeastern parts of the Chiadamu basin (figs. 4 and 5). The coal was deposited in a swamp environment and confined in the Lower Jurassic Xiaomeigou Formation and the Middle Jurassic Dameigou Formation (fig. 16).

The best quality and thickest coal beds occur in the Middle Jurassic sedimentary sequences that are about 1,029 meters thick (at Dameigou) (Wang, 1981, p. 21). The coal is in 22 beds that have a total aggregate thickness of 57.48 m. The thickest coal bed is as much as 27.97 m thick. The coal-bearing strata are generally faulted and folded into monocline or syncline structure. Fresh-water fauna are abundant in the lacustrine mudstone, siltstone, and oil shale deposits.

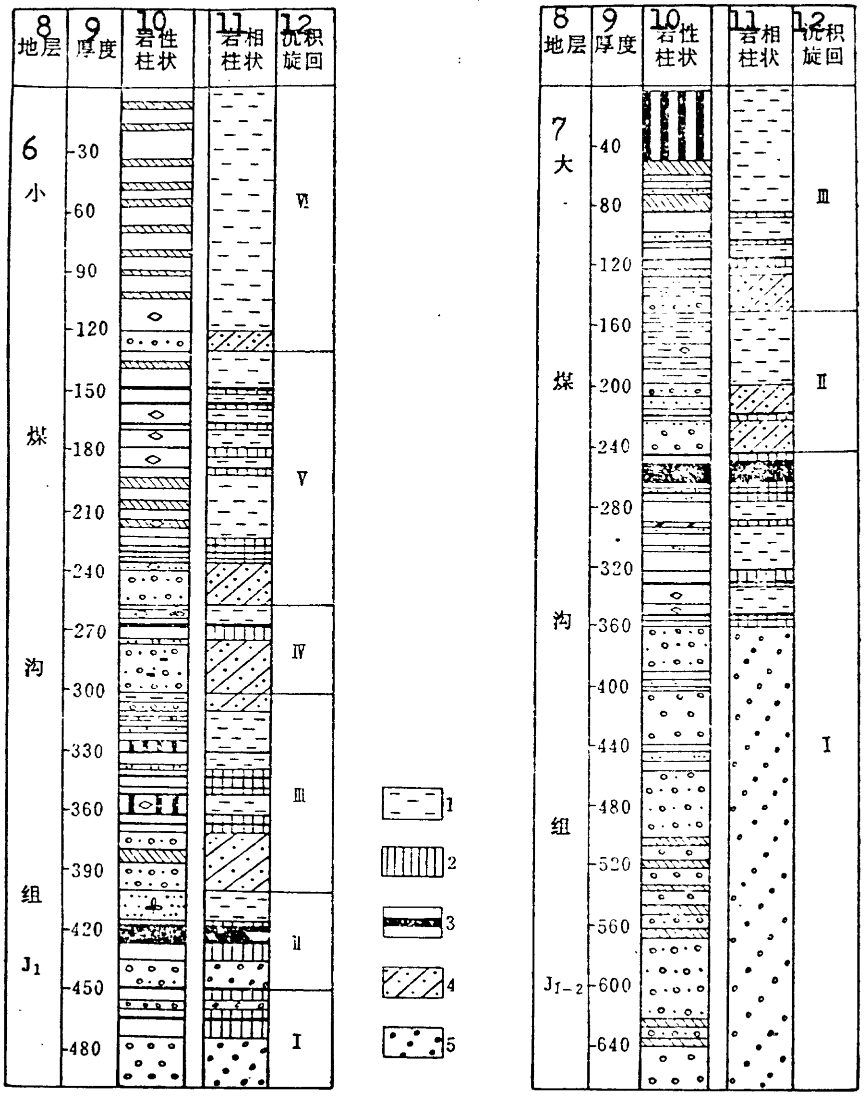


Figure 16.--Lithofacies columnar sections of the Lower Jurassic and Middle Jurassic coal-bearing sedimentary sequences along the northern and northeastern border areas of the Chaidamu basin (after Han and Yang, 1980, p. 304).

1. Lacustrine facies. 2. Swamp facies. 3. Peat swamp facies.
4. Alluvial facies. 5. Diluvial and alluvial facies. 6. Xiaomeigou Formation.
7. Dameigou Formation. 8. Stratigraphy. 9. Thickness.
10. Columnar lithology. 11. Columnar lithofacies. 12. Cycle of sedimentation.

SUMMARY

The Chaidamu basin is an intermontane depression in the northwestern part of the Qinghai Province, Northwest China. The depositional framework of the basin was initially formed on the Paleozoic basement of the Variscan eastern Kunlun Fold System during the late episode of the Indosinian orogeny; the basin was then broken up, in its northwestern and eastern parts, by a northwesterly faulting system, receiving more than 3,000 meters of Mesozoic sedimentary rock deposits. During the Tertiary Eocene and Oligocene-Miocene Himalayan orogeny, the Chaidamu basin has since evolved into its present shape.

The source rocks of petroleum and natural gas deposits are confined to the lacustrine deposits of clay, shale, and mudstone of Jurassic, Oligocene, Miocene, Pliocene and Pleistocene age. The reservoir rocks are fluvial sand, sandstone, and conglomerate of the Upper Jurassic, Upper Cretaceous, Oligocene, Miocene, Pliocene, and Pleistocene sedimentary sequences. Fifteen oil and gas fields have been discovered in the northern, central, and western parts of the basin. The oil or gas pools occur in domes, anticlinal structures, and locally fractured zones. Generally they are confined laterally by the shale facies. The sealing rocks are the evaporite beds and shale.

Detailed chromatographic analyses of hydrocarbon patterns define three types of crude oil from the oil pools of Chaidamu basin. They were generated from the source rocks of the Middle Jurassic, Oligocene to Lower Pliocene, and Upper Pliocene.

Huang and others (1983) defined the burial boundary of a turning point at 4,100 m depth for the evolution of organic matter from low maturity to full maturity during a study of the evolution characteristics and the geochemical significance of the immature, mature, highly mature steranes and polycyclic terpanes from the Quaternary and Pliocene source rocks in the well samples of Han No. 2. The principal oil generating zone with vitrinite reflectanes of 0.8 to 1.1 percent is in the burial interval between the depths of 4,100 and 4,800 m.

Coal deposits occur in the Lower and Middle Jurassic sedimentary sequences. The best quality coal is confined to the Dameigou Formation of Middle Jurassic age. The thickest coal bed is 27.97 m thick and is mined locally.

REFERENCES CITED

Chen Shaozhou, Gao Xinchen, and Qiu Dongzhou, 1982, A preliminary study on China's Eogene transitional facies: Oil and Gas Geology, v. 3, no. 4, p. 343-350 (in Chinese with English abstract).

Compilation Group of the Geological Map of Asia, Chinese Academy of Geological Sciences, 1982, Figures and Tables of the Geology of Asia: Beijing, Geology Press (in Chinese).

Chang, W. T., Chang, J. T., and Yu, C. M., 1958, Brief notes on the stratigraphy of the western border of Tsaidam Basin: Acta Geologica Sinica, v. 38, no. 1, p. 123-133 (in Chinese with English abstract).

Group of Tectonics, Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences, 1977, An outline of the tectonic characteristics of China: Beijing. Special Paper of the Chinese Academy of Geological Sciences, 24 p. (in English).

Han Dexin and Yang Qi, chief eds., 1980, Coal Geology of China: Beijing, Coal Industry Press, v. 2, 415 p. (in Chinese).

Huang Juichang, 1959, On the Tertiary stratigraphy, its petrological characteristics and oil possibilities of the western Tsaidam: Acta Geologica Sinica, v. 39, no. 1, p. 1-22. 2 pls (in Chinese with English abstract).

Huang, T. K., Ren Jishun, Jiang Chunfa, Zhang Zhengkun, and Qin Deyu, 1980, The Geotectonic evolution of China: Beijing, Science Press, 122 p., 16 plates (in Chinese with English "Contents").

Huang Difan, Li Jinchao, and Zhou Zhuhong, 1981, Evolutionary characteristics of soluble organic matter in Quaternary to Pliocene of the Tsaidam Basin: Acta Petrolei Sinica, Special Issue, v. 2, no. 4, p. 100-112 (in Chinese with English abstract).

Huang Difan, Li Jinchao, Jiang Naihuang, and Tong Yuying, 1983, Steranes and terpanes in Upper Tertiary of Qaidam basin as indicators for source rocks and their maturity: Scientia Sinica Series B, v. 16, no. 11, p. 1216-1232.

Institute of Geology, Academia Sinica, 1958 [Tables of Geological strata in various areas of China] (rough draft) (Supplement): Beijing, Science Press, 190 p. (in Chinese).

Masters, C. D., Girard, O. W., Jr., and Terman, M. W., 1980, A perspective on Chinese petroleum geology: Southwestern Legal Foundation, Proceedings, Exploration and Economics of the Petroleum Industry, v. 18, p. 199-225.

Meyerhoff, A. A., 1982, Petroleum basins of the Union of Socialist Soviet Republics and the People's Republic of China and the Politics of Petroleum: Petroleum Exploration Society of Australia, Distinguished Lecture Series, 341 p., 140 figs.

Petroconsultants S.A., 1979-82, Oil and gas data sheets, Geneva, Switzerland, 4 pages each.

Robertson Research International Limited, 1978, The People's Republic of China: its petroleum geology and resources: Great Britain and France, The Robertson Research Group, v. 1, text, and v. 2, plates.

Shang Huiyun and Li Jinchao, 1981, Abundance and types of organic matter in source rocks of continental facies: Acta Petrolei Sinica, Special Issue, December, v. 2, no. 4, p. 8-16 (in Chinese with English abstract).

Song Jianguo and Liao Jian, 1982, Structural characteristics and petroliferous regions in the Chaidamu (Tsaidam) Basin: Acta Petrolei Sinica, Special Issue, p. 14-23 (in Chinese with English abstract).

Wang Hongchen and Liu Benpei, 1980 [Historical Geology]: Beijing, Science Press, 352 p. (in Chinese).

Wang Ningguo, 1982, The Aerjin arcuate structural zone and its relationship with oil and gas: Acta Petrolei Sinica, v. 3, no. 2, p. 21-27 (in Chinese with English abstract).

Wang Youxiao, Cheng Xuehui, Wu Yihua, and Chuan Lanlan, 1983, Geochemical characteristics of crude oils from Qaidam basin: Oil and Gas Geology, v. 4, no. 1, p. 121-127.

Wang Zuzhi, 1981, [Distribution characteristics of the Mesozoic deposits in the northern border areas of Chaidamu basin]: Petroleum Exploration and Development, No. 2, p. 20-26 (in Chinese).

Yan Xiugang, 1980, A perspective of oil and gas exploration in the large sedimentary basins in the light of the wave-like movement of the earth crust: Oil and Gas Geology, v. 1, no. 2, p. 116-125 (in Chinese with English abstract).

Zhang, W. Y., Chief Compiler, 1983, The marine and continental tectonic map of China and its environs: Beijing, Science Press. I : 5,000,000, 6 sheets (in Chinese and limited English edition).

Cretaceous System

Caishiling Series at Caishiling, western Chaidamu basin

	Thickness in meters
Cretaceous	
Caishiling Series	
Overlying strata - Tertiary	
-------unconformity-------	
31. Mudstone, red, the upper part not exposed	34
30. Conglomerate, light-red or grayish-yellow; soft, chiefly granite, limestone and conglomerate rounded fragments	342
29. Sandstone and conglomerate, gray and grayish-white sandstone interbedded with pebbly conglomerate	46
28. Conglomerate, grayish-yellow and pebbly	28
27. Sandstone and conglomerate, coarse sandstone interbedded with pebbly conglomerate	9
26. Conglomerate, pebbly	9
25. Sandstone, gray and grayish-white; coarse grained	14
24. Conglomerate, pebbly	22
23. Sandstone, fine-grained	2
22. Conglomerate, pebbly	1
21. Mudstone, dark red and sandy	6
20. Sandstone, red and fine-grained	28
19. Conglomerate, pebbly	3
18. Sandstone, red and grayish-green, fine-grained	7
17. Conglomerate, gray or light-yellow; pebbly	40
16. Sandstone, dark-red and fine-grained	23
15. Conglomerate, pebbly	7
14. Sandstone, pinkish-red and fine-grained	8

13. Conglomerate and sandstone, red, pebbly conglomerate interbedded with clayey fine-grained sandstone ------------- 32

12. Conglomerate, pebbly and contains clayey fine-grained sandstone lenses -- 52

11. Sandstone, light-red and clayey ---------------------------- 8

10. Gray (incomplete)

9. Mudstone, brownish-red ------------------------------------ 45

8. Mudstone and sandstone, red mudstone interbedded with fine-grained sandstone; contains abundant ostracode fauna -- 28

7. Mudstone, brownish-red intercalated with bluish-gray, fine-grained sandstone layers ----------------------------- 139

6. Sandstone, bluish-gray, fine-grained interbedded with red mudstone --- 29

5. Mudstone, brownish-red; interbedded with bluish-gray, fine-grained sandstone ------------------------------------- 88

4. Shale, light-gray and sandy; interbedded with thin-bedded, dark-purple and brownish-red shale; truncated by fault -- 172

3. Shale, sandstone, and siltstone, purple shale and light grayish-green sandstone interbedded with siltstone ---------- 258

2. Shale, dark-purple; interbedded with thin-bedded brownish-red shale or siltstone ---------------------------- 108

1. Conglomerate, light-gray and grayish-green, pebbly; locally intercalated with carbonaceous shale or purplish-gray sandy shale ----------------------------------- 110

--------unconformity--------

Total thickness of the Caishiling Series 1,698

Tertiary System

Xichagou Series at Xichagou, western Chaidamu basin

	Thickness in meters
Tertiary	
Xichagou Series	
Quaternary gravel	
--------conformity-------	
11. Conglomerate, gray, shoft; consisting of sandstone, quartzite, quartz veins and metamorphic rocks fragments. Diameter ranges 0.2-1 cm and as large as 15-20 cm. Most of them subrounded to angular. Fine-grained sandstone and mudstone lenses are common. ------------------------------	304
10. Mudstone, gray, sandy, intercalated with gray sandstone and conglomeratic sandstone. Gastropods fauna near base -----	686
9. Siltstone, mudstone and sandstone, orange-brown siltstone, sandy mudstone and gray sandstone contain small amounts of gray pebbly conglomerate ----------------------------------	483
8. Conglomerate, sandstone and mudstone, gray pebbly conglomerate and sandstone interbedded with orange-brown sandy mudstone.	650
7. Sandstone, mudstone, marl, and conglomerate, orange-red, clayey, fine-grained sandstone and sandy mudstone, intercalated with gray sandstone and thin-bedded marl in the lower part; grading upward into gray pebbly conglomerate, sandstone, red and clayey fine-grained sandstone, gray mudstone, and light-gray marl --------------------------------	850
6. Sandstone and shale, grayish-green, fine-grained sandstone intercalated with grayish-green, light-gray calcareous shale and orange-brown, sandy mudstone, grading upward into light-gray marl and thin lenses of conglomerates. Fish fauna occur near the top of sequence. Generally contain abundant ostracodes ----------------------------------	388
5. Conglomerate, sandstone and shale, gray, pebbly conglomerate interbedded with sandstone and dark-gray and purplish-red shale in lower part; grading upward into greenish-gray sandstone or green fine-grained sandstone, grayish-green mudstone and light-gray shale; containing ostracodes ---	458
4. Conglomerate, sandstone, mudstone and shale, gray, light-yellow conglomerate, fine-grained sandstone interbedded with sandy mudstone and shale; containing ostracodes ---------	268

3. Conglomerate, gray; containing sandy mudstone in lower part and light-yellow, thin-bedded sandstone in upper part; ostracodes fauna abundant ------------------------------ 369

2. Conglomerate, sandstone and mudstone, gray, pebbly conglomerate interbedded with sandstone and sandy mudstone; contains abundant ostracodes ---------------------- 163

1. Conglomerate (partially covered), gray conglomerate, locally contains yellowish-brown sandy mudstone lenses. Rock fragments chiefly 0.5-1 m quartzose sandstone. Generally diameter of rock fragment is less than 5 cm.-------- 20

--------unconformity---------

Total thickness of the Xichagou Series ---------------------- 4,639